PROCEEDINGS OF THE

# 3RD INTERNATIONAL CONFERENCE OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY

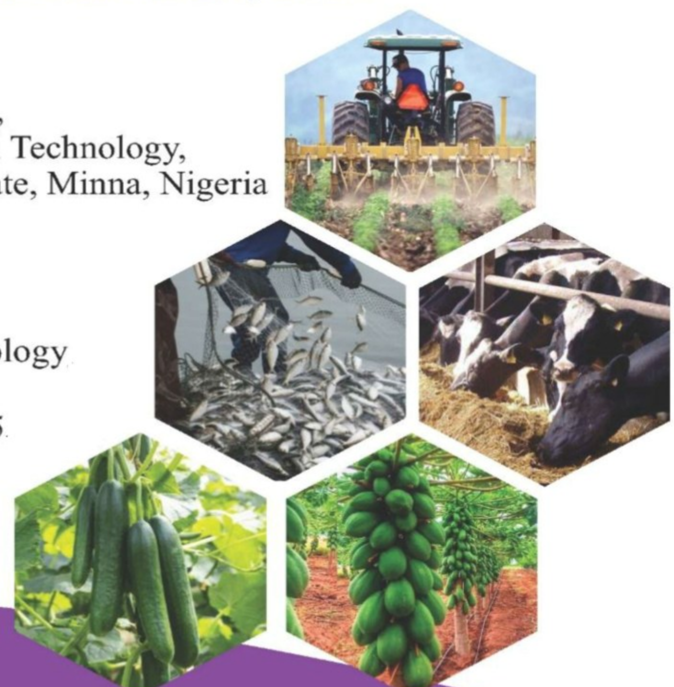
# ICAAT 2024

*Theme:*

**Integrated Approaches to:** *Achieving Food Security Through* **Artificial Intelligence and Effective Policy Implementation**

**Held on the 1ST - 4TH DECEMBER, 2024**

Caverton Lecture Theatre,
School of Agriculture and Agricultural Technology,
Federal University of Technology, Niger State, Minna, Nigeria



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# PROCEEDINGS

*of the*

# 3rd International Conference

*of*

# School of Agriculture and Agricultural Technology (SAAT)

*Held at*

Caverton Hall

Federal University of Technology Minna

ICAAT 2024

*1st –4th December 2024*

School of Agriculture and Agricultural Technology Federal University of Technology
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And you will ever be
Our love-for-you won't cease

## HISTORICAL BACKGROUND OF SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY

The School of Agriculture and Agricultural Technology (SAAT) was established in January 1986 with two Departments (Animal Production and Crop Production) With subsequent development, six more departments (i) Soil Science and Land Management (ii) Water Resources, Aquaculture and Fisheries Technology (iii) Agricultural Economics and Farm Management (iv) Agricultural Extension and Rural Development (v) Food Science and Technology, and (vi) Horticulture were created. The Department of Fisheries Technology started in 1987 as a Unit in the Department of Animal Production which transformed to the Department of Animal Production and Fisheries Technology in 1989 and was split into Department of Animal Production and Department of Fisheries Technology in 1991. The Department was repackaged and renamed Department of Water Resources, Aquaculture and Fisheries Technology in 2006.

A new Unit, Agricultural Economics and Extension Technology was created during the 1997/1998 session under the Department of Crop Production. In 2002, the Unit was separated from the mother Department and upgraded to a full-fledged Department which in turn gave birth to Department of Agricultural Economics and Farm Management and Department of Agricultural Extension and Rural Development in 2017. In 1997, the proposed Department of Food Science and Nutrition took off as a Unit in the Department of Animal Production and became a full-fledged Department of Food Science and Technology in 2013. Similarly, the Horticulture Unit in the Department of Crop Production became a separate Department of Horticulture in 2020. In 2019, the Vice-Chancellor approved an interim Centre for Shea Research and Development. Prof. K.M. Baba was appointed as pioneer Centre Coordinator while a Technical Committee which serves as a Board for the Centre was also constituted, with Prof. M.A.T. Suleiman as Chairman, to provide policy and strategy direction for the Centre.

The student intake into the school at inception in 1986 was two (one student each for Department of Animal Production and Department of Crop Production), and both graduated in 1989. Since then, the school has witnessed tremendous progress in terms of staff recruitment and development, infrastructural development and student enrolment. In the current 2019/2020 session, academic staff strength is 115 and student population stands at 2,895 for undergraduates and 314 for postgraduate students, totaling 3,209 students.

Dr. Z. Stecki was the first Coordinator for the school (January 1986 to September 1988). Dr. E.A. Salako took over as School Coordinator from October 1988 to 1990 and served later as Acting Dean. When he became the only Professor in the School, he was made the substantive Dean. After his tenure, the school reverted to the position of Acting Deanship since no Professor was on ground then. The Acting Deans were Dr. J.A. Oladiran (1995-1998) and Dr. S.L. Lamai (1998-2001). By September 2001, with more Professors on ground, the Board of School of Agriculture and Agricultural Technology, in accordance with the University regulations, elected Prof. O.O.A. Fasanya as the Dean of the School for a two-year term. Since then, the Deanship position in the school has been filled by election. Prof. E.A. Salako took over from Prof. O.O. A. Fasanya in 2003 and Prof. S.L. Lamai took over from Prof. E.A. Salako in 2005. In January

2008, following the appointment of Prof. S.L. Lamai as the Dean of Postgraduate School, Prof. K.M. Baba assumed Deanship of the School. In February 2012, Prof. M.G.M. Kolo succeeded Prof. K.M. Baba who had completed his second two-year term. Professor M.G.M. Kolo was re-elected for another two years from February 2014 but while in his second term, he was appointed Dean of Postgraduate School. In April 2015, Prof. R.J. Kolo was elected as the new Dean of the School and re-elected for second term. Prof. A.J. Odofin assumed the Deanship of the School in April 2019 and served for only one term of two years. Prof. Job Nmadu took over from Prof. A.J. Odofin as the Dean of School of Agriculture and Agricultural Technology on 9th April, 2021 to April 8th 2023. Prof. Jacob H Tsado is the current Dean of School of Agricultural Technology who assumed duty on 9th April 2023 to date.

Under the leadership of Prof. Faruc Kuta as the Vice Chancellor, the School has witnessed tremendous growth which has resulted in the creation of new departments (Department of Forestry and Wildlife Conservation, and Human Nutrition and Dietetics), also a new programme has been proposed to NUC (Seed Science and Technology) which is awaiting approval.

## PROGRAMME OF EVENTS

| | |
|---|---|
| **DAY ONE** | **Sunday, 1st December, 2024** |
| 4.00 pm | Arrival of Participants and Settling in |
| **DAY TWO** | **Monday, 2nd December, 2024** |
| | **Opening Ceremony (Moderator)** |
| 8.00 – 9.40 a.m. | Registration of Participants |
| 9.45 – 10.00 a.m. | Arrival of Dignitaries and Participants |
| 10.00 a.m. | University Anthem<br>National Anthem |
| 10.10 – 10.15 a.m. | Opening Prayer |
| 10.15 – 10.25 a.m. | Welcome Address by the Vice-Chancellor, Federal University Technology, Minna |
| 10.25 – 10.45 a.m. | Address by the Dean School of Agriculture and Agricultural Technology |
| 10.45 – 11.15 a.m. | **Keynote Address One by:**<br>Prof. (Mrs.) Mona Zayed<br>Director of Microbial Inoculants Center, Faculty of Agriculture Ain Shams University, Cairo, Egypt |
| 11.15 – 11.25 a.m. | Goodwill Messages |
| 11.25 – 12.05 a.m. | **Keynote Address Two by:**<br>Alh. Musa Salihu Bawa Bosso, Niger State Commissioner for Agriculture. Niger State Ministry of Agriculture, Minna |
| 12.05 – 12.35 p.m. | **Keynote Address Three by:**<br>Dr. Sanusi Muhammad<br>Director, Department of Artificial Intelligence and Robotics, National Space Research and Development Agency (NASRDA), Abuja, Nigeria |
| 12.35 – 12.45 p.m. | Group Photograph |
| 12.45 – 2.00 p.m. | Lunch Break and Registration |
| 2.00 – 4.30 p.m. | Scientific Session 1 Venue: Rooms 1. 2 & 3 PG Classes, SAAT Phase 2 |
| **DAY THREE** | **Tuesday, 3rd December, 2024** |
| 10.00 – 12 noon | Scientific Session 2 Venue: Rooms 1. 2 & 3 PG Classes, SAAT Phase 2 |
| 12.00 noon | Excursion/ Departure |

**TECHNICAL SESSIONS**

| Session | Subject | Venue | Chairman | Rapporteur |
|---|---|---|---|---|
| 1 and 2 | Agricultural Economics and Farm Management, Agricultural Extension and Rural Development, Agribusiness | Room 1 PG Class, SAAT Phase 2 | Prof. A. A. A. Coker | Dr. M. Ibrahim |
| 1 and 2 | Animal Production, Food Science and Technology, Nutrition and Dietetics, and Water Resources, Aquaculture and Fishery Technology | Room 2 PG Class, SAAT Phase 2 | Prof. A. A. Malik | Dr. S. James |
| 1 and 2 | Crop Production, Horticulture, Seed Science and Technology, Soil Science and Land Management, Forestry and Wildlife Technology, and Environmental Management | Room 3 PG Class, SAAT Phase 2 | Prof. P. A. Tsado | Dr. (Mrs.) A. Y. Mamudu |

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**WELCOME ADDRESS BY THE DEAN, SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY, MINNA ON THE OCCASION OF THE OPENING CEREMONY OF THE 3RD INTERNATIONAL CONFERENCE OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY (ICAAT) HELD ON DECEMBER 1ST - 4TH, 2024 AT THE CAVERTON LECTURE THEATRE AT 10.00AM PROMPT**

Good morning, distinguished Vice Chancellor, members of the university management team, Deans, Professors, HODs, esteemed keynote and plenary speakers, honoured invited guests, colleagues, scholars, students, and friends.

It is a great privilege and a profound honour to stand before you today as we gather for the opening ceremony of the 3rd International Conference of the School of Agriculture and Agricultural Technology, here at the Federal University of Technology, Minna. I warmly welcome each of you and extend my sincere appreciation for making the time to join us in this significant discourse. Your presence here is a testament to your dedication to the advancement of agricultural research and development for a better and more food-secure world.

The theme for this year's conference, "Integrated Approaches to Achieving Food Security through Artificial Intelligence and Effective Policy Implementation," underscores the urgency and complexity of our collective mission. As we confront mounting challenges, including food scarcity, climate change, and evolving agricultural demands, we must embrace innovative solutions to ensure the availability, accessibility, and sustainability of food for every member of our global community.

Artificial intelligence has emerged as a transformative tool, offering unprecedented opportunities for precision agriculture, predictive analysis, resource optimization, and data-driven decision-making. However, technological innovation is only one piece of the puzzle. Effective policy implementation—grounded in collaboration, inclusivity, and the practical realities of our farmers and stakeholders—will serve as the necessary enabler for meaningful change. It is this dynamic intersection of innovation and governance that we seek to explore and strengthen over the course of this conference.

I am deeply encouraged by the wealth of knowledge and expertise represented here today. Our esteemed keynote and plenary speakers will provide valuable insights that challenge conventional thinking and illuminate new pathways for progress. The diverse range of research presentations, discussions, and networking opportunities will undoubtedly inspire fresh perspectives and collaborative ventures.

I would like to express my heartfelt thanks to our Vice Chancellor, whose unwavering support and leadership continue to propel the Federal University of Technology, Minna, to the forefront of academic excellence. To the university management, the Niger State Government, our sponsors, and all those who have contributed to the organization of this conference, your dedication and hard work are the backbone of this success.

As we embark on this important journey together, I encourage every participant to engage openly, exchange ideas, and form connections that extend beyond these sessions. Our shared commitment to food security demands innovation, resilience, and collective action, and I am confident that the deliberations here will leave a lasting impact.

Thank you, and I wish you all a highly successful, enriching, and productive conference.

**Professor Jacob Haruna Tsado,**
**Dean, School of Agriculture and Agricultural Technology**
**December 2, 2024**

# ASSESSMENT OF SMALLHOLDER FARMERS PERCEPTION ON CLIMATE CHANGE AND ADAPTATION STRATEGIES IN AGAIE LOCAL GOVERNMENT AREA NIGER STATE, NIGERIA

M. Salihu[1], I. U Gbogan & C. Bature
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## ABSTRACT
Smallholder farmers, particularly rural or communal farmers, are vulnerable to the effects of climate change due to their low levels of technology, limited access to climate information, their high dependence on rain-fed agriculture and prevailing drought conditions among others in the guinea savanna region such as Agaie Local Government Area. The study assessed smallholder farmers' perception of climate change and adaptation strategies in Agaie Local Government Area of Niger State, Nigeria. Simple random sampling was employed in the collection of data from a sample of 399 households; however, only 252 farm household heads provided data, representing a response rate of 63.2%. Multi-Variate Probit (MVP) model was fitted to assess several factors influencing smallholder farmers' selection of adaption strategies and potential interrelationship among these strategies. Findings revealed that majority (58.57%) believed that rainfall had decreased Additionally, they showed that there was a problem with delay of rainfall (88.3%), rainfall after the anticipated time (12.41%), problem of rainfall cessation (67.4%) and ending before the anticipated time (39.8%). Also, majority (68.03% and 70.92%) of respondents reported that the temperature had increased, and droughts (dry spells) occur frequently respectively. Because crop growing is heavily dependent on rainfall, smallholder farmers have faced challenges due to the unpredictable nature of rainfall. Therefore, rainfall characteristics influence pre-production, pre-harvest, and post-harvest production activities, which in turn influence overall farm-level productivity. The study suggested creating farm finance and strengthening extension services (including those related to climate change).
**Keywords:** Smallholders farmers; Perception; Climate change; Agaie

## INTRODUCTION
Recent scientific findings by individuals (Cornell & Gupta, 2020), and institutions such as the Inter-Governmental Panel on Climate Change (IPCC, 2007), the United Nations Development Programme and the World Bank (2010) have demonstrated that climate change is a reality that threatens various sectors of economic development including natural resources, agriculture and food security, forestry, tourism, manufacturing and health. The effects of climate change are characterized by changes in rainfall variability, increasing number of seasons without enough rainfall and increased temperatures which lead to extensive droughts and heat stress lowering crop productivity (Aune, 2012; Komba *et al.,* 2015). IPCC (2007) highlighted that about 23 million people in 11 African countries are affected by acute food insecurities and facing malnutrition. Where smallholder farmers are aware of the effects of climate change, that they can employ coping and adaptation measures such as planting different varieties of the same crop, mixed cropping and water conservation practices (Komba and Muchapundwa, 2015). Several studies have examined farmer perspectives of climate change and its risks, as well as the

potential adoption of adaptation and mitigation behaviors (Niles *et al.,* 2013; Niles *et al.,* 2015; Prokopy *et al.,* 2015). There is little or no publish data on smallholder's farmer's perception on climate change and adaptation strategies in Agaie local government in Niger State. Thus, this study is design to assessed smallholder farmers' perception on climate change and adaptation strategies in Agaie Local Government Area of Niger State, Nigeria.

## METHODOLOGY

### Description of the study area

This study was carried out in Agaie Local Government Area (LGA) of Niger State, Nigeria. The LGA shares boundary with Lapai LGA in the East, Katcha LGA in the West, Paiko LGA in the north and Kogi LGA in the south with River Niger as demarcating line. The land area of Agaie is 874 Square miles with Longitude 60°30'E-70°30'E and Latitude 80°30'E-90º00' E of the Equator. Rainfall concentration in July and August varies from 1,600mm in the south to 1,200mm in the North with duration of 150 -210 days and a temperature of 28-32ºC.

### Source of Data and Methods of Collection

The data for the study was collected through simple random sampling using self-administered questionnaires. It comprised demographic, socioeconomic, institutional, and perceived changes in climate conditions and adaption strategies during the past 20 years years. The study also used secondary data from government offices, journals, and bulletins. Smallholder farm households who own or cultivate less than 2 ha of land comprised the study population, with the heads of such households being the units of analysis. In the 2006 census for Agaie had a population of 132,907; by 2023, the projected population was 234,634. Based on this, a sample size of 399 was determined from Yamane (1967); however, at a response rate of 63.2%, only 252 household heads provided data for the cross-sectional household survey.

### Method of Data Analysis

Descriptive statistics such as frequency, mean, percentage, and standard deviation were used to summarize the institutional, socioeconomic, and demographic features of households, as well as the ways in which smallholder farming households perceived and responded to climate change. To assess the several factors influencing smallholder farmers' selection of adaption strategies and potential interrelationship among these strategies, an MVP model was fitted.

### Empirical estimation of Multi-Variate Probit (MVP) model

Smallholder farmers select an alternative adaptation strategy if its utility *(U)* exceeds that of other alternatives, denoted as $U_{in} > U_{jn} \; \forall \; j \neq i$, where $j$ represents the various choices of adaptation strategies from the given choice set $C_n$ and $n$ denotes the smallholder farmers. The utility can be divided into two components: deterministic $(V_{ij})$ and random $(\mathcal{E}_{ij})$.

$$V_{jn} + \mathcal{E}_{jn} = U_{jn} \qquad (1)$$

The likelihood that a smallholder farmer will select a particular alternative adaptation approach is:

$$P\,(i)\,C_n = Pr(U_{in} \geq U_{jn},\; \forall \in \; C_n, \qquad (2)$$

The model assumes that the response variable has different K binary responses (Greene, 2000).

$$Y^*_{ij} = (X_i\beta + \mathcal{E}_i),\; Yik = \{1 \text{ if } Y * ik > 0;\; o \text{ otherwise}\}\; i = 1...n \text{ and } k = 1,...,k \qquad (3)$$

The likelihood that the households will adopt the provided adaptation techniques data is:

$$Y^* = P(Y_{ik} = 1|X,\beta,\mathcal{E}) \int A_{ki}\; \eth\; k\,(z_{ik}= 1)\,|\; jx_i, \beta, \textstyle\sum)\; dY^*_{ik} \qquad (4)$$

Marginal effects, not parameter estimates, are used to interpret MVP results. Accordingly, the marginal impacts on the choice of various adaptation alternatives (Charles *et al.,* 2014) are:

$$\frac{\partial P_i}{\partial x_i} \Phi\,(x * \beta)\beta i,\ \ i = 1, 2, 3 \ldots n \quad (5)$$

The resulting five primary adaption strategies (ADS) employed by smallholder farmers are:

$Y^*_{11} = (x^*_i\ \beta + \mathcal{E}_{1})\ Y_{11} = \{1 \text{ if } Y^*_{11} > 0; o \text{ otherwise}\},$

$Y_{11}$ refers crop diversification strategy (6)

$Y^*_{21} = (x^*_i\ \beta + \mathcal{E}_{1})\ Y_{21} = \{1 \text{ if } Y^*_{21} > 0; o \text{ otherwise}\},$

$Y_{21}$ refers improved varieties and intensity of input use strategy (7)

$Y^*_{31} = (x^*_i\ \beta + \mathcal{E}_{1})\ Y_{31} = \{1 \text{ if } Y^*_{31} > 0; o \text{ otherwise}\},$

$Y_{31}$ refers adjusting plant date strategy (8)

$Y^*_{41} = (x^*_i\ \beta + \mathcal{E}_{1})\ Y_{41} = \{1 \text{ if } Y^*_{41} > 0; o \text{ otherwise}\},$

$Y_{41}$ refers soil and water conservation practices (9)

$Y^*_{51} = (x^*_i\ \beta + \mathcal{E}_{1})\ Y_{51} = \{1 \text{ if } Y^*_{51} > 0; o \text{ otherwise}\},$

$Y_{51}$ refers change crop type strategy (10)

## RESULTS AND DISCUSSION

### Socio-economic characteristics

In the socio-economic characteristics 74% of the farmers that were surveyed are within the age range of 15-45 years; 91% are male, and 94% are married. This agrees with the findings of Baba *et al.* (2019) which reported that people of age ranged 20-45 are actively involved in farming activities most especially in rural areas. In terms of farming experience 79.8% have at least 11 years of experience in farming.

**Table 1: Socio-economic characteristics of smallholder farmers**

| Variables | Frequency | Percentages (%) |
|---|---|---|
| **Age (years)** | | |
| 15-30 | 99 | 39 |
| 31-45 | 88 | 35 |
| 46-60 | 42 | 17 |
| >60 | 23 | 9 |
| **Gender** | | |
| Male | 229 | 91 |
| Female | 23 | 9 |
| **Marital Status** | | |
| Married | 237 | 94 |
| Single | 9 | 3.6 |
| Divorce | 2 | 0.8 |
| Separate | 4 | 1.6 |
| **Education** | | |
| Quranic | 101 | 40.1 |
| Primary | 44 | 17.5 |
| Secondary | 34 | 13.5 |
| Tertiary | 73 | 28.9 |
| **Years of farming experience** | | |
| 1-10yrs | 51 | 20.2 |
| 11-20yrs | 113 | 44.8 |
| 21-30yrs | 88 | 35.0 |
| 31-40yrs | - | - |
| Total | 252 | 100 |

Source: Field survey, 2023

**Farmers' perceptions of climate change**

Smallholder farmers were asked about the trends they had noticed in the major climate indicators during the previous 20 years - rainfall, temperature and drought. The responses revealed their perceptions that rainfall had decreased (58.57%); had increased (2.21%); no change (25.75 %). In terms of problems with onset of rainfall, perceptions included rainfall after the anticipated time (12.41%), problem of rainfall cessation (67.4%) and ending before the anticipated time (39.8 %). With respect to changes in temperature, the belief was that the temperature had increased (68.03 %); had decreased (2.11%); had remained unchanged (20.51%) as shown in figure 1.

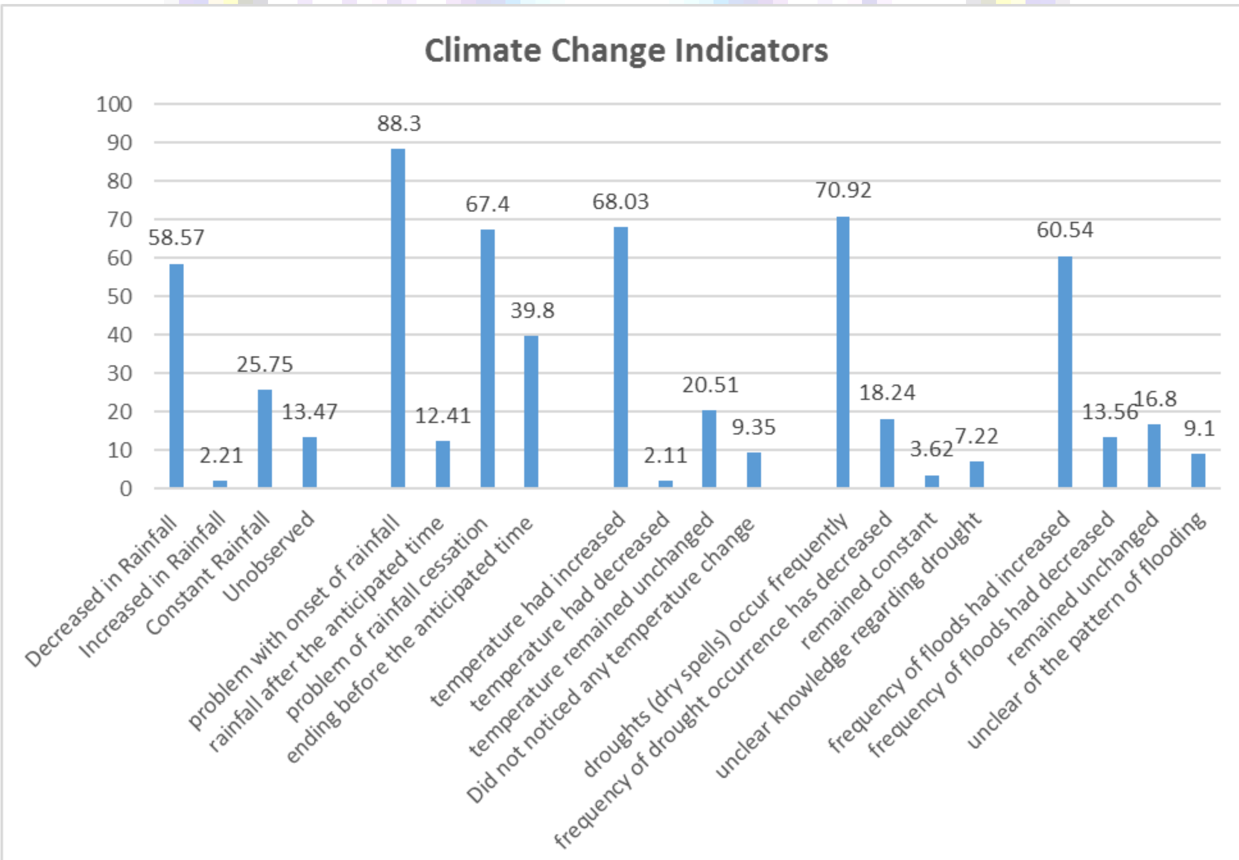


Figure 1: Smallholder farmers' perceptions about current rainfall variability, temperature, drought and flood characteristics in Agaie LGA

With regards to drought as a significant climatic indicator variable, dry spells occur frequently (70.92%); have decreased (18.24%); remained constant (3.62%). The pattern of responses was similar for floods - increased frequency of floods (60.54%); reduced frequency (13.56%); unchanged frequency (16.8%). These findings are consistent with the research conducted in Ethiopia by Yonnas and Solomon (2021) and in central Kenya by Asayehegn *et al.* (2017), who reported significant changes in indicators of climate change.

**Farmers' adaptation strategies to climate change**

The majority (72.26%) of households investigated have implemented adaption strategies to mitigate the impact of climate change in response to its variability and changes as shown in figure 2. Crop diversification (63.06%), improved crop varieties (75.31%), input use intensity (79.44%), changing the planting date (61.72%), and changing to a different crop type (81.78%) were the primary adaptation techniques employed. Changes in crop type were adopted by most respondents (81.78%). Additionally, 61.72 %of the farm households in Agaie LGA employed the strategy of changing plant date adaption. However, farm households in the study area do not have a strong practice of adapting soil and water conservation strategies. This finding is consistent with studies by Dasmani *et al.* (2020) in Ghana and Yonnas and Solomon (2021) in Ethiopia, which found that crop diversification is mostly used by smallholder farmers as an adaptation strategy.

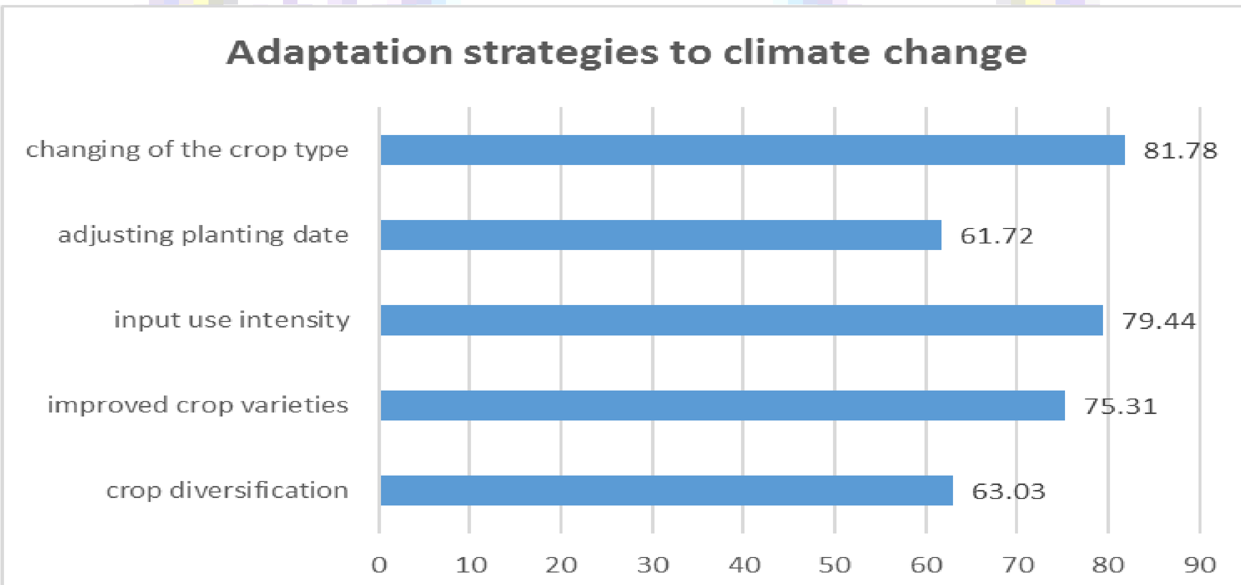


**Figure 2: Major Adaptation strategies to climate change**

Large family sizes are associated with a lower probability of using crop diversification in Ethiopia (Ademe *et al.,* 2019); however, this study's findings are consistent with Yonnas and Solomon (2021), reported that large families are associated with a higher likelihood of using crop diversification. The literacy status of the household head in formal education significantly influences the use of climate change adaptation strategy, with households with formal education accessing adaptation measures at a higher rate (69%). This outcome is consistent with the discovery made by Adégnandjou *et al.* (2018) in South Benin, which showed that knowledgeable farmers make better decisions when it comes to adaption strategies.

**CONCLUSION**

The study comes to the conclusion that throughout the past 20 years, smallholder farming households in Agaie LGA Niger State, have seen variations in various climate change variables, such as rainfall, temperature, floods, and droughts. Majority of the farmers have employed adaptation strategies to lessen the negative effects of climate change and its unpredictability. The study found that institutional factors such as access to credit, extension services, and distance from markets and research centers as well as demographic factors such as sex, family labor, age groups, farming experience, and literacy status were more important in influencing farmers' choice of adaptation than socioeconomic factors. The study suggested creating farm finance, strengthening extension services (including those related to climate change, considering the use of technical language and location-specific considerations), guaranteeing farmers' access to market infrastructure (roads, markets, and transportation services), and enhancing farmers' experience (training, awareness campaigns). Future studies should concentrate on how each adaptation method is used and how climate change affects smallholder farmers' livelihoods throughout Niger State.

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# RISK SOURCES AND MANAGEMENT STRATEGIES AMONG SOYA BEANS FARMER IN NIGER STATE, NIGERIA

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**ABSTRACT**
The study was carried out to assess risk sources and management strategies among soybean farmers in Niger State, Nigeria. Multi-stage sampling procedure was used to select 144 soybean farmers in the study area. The results of the findings revealed that changes in consumer preferences (92.4%) and Competition from other oilseed crops (91.7%) (market risk), Lack of storage facilities (94.6%) and Grain spoilage or contamination during processing (87.4%) (production risk). High rates of rural-urban migration (86.8%) and Health status of the farmers (85.4%) (Farmers risk), reduced water availability and increased competition for water resources (91.7%) (climate risk) and Changes in agricultural policies (government policy risk) were the major sources of risk in the study area. Value addition (91.0%), Joining producer organizations, crop rotation (93.8%), family involvement (88.2%) and price regulation (93.1%) were the management strategies adopted by soybean farmers. the study recommended that farmers should adopt cost-effective agricultural practices. This may involve assess alternative and more affordable inputs sources, negotiating bulk purchase discounts with suppliers or participating in cooperative buying initiatives.
**KEYWORDS: risk, sources, management and soybean**

## INTRODUCTION

Agricultural production in Nigeria, like in many other countries, is characterized by a myriad of uncertainties and risks. Despite these challenges, the agricultural sector remains the backbone of the Nigerian economy, providing livelihoods for the majority of the population. In rural Nigeria, where agriculture is the primary source of income, nearly 70% of households depend on agricultural activities, either through self-employment or as agricultural laborers (Jirgi, 2013). However, the decision-making process in agriculture is fraught with uncertainties, ranging from unpredictable weather patterns to fluctuating market conditions, which significantly impact the financial returns and overall welfare of farmers. Farmers in Nigeria face numerous challenges in agricultural production. Decisions made by farmers, such as crop selection, input usage and marketing strategies, are influenced by factors beyond their control, including weather variability, market developments and unforeseen circumstances (RERAD, 2010). Moreover, farming is inherently a financially risky occupation, with farmers constantly confronted by the ever-changing dynamics of prices, yields and other outcomes that affect their financial viability and livelihoods. Agricultural decisions are made in an environment characterized by inherent risks and uncertainties, requiring farmers to make decisions now that will impact their production outcomes in the future (Akinola, 2020). These risks encompass various dimensions, including financial risks, production risks, market risks, and environmental risks, all of which contribute to the complexity of agricultural decision-making. Risk in agriculture vary, but fundamentally, risk refers to uncertainty that affects an individual's welfare, often associated with adversity and loss (Olarinde *et al*., 2020). In the context of agriculture, risk involves the probability of unfavorable outcomes that can lead to financial losses, harm to human health, depletion of resources, and other adverse repercussions that affect the well-being of farmers (RERAD, 2010). It is characterized by the uncertainty surrounding the outcomes of decisions or actions, with each action leading to a set of possible outcomes, each occurring with a known probability (Debertin, 2022). Nigeria's soybean production is witnessing an upward trend, yet it struggles to meet the soaring demand from the poultry industry and vegetable oil processors due to various challenges such as low yield and poor agronomic practices (USIDA, 2020). The poultry sector's increasing consumption is projected to drive soybean demand to 2.3 million MT by 2020. However, the country faces an annual shortfall of approximately 100,000 tons for soybean meal and 300,000 tons for vegetable oil (USIDA, 2020).

Farmers in Nigeria encounter numerous risks in their agricultural activities, with their ability to absorb risk and their psychological attitudes towards risk influencing their decision-making processes (Knight *et al.*, 2023). In agriculture, uncertainties regarding yields and prices significantly impact farm productivity and profitability, constituting major sources of risk for farmers. Farmers' attitudes towards risk play a crucial role in shaping their responses to perceived opportunities and challenges in the agricultural sector (Domingo, 2015).
While recent research has focused on identifying sources of risk and methods of risk management, there remains a gap in understanding farmers' attitudes towards risk and the factors influencing these attitudes. Therefore, there is a compelling need to assess farmers' risk attitudes and their determinants to gain insights into their decision-making behavior. Base on the foregoing, the study was conducted to:

i. identify soybean farmer’s sources of risk in the study area; and
ii. identify the management strategies adopted by soy bean farmers in managing risks risk in the study area

## RESEARCH METHODOLOGY

The study was conducted in selected Local Government Area of Niger State, it is located between Latitudes 8º22'N and 11º30'N and Longitudes 3º30'E and 7º20'E. The State covers an estimated total land area of 74.244sq.km, which is about 8% of Nigeria’s total land area (Knight *et al.*, 2023).

The population of the State is 3,950,249, comprising 2,082,725 males and 1,867,524 females (National Population Commission (NPC), 2006). The projected population of the State as at 2021 was 5,644,139 at 3.2% population growth. The average annual rainfall in the State is 1,219 mm. The dry season is between November and March. Temperature is regular and ranges from 26.1$^0$C (June – February) to 30.3$^0$C (March – April) (Tambo and Abdoulaye, 2016).
Multi-stage sampling technique was employed in the selection of soybean farmers for the study. The first stage involved purposive selection of Bosso and Chanchaga Local Government Area, this is due to their preponderance in soybean production. The second stage involved random selection of three (3) villages from the each of the selected LGA namely; Bosso (*Garatu, Maikunkele, Gidan kwano*) Chanchaga (*Kure, Kasuwa gwari and Tunga)*. The last stage was random selection of fifteen percent (15%) of soybean farmers from each of the selected villages. This was attained through obtaining the total population of all soybean farmers in each villages from the Village Heads and *Niger* State *Agricultural Mechanization* Authority (NAMDA). The

population and sample size of the respondent in the LGA is summarized and presented in Table 1. A total of 144 soybean farmers was used for the study.

**Table 1: Sampling outlay and sample size of respondents**

| LGA | Village/communities | Sampling frame | Sample size |
|---|---|---|---|
| | Garatu | 160 | 24 |
| **Bosso** | Maikunkele | 185 | 28 |
| | Gidan kwano | 170 | 26 |
| | Langbazi | 130 | 20 |
| **Chanchaga** | Kasuwa gwari | 125 | 19 |
| | Tunga | 190 | 29 |
| **Total** | 6 | 960 | 144 |

**Source**: Community-based records from Village Heads and Niger State Agricultural Mechanization Authority.

Primary data were used for the study. A structured questionnaire complemented with an interview schedule was used to collect data from respondents. The data collected were analysed using descriptive statistics.

## RESULTS AND DISCUSSION

### Soybean farmer's sources of risk

The result in Table 2 shows the soybean farmer's sources of risk in the study area. It showed the market, production, farmer, climate and government policy risk

### Market risk

Changes in consumer preferences represent the highest risk under market-related challenges, with 92.4% of farmers identifying it as a significant concern. This is a critical issue because consumer demand dictates market trends and prices, ultimately influencing the profitability of soybean production. As global awareness of health, environmental sustainability, and dietary choices continues to grow, consumer preferences are increasingly shifting towards alternative protein sources, such as plant-based proteins, which can either benefit or harm the soybean market. Soybeans, traditionally used for oil and animal feed, are now in competition with other crops like almonds, oats, and peas, which are being marketed as healthier and more sustainable alternatives. If the demand for these alternatives rises, it could reduce the market share for soybeans, thereby threatening the income and stability of soybean farmers. Farmers are concerned that they may not be able to adapt quickly enough to these changes, which could lead to reduced profitability and increased financial instability. This is similar to the study of Agwu *et al.* (2014) who found that 88% of farmers in Nigeria experienced difficulties due to shifting consumer demands, which affected their ability to sell produce at profitable prices. These changes often resulted in unpredictable market conditions, further exacerbating the challenges faced by farmers, aligning with the 92.4% reported in this case.

Competition from other oilseed crops is a critical concern for 91.7% of soybean farmers. This competition can affect soybean prices and market share; as other oilseeds might offer better yields or lower production costs. Farmers must consider strategies to differentiate their soybeans, such as emphasizing quality or investing in unique processing methods. Inadequate market information affects 78.5% of soybean farmers. Poor access to timely and accurate market data can hinder farmers' ability to make informed decisions about pricing, sales, and marketing strategies. This lack of information can lead to missed opportunities and suboptimal pricing. In a related study Ayodele *et al*. (2015) revealed that competition from other oilseeds, such as palm kernel and groundnut, significantly impacted soybean farmers in Nigeria, with 89% of respondents indicating reduced market share and profitability due to price competition.

**Production Risk**

Grain spoilage or contamination during processing is highlighted as the most significant production risk, with 87.5% of farmers expressing concern. This risk is particularly alarming because it directly affects the quality and marketability of the harvested soybeans. Poor handling, inadequate storage, and improper processing techniques can lead to the deterioration of soybean quality, which not only reduces the market value but can also result in total loss if the grains are deemed unfit for sale. Given the high perishability of soybeans, effective management of post-harvest processes is crucial. Contamination can occur due to various factors, including exposure to moisture, pests, and improper storage conditions. Land tenure issues or disputes with neighbouring landowners affect 80.6% of soybean farmers. These disputes can disrupt farming operations, cause legal challenges, and affect productivity. Clear and secure land tenure arrangements are essential for long-term farming success. Also, rise in the cost of inputs, such as seeds, fertilizers, and agro-chemicals, is a significant risk for 83.3% of soybean farmers. Increased input costs can squeeze profit margins and make farming less economically viable. Ojo and Adebayo (2017) revealed that 85% of soybean farmers in Nigeria faced significant risks from grain spoilage during storage and processing, and 82% experienced land tenure disputes, impacting productivity and profitability.

**Farmer’s Risk**

High rates of rural-urban migration are the most pressing risk identified under farmer's risks, with 86.8% of farmers acknowledging it as a critical issue. This is similar to the study of Olayemi *et al*. (2016) who noted that 88% of rural farmers in Nigeria identified rural-urban migration as a significant challenge, leading to reduced agricultural labour availability and negatively affecting productivity in rural areas. Rural-urban migration significantly affects the availability of labour, as younger, able-bodied individuals leave rural areas in search of better employment opportunities in cities. This migration trend leads to a shortage of labor in farming communities, leaving many farmers with insufficient human resources to maintain or expand their operations. The labour shortage can result in delayed planting, inadequate crop maintenance, and reduced productivity, as farmers struggle to keep up with the demands of managing their fields. Additionally, this migration trend often leaves behind an aging farming population, which may not have the physical capacity to handle the labor-intensive tasks required in soybean farming. The long-term implications of this migration trend include reduced agricultural output, diminished economic viability of farming, and the potential decline of rural communities as young people continue to relocate to urban areas. Also, the he health status of farmers is a major risk for 85.4% of respondents. Health problems can lead to reduced productivity, increased absenteeism, and higher medical costs. Ensuring that farmers remain healthy is crucial for maintaining farm operations and productivity.

### Climate Risk

Reduced water availability and increased competition for water resources are identified as the top climate-related risks, with 91.7% of farmers expressing concern. Water is a critical resource for soybean farming, and its availability directly affects crop yields and quality. Changes in climate patterns, such as prolonged droughts or reduced rainfall, can lead to water scarcity, making it difficult for farmers to irrigate their crops adequately. Moreover, increased competition for water resources from other agricultural activities, industrial uses, and growing urban populations further exacerbates the challenge. In regions where water is already a limited resource, the pressure on farmers to secure sufficient water for their crops can be immense. This risk not only threatens the current production levels but also poses long-term challenges for the sustainability of soybean farming, as farmers may be forced to reduce their cultivation area or switch to less water-intensive crops. Ajayi *et al*. (2020) reported that 89% of soybean farmers in Nigeria identified reduced water availability and competition for water resources as significant climate-related risks, directly impacting crop productivity and quality.

Table 2: Soybean farmer's sources of risk

| Sources of risks | Frequency | Percentage |
|---|---|---|
| **Market risk** | | |
| Fluctuation of prices | 115 | 79.9 |
| Low market demand | 94 | 65.3 |
| Inadequate market information | 113 | 78.5 |
| Competition from other oilseed crops | 132 | 91.7 |
| difficulties in negotiating fair prices with buyers or middlemen | 100 | 69.4 |
| Changes in consumer preferences | 133 | 92.4 |
| Poor transportation of soybean grains to market | 111 | 77.1 |
| **Production Risk** | | |
| Disease outbreak is a major risk | 110 | 76.4 |
| land tenure or disputes with neighboring landowner | 116 | 80.6 |
| Poor sol nutrient | 107 | 74.3 |
| Rise in cost of inputs | 120 | 83.3 |
| Grain spoilage or contamination during processing | 126 | 87.5 |
| Theft and pilfering | 96 | 66.7 |
| Pest attack | 119 | 82.6 |
| Inadequate agro-chemicals | 120 | 83.3 |
| Poor seed quality | 98 | 68.1 |
| Lack of storage facilities | 133 | 92.4 |
| Contamination of soybean | 120 | 83.3 |
| **Farmers Risk** | | |
| Inadequate family labour | 108 | 75.0 |
| Conflict within the community | 104 | 72.2 |
| Death of the farmer | 101 | 70.1 |
| Low levels of education | 120 | 83.3 |
| Dependence on a single crop | 105 | 72.9 |
| Inadequate family labour | 115 | 79.9 |
| Health status of the farmers | 123 | 85.4 |
| High rates of rural-urban migration | 125 | 86.8 |
| **Climate Risk** | | |
| Changes in temperature and rainfall patterns | 103 | 71.5 |
| Increased frequency and severity of extreme weather events | 130 | 90.3 |
| Reduced water availability and increased competition for | 132 | 91.7 |

| | | |
|---|---|---|
| water resources | | |
| Changes in the timing and duration of growing seasons | 120 | 83.3 |
| Fire hazard | 120 | 83.3 |
| **Government Policy Risk** | | |
| Changes in agricultural policies | 109 | 75.7 |
| Political instability | 123 | 85.4 |
| Removal of fuel subsidy | 103 | 71.5 |
| Changes in agricultural policies | 128 | 88.9 |

**Source: Field survey, 2024**

**Government Policy Risk**

Changes in agricultural policies are the most significant government policy-related risk, with 88.9% of farmers highlighting it as a major concern. Agricultural policies directly influence farming practices, input costs, subsidies, and market access. Sudden or poorly communicated changes in these policies can disrupt farming operations, leading to increased uncertainty and financial strain for farmers. This is supported by Obasi *et al*. (2021) who showed that 87% of Nigerian farmers expressed concern over frequent changes in agricultural policies, which significantly impacted their input costs, access to subsidies, and overall farming operations, causing financial instability.

For instance, the removal of fuel subsidies skyrocketed the price of inputs like fertilizers or seeds which significantly raise production costs, making it harder for farmers to maintain profitability. Similarly, changes in trade policies or export restrictions can limit market access, reducing the demand for soybeans and lowering prices. Farmers rely heavily on stable and supportive government policies to plan their operations effectively. When these policies are altered, it can create a volatile environment that makes long-term planning and investment difficult, ultimately threatening the viability of soybean farming.

**Risk management strategies employed by the soybean farmers**

Table 3 presented the management strategies adopted by maize farmers in managing risks risk in the study area. It revealed that value addition (91.0%), diversified market channel (88.9%) and joining of producer organization (84.0%) were the major market management strategies adopted by soybean farmers. Value-addition involves enhancing the value of soybeans through processes such as improving quality or adding value-added products. This strategy is highly favored because it directly affects the marketability and profitability of the soybeans. By increasing the value of their products, farmers can potentially secure better prices and attract more buyers. This approach helps in negotiating higher returns, even in fluctuating markets. The adoption of value-addition helps farmers to buffer against market volatility. By creating high-quality or differentiated products, they can maintain or improve their market positions despite price fluctuations. This strategy also opens up opportunities for accessing premium markets or niche segments, which can provide more stable income streams.

**Table 3: Risk management strategies employed by the soybean farmers**

| Management strategies | Frequency | Percentage |
|---|---|---|
| **Market Risk** | | |
| Price Hedging | 120 | 83.3 |
| Diversified Marketing Channels | 128 | 88.9 |
| Direct Marketing to Consumers | 111 | 77.1 |
| Value-Auditioning | 131 | 91.0 |
| Using Price Forecasting Tools | 105 | 72.9 |
| Joining producer organizations | 121 | 84.0 |
| **Production Risk** | | |
| Crop Rotation | 135 | 93.8 |
| Integrated Pest Management | 124 | 86.1 |
| Planting Disease-Resistant Varieties | 115 | 79.9 |
| Soil Testing | 94 | 65.3 |
| Cover cropping | 117 | 81.3 |
| Conservation Tillage | 98 | 68.1 |
| Timely Planting | 132 | 91.7 |
| Drought resistance Varieties | 124 | 86.1 |
| Adoption of modern technologies | 117 | 81.3 |
| Agroforestry | 88 | 61.1 |
| Green house production | 121 | 84.0 |
| **Farmers Risk** | | |
| Safety training | 103 | 71.5 |
| Emergency Preparedness | 124 | 86.1 |
| Work-Life Balance | 96 | 66.7 |
| Regular Medical Checkups | 100 | 69.4 |
| Time Management | 113 | 78.5 |
| Proper record keeping | 99 | 68.8 |
| Stress Management Techniques | 112 | 77.8 |
| Family Involvement | 127 | 88.2 |
| **Climate Risk** | | |
| Planting of wind breaker | 90 | 62.5 |
| Contour farming | 107 | 74.3 |
| No till farming | 116 | 80.6 |
| Mobile weather apps | 80 | 55.6 |
| Fire tracing | 98 | 68.1 |
| **Government risk** | | |
| Price regulation | 134 | 93.1 |
| Adopting Button down approach to policy | 127 | 88.2 |

**Source**: Field survey, 2024

Diversifying marketing channels reduces dependency on a single market or buyer, thereby spreading risk. Farmers who use multiple channels, such as local markets, cooperatives, and direct sales, can better manage market fluctuations and reduce the impact of any one channel's poor performance. This strategy is crucial for enhancing market access and stability. By employing diverse marketing strategies, farmers can adapt to changes in market demand and prices more effectively. This approach allows them to tap into different consumer segments and reduce the risk of having unsold inventory or facing price crashes in a single market.

Joining producer organizations offers several benefits, including collective bargaining power, shared resources, and access to market information. These organizations can provide a platform for farmers to collaborate, share knowledge, and gain better negotiating leverage with buyers and suppliers. Producer organizations help mitigate market risks by providing support in marketing, negotiating prices, and accessing bulk purchasing options. This collective approach enhances the ability of individual farmers to compete and succeed in the market.

Similarly, crop rotation (93.8%), timely planting (91.7%) and planting of drought resistance variety (86.1%) were the major production risk management strategies adopted by soybean farmers. Crop rotation helps in maintaining soil fertility, reducing pest and disease build-up, and improving overall crop yield. This strategy is widely adopted because it promotes sustainable farming practices and reduces the reliance on chemical inputs. Implementing crop rotation enhances soil health and reduces the risk of crop-specific pests and diseases. This leads to more consistent yields and lowers production risks over time.

Also, timely planting is crucial for maximizing yield potential and avoiding adverse weather conditions. Farmers who adhere to optimal planting schedules can better manage production risks associated with weather and pests. Ensuring timely planting helps in synchronizing crop growth with favourable weather conditions, thus enhancing productivity and reducing risks related to late planting. In respect to farmers risk management strategies, family involvement (88.2%) and emergency preparedness (86.1%) were the strategies adopted. Involving family members in farming operations helps in managing labor needs and reducing the dependency on hired labor. This strategy also strengthens the support system for farmers, both in terms of work and emotional support. Also, family involvement ensures a more reliable and committed workforce, reduces labour costs, and enhances the overall management of the farm. Being prepared for emergencies, such as health issues or accidents, is crucial for maintaining farm operations. Emergency preparedness includes having contingency plans and resources in place.

## CONCLUSION AND RECOMMENDATIONS

From the findings, it can be concluded that the major sources of risk to soybean farmer in the study area were Changes in consumer preferences (market risk), Grain spoilage or contamination during processing (production risk). Rural-urban migration (farmers risk), reduced water availability and increased competition for water resources (climate risk) and change in government policy (government policy risk).  Also value addition, diversified market channel and joining of producer organization were the major market management strategies adopted by soybean farmer. Given the significant concern over the rise in the cost of inputs, the study recommended that farmers should adopt cost-effective agricultural practices. This may involve assess alternative and more affordable inputs sources, negotiating bulk purchase discounts with suppliers or participating in cooperative buying initiatives. Also, Strategies such as promoting labour-saving technologies, providing training on efficient labour use, and developing cooperative labour arrangements should be adopted.

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# DETERMINATION OF RESOURCE USE EFFICIENCY OF VITAMIN A BIOFORTIFIED CASSAVA PRODUCTION IN NIGER STATE

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## ABSTRACT

The study was undertaken to determine the resource use efficiency of vitamin A bio-fortified cassava production in Niger State. Multistage sampling technique was employed to select one hundred and five vitamin A bio-fortified cassava farmers as respondents. Data were gathered through primary source with the aid of a structured questionnaire. The results showed that the mean age of respondents was 39 years. About 73.3% of the respondents were male with an average household size of 10 persons, average years of farming experience of 16 years, and cultivating on an average farm size of 3.72 hectares. The average annual income of the respondents is ₦1,623,251.71. The vitamin A bio-fortified cassava farmers in the study area failed to achieve efficient utilization (r=1) of resources as resources such as farm size (-0.20), agrochemicals (-4.12), and fertilizer (0.29) were over-utilized (r <1), while labour (8.70) and cassava cuttings (21.42) were under-utilized (r >1). High cost of inputs, insecurity, poor access to financial services, inadequate storage facilities, and inadequate extension services were ranked as the most severe constraints faced by respondents in producing vitamin A bio-fortified cassava in the study area. The study concludes that adjustment needs to be made in order to achieve optimum utilization of resources thereby enhancing nutritional and economic status of consumers in the study area. It is recommended that government should put more effort in training farmers focusing on resource optimization and sustainable farming techniques.
**Keywords**: Resource use, Efficiency, Vitamin A, Cassava, Bio-fortification, Production

## INTRODUCTION

Cassava (*Manihot esculenta* Crantz**)** is one of the major staple food and a major source of energy in the diet of many Nigerians, it adapt to wide range of climatic and soil conditions [6]. Globally, cassava has experienced consistent growth of well above 3% annually, and as of 2022, world cassava production stood at about 308 million metric tones [7]. Africa is the largest cassava growing region in the world, with total production of 203 million metric tones (about 65% of world production) and indisputably, Nigeria remains the highest producer of cassava in the world with over 60.8 million metric tones (about 20% of world production) [13]. Cassava is traditionally consumed by processing the fresh roots into Garri, flour, fufu, lafun, tapioca, kpokpo, starch etc. [23]. Cassava root is a good source of carbohydrates (32g/100g) but relatively low in protein (1.9g/100g) and micronutrients like Vitamin A, hence predisposing the consumers to health risks. As a result, Nigerians who are restricted to the consumption of cassava-based diet could be at risk of being exposed to having diseases associated with vitamin A deficiency (VAD) [19].

Vitamin A deficiency (VAD) increases the risk of diseases such as diarrhea and measles and when severe, can lead to blindness in children. Low availability and inadequate consumption of Vitamin A diets constitute the major determinants of Vitamin A deficiency (VAD) [9]. It is against this background, that Federal Government of Nigeria in collaboration with other organizations brought about the vitamin A bio-fortified cassava through a process called **bio-fortification**. Bio-fortification is the process of breeding nutrients into food crops, either by using natural breeding techniques or by using genetically modified organisms [9]. The Federal Government of Nigeria announced the release of the Vitamin A cassava varieties on 7$^{th}$ December, 2011, developed by International Institute for Tropical Agriculture (IITA), Ibadan in collaboration with the National Root Crops Research Institute (NRCRI), Umudike and funded by HarvestPlus project and the cassava transformation agenda of the Federal Ministry of Agriculture and Rural Development of Nigeria to cushion the effects of vitamin A deficiency, a micronutrient. The first three-wave Vitamin A cassava varieties released by National Varietal Release Committee of Nigeria are UMUCASS 36, UMUCASS 37, and UMUCASS 38 and recognized as IITA genotypes - TMS 01/1368, TMS 01/1412, and TMS 01/1371 with intermediate content of vitamin A (40%) [10]. In 2011, the biofortification (Vitamin A Cassava) programme commenced with stem multiplication in ten Local Government Areas (LGAs) in each of the four states of Nigeria; Oyo in the South-west, Imo in the South-east, Akwa Ibom in the South-south and Benue in the North-central. Other developed improved varieties released from 2014-2022 includes NR07/0326, NR07/0506, NR07/0497, NR07/0499, NR07/0427, NR07/0432 [16].

The agricultural problem in Nigeria relates to low productivity, and inefficiency with which farmers use resources on the farms [17]. Many factors may have contributed to the low yields experienced in cassava production. One of the major causes is resources (land, labour, fertilizer, Agrochemicals and cuttings) misallocation by the smallholder farmers which results into inefficiency in their production. Malnutrition of nutrients like Vitamin A, which lead to Vitamin A deficiency (VAD) most especially in children and lactating mothers, is prevalent in Niger state. As breaking the jinx of perpetual low yield of cassava production remains a challenge, it became necessary to determine the resource use efficiency of vitamin A bio-fortified cassava production in Niger State. The specific objectives are to: describe the socio-economic characteristics of vitamin A cassava production in the study area, ascertain the resource-use efficiency of vitamin A cassava production in the study area, and identify the production constraints faced by vitamin A cassava producers in the study area.

## MATERIALS AND METHODS

### Study Area

The study was conducted in Niger state, Nigeria. The state is located in the North-Central geo-political zone of Nigeria and lies between Longitude $3^0$ 30” E and $7^0$ 20” E and Latitude $8^0$ 20” N and $11^0$ 30” N. It shares boundaries with Kaduna State and FCT (north-east and south-east respectively); Zamfara State (north); Kebbi State (west); Kogi State (south); Kwara State (south-west); Republic of Benin (north-west). According to [14], the estimated population of the State was about 3,950,249, and base on the annual growth rate of 3.2%, the State has an estimated population of 5,586,000 as at 2017 [15], with males representing 51.5% of the State's population while females represent 48.5%. Niger state comprises of 25 Local Government Areas and three agricultural zones. Nupe, Gbagi and Hausa are the major ethnic groups in the State.

**Sampling Procedure and Sample Size**

A multistage sampling method was employed for the study. The first stage was the purposive selection of one Local Government Area (LGA) from each of the three agricultural zones (I, II and III), these is based on their relatively high concentration of cassava production and been among the beneficiaries of HarvestPlus vitamin A cassava stem multiplication program championed by the international financial trust fund (IFAD), the selected LGAs includes; Mokwa, Shiroro, and Wushishi. The second stage involves the random sampling of one (1) community from each of the selected Local Government Areas due to the plethora of vitamin A cassava farmers in the communities. The selected communities are; Muwo, Gwada, and Loko goma. The third stage involves the random selection of 35 farmers from each community based on IFADs grouping making a total of 105 respondents as sample size. Active vitamin A bio-fortified farmers were identified with the help of the State's ADP/IFAD Staff in the selected local governments.

**Data Collection**

Primary data used for the study were derived from set of structured questionnaire administered with the aid of staff from ADP/IFAD and also subjected to descriptive (mean, frequency, percentage, and ranking) and inferential analysis (multiple regression).

**Model Specification**

The multiple regression analysis was used to examine the resource-use efficiency using ordinary least square method. Four functional forms (linear, semi-log, exponential and double log) were fitted to the data generated from the field under the notion that data fulfilled the assumption of the multiple regression models and the one that gave the best fit was selected on the basis of: The value of the coefficient of determination ($R^2$), Significance of the F- value, Significant level of the parameters (P-value) and Signs of the estimated coefficient that conform to the *a priori* expectations.

The explicit forms of these four functional forms are expressed as follows:

1. **Linear function**

$$Y=b_0 + b_1X_1+ b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + U \quad (1)$$

2. **Semi-log function**

$$Y=\ln b_0 + b_1\ln X_1+ b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + U \quad (2)$$

3. **Exponential function**

$$\ln Y = b_0 + b_1X_1+ b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + U \quad (3)$$

4. **Double log function**

$$\ln Y = b_0 +b_1\ln X_1+ b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + U \quad (4)$$

For all the functional forms:

Y = Vitamin A bio-fortified cassava output (tonnes)

$X_1$ = Farm size (ha)

$X_2$ = Labour (man-days)

$X_3$ = Cassava cuttings (bundles)

$X_4$ = Quantity of fertilizer (kg)

$X_5$ = Quantity of agro-chemicals (litres)

U = Error term
$b_0$ = Constant
$b_1$ to $b_5$ = Estimated regression coefficients.
To estimate the level of resource usage, the Marginal Value Product (MVP) for each resource was derived and compared with its respective Marginal Factor Cost (MFC). The MVP of a resource was computed as:

$$MVP_{Xi} = MPP_{Xi}.Py \quad (5)$$

Where,

$MVP_{Xi}$ = Marginal Value Product of input $X_i$
$MPP_{Xi}$ = Marginal Physical Product of input $X_i$
Py = Unit Price of Output (cassava)

$$MPP = \frac{dy}{dx} = bi\,\frac{y}{x} \quad (6)$$

The resource use efficiency was estimated using the formula in equation (7):

$$\text{Resource use efficiency (r)} = \frac{MVP}{MFC} \text{ or } \frac{MVP}{PXi} \quad (7)$$

Where,
r = Efficiency ratio
MVP = Marginal Value Product of a variable input
MFC = Marginal Factor Cost (Price per unit input)
$bi$ = Estimated regression coefficient of input Xi
Pxi = Unit price of input resource
Decision rule:
If:
r = 1; there is optimal/efficient utilization of resources
r >1; there is under-utilization of the resources
r <1; there is over-utilization of the resources

**Marginal Value Product (MVP) Adjustment:** The relative percentage change in MVP of each resource required to obtain optimal resource allocation that is r = 1 or MVP = MFC, was estimated following [22] as:

$$D = (1 - 1/r) * 100. \quad (8)$$

Where,
D = absolute value of percentage change in MVP of each resource.

## RESULTS AND DISCUSSION

### Socioeconomic characteristics of Respondents

The result presented in Table 1 reveals that majority of the respondents were male constituting about 73.3% to females 26.7%. The data shows that the male gender were mostly involved in vitamin A bio-fortified cassava production than female gender in the study area. However, this may be attributed to the fact that women are more involved in processing than production. This assertion is further supported by the findings of [11] who reported that majority of farmers in Niger State are male. The mean age of the farmers is 39years indicating that most of the farmers were young; still within their active age, agile and energetic. Hence, technologies to enhance their productivity could be successfully introduced and adopted. Majority (89.5%) of the respondents had formal education while 10.5% had no formal education. Those who are literate are expected to be more innovative because of their ability to get information more quickly, their ability to take more risk and shrewd in resource management. Table 1 further reveals that household size in the study area is relatively large with most of the respondents (48.6%) ranging from 6-10 persons. Thus, with a mean household size of 10 persons, this could increase the supply of family labor and reduce the cost of hiring labor [12]. In addition, 46.7% of the respondents had a farming experience of >15 years, while the least (9.5%) had an experience 0f 1-5 years. The mean number of years of farming experience of the respondents was 16 years. This is in conformity with the findings of [8] who found that the average farming experience of cassava producers in Delta State is 16 years. The long years of experience is tangible in sustainability of production and productivity as stated by [3] that long years of farming could enhance efficient utilization of farm resources by small scale cassava farmers. Table 1 further reveals that the average farm size in the study area is 3.72 hectares. This implies that majority (82.9%) of vitamin A cassava farmers in the study area were predominantly small-scale farmers. This result is in agreement with [1], who stated that the size of farm possessed by a particular farm family is believed to determine the extent to which other resources (capital, labour etc.) will be utilized for optimum productivity. Most (51.4%) of the farmers had contact with extension agents while 48.6% had no contact with extension agents. Table 1 concluded by showing an average annual income of more than 1 million earned by the respondents. This means that farmers in these communities relied absolutely on farm business and must have acquired a lot of farming experience over time.

**Multiple Regression Analysis**

Table 2 depicts the results obtained from the multiple regression model for Vitamin A bio-fortified cassava production in Niger State. The double log functional form was chosen as lead equation based on statistics criterion. The coefficient of multiple determination, Adjusted $R^2$ was 0.747, indicating that 74.7% of the variation in dependent variable (output) was explained by the independent variables (inputs) included in the model (Table 2) and the remaining 25.3% was as a result of non-inclusion (random error) of other explanatory variables. The F-ratio was 43.488 and significant at 1% which implies that the explanatory variables jointly explained the dependent variable. Results obtained for Vitamin A cassava shows significant values at 1% for all the explanatory variables (inputs) used with only farm size and agrochemicals having a negative coefficient. Farm size was negative and significant at 1%, suggesting an inverse relationship with vitamin A bio-fortified cassava output. This implies that if these factor is increased above its present level, vitamin A cassava production will decrease significantly by 4.309 units. This may indicate that farmers with small farms use/manage the land diligently, which reduces the loss in soil fertility level hence making them more productive. However, the statistical value indicates the contribution of farm size to the overall output of vitamin A bio-fortified cassava which conforms to the *a priori* expectation. Similar results were reported by [5]. Agrochemicals was negative, hence, increase in the use of agrochemicals by one unit will lead to decrease of vitamin A cassava output by 3.272 units, this is because increasing the use of agrochemicals will lead to accrual (increase) of more cost of production and reduce total revenue. This is consistent with the findings of [17]. The coefficient of cuttings (2.252) and fertilizer (0.081) were positive and significant at 1%, this shows that any unit increases in the use of cuttings or fertilizer would lead to an upsurge in Vitamin A bio-fortified cassava output ceteris paribus. As expected, the coefficient of labour (2.873) was positive and significant at 1% level of probability which was in line with the *a priori* expectation. This shows that an improvement in unit of labour would lead to an upsurge in Vitamin A cassava output ceteris paribus. This is because increasing labour in cassava production adds additional output to decrease the total production costs and this increase farmers' returns. This result is in conformity with the findings of [2].

**Resource Use Efficiency of Vitamin A Bio-fortified Cassava**

Table 3 reveals that farm size, fertilizer and agrochemicals were over-utilized, while labour and cassava cuttings were under-utilized in the production of vitamin A bio-fortified cassava. The over-utilization of farm size (-0.20) might be attributed to the availability of vast land in the study area. Agrochemicals (-4.12) was also over-utilized. The over-utilization of fertilizer (0.29) might be due to the limited use of animal manure as fertilizer by farmers from their farms for the crop production which has no significant cost implication [20], this is in sync with the findings of [22]. While subsidies on fertilizer and agrochemicals might also be a reason for the over-utilization of these inputs in the study area. The underutilization of labour (8.70) and cassava cuttings (21.42) in the study area might be due to lack of effective incentives to farmers for the use of improved technologies might be another reason because most of the farmers in the study area still use crude methods of production which leads to the usage of inputs below economic level and hence, leads to low productivity. This finding was in agreement with [21], who reported that high cost of the resource (cassava cuttings) could be the reason for the under-utilization of the resource, especially by the low income farmers indicating that more than profit maximization levels of resources were used

Therefore, for resources to be efficiently utilized, vitamin A cassava farmers needs to make an adjustment of their resource use by reducing the use of farm size by 600%, fertilizer by -245%, agrochemicals by 124% and an increase in the use of labour by 89%, and cuttings by 95% respectively.

**Constraints to Vitamin A Bio-fortified Cassava Production**

The results of the constraints associated with vitamin A bio-fortified cassava production practices in Niger State is presented in Table 4. The constraints were ranked based on their severity and seriousness as perceived by farmers. High cost of inputs, insecurity, poor access to financial services, inadequate storage facilities, and inadequate extension services were perceived as the most severe constraints encountered by vitamin A bio-fortified cassava producers. High cost of inputs ranked highest as reported by 82.2% of the respondents, the high cost of inputs leads to most farmers planting without certain farm inputs which results to poor yield. Insecurity (67.1%) ranked next with the menace and detriment of insurgencies across the state taking its toll on farming activities. The result is consistent with the findings of [4], who found that high cost of inputs and insecurity were found to be the most severe and highest ranked constraints faced by cassava farmers during its production in Akpabuyo LGA. The least ranked constraint is the problem of pest and diseases infestation (54.4%) which was termed as not severe along with poor access to improved planting materials and poor market pricing. The result is in agreement with [8], who reported pest and diseases to be the least constraints affecting cassava production in Delta State.

## CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it was revealed that majority of cowpea farmers in the study area were in their active and productive age, well experienced in cassava production and mostly male. The vitamin A bio-fortified cassava farmers in the study area failed to achieve efficient utilization (r=1) of resources, thus required MVP percentage adjustment (D %) to achieve optimum utilization. This study concludes that the resources should be used wisely to maximize productivity. Hence, by addressing the identified challenges and implementing the recommended strategies, it is possible to enhance both the productivity and profitability of vitamin A bio-fortified farming, thereby contributing to better nutritional outcomes and economic development in the study area.

Based on the findings of the study, the following recommendations were made;

i. Since resources were not efficiently utilized, government should put more effort in training farmers focusing on resource optimization and sustainable farming techniques.
ii. Financial assistance should be given to farmers in form of grants or subsidies so as to support resource poor farmers in improving their productivity, this will curtail the problem faced due to high cost of inputs (fertilizer, agrochemicals etc.) in the study area.
iii. Government should promote training on bio-fortified foods derived from vitamin A cassava so as to curb the menace of malnutrition and enhance economic development in the study area.

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**Table 1: Socioeconomic Characteristics of Vitamin A Bio-fortified Cassava Farmers**

| Variables | Frequency | Percent | Mean |
|---|---|---|---|
| **Gender** | | | |
| Male | 77 | 73.3 | |
| Female | 28 | 26.7 | |
| **Total** | **105** | **100.0** | |
| **Age** | | | |
| <20 | 5 | 4.8 | |
| 20-40 | 64 | 60.9 | 39.02 |
| 41 and above | 29 | 27.6 | |
| >60 | 7 | 6.7 | |
| **Total** | **105** | **100.0** | |
| **Level of Education** | | | |
| Primary education | 28 | 26.7 | |
| Secondary education | 41 | 39.0 | |
| Tertiary education | 25 | 23.8 | |
| No formal education | 11 | 10.5 | |
| **Total** | **105** | **100.0** | |
| **Household Size** | | | |
| 1-5 | 24 | 22.8 | |
| 6-10 | 51 | 48.6 | 10 |
| 11 and above | 30 | 28.6 | |
| **Total** | **105** | **100.0** | |
| **Farming Experience** | | | |
| 1-5 | 10 | 9.5 | |
| 6-10 | 29 | 27.6 | 16 |
| 11-15 | 17 | 16.2 | |
| >15 | 49 | 46.7 | |
| **Total** | **105** | **100.0** | |
| **Farm Size** | | | |
| <1 | 11 | 10.5 | |
| 1-5 | 76 | 72.4 | 3.72 |
| 6-10 | 14 | 13.3 | |
| >10 | 4 | 3.8 | |
| **Total** | **105** | **100.0** | |
| **Extension Contact** | | | |
| Yes | 54 | 51.4 | |
| No | 51 | 48.6 | |
| Total | **105** | **100** | |
| **Annual Income** | | | |
| <500,000 | 21 | 20.0 | |
| 500,000-1,000,000 | 28 | 26.7 | 1,643,251.71 |
| >1,000,000 | 56 | 53.3 | |
| **Total** | **105** | **100.0** | |

Source: Field Survey, 2024.

**Table 2: Estimated Multiple Regression Production Function for Vitamin A Cassava Production in Niger State.**

| Inputs | Linear | Semi-log | Exponential | Double log (+) |
|---|---|---|---|---|
| Constant | -7.374 | -287.593 | 1.868 | -11.090 |
| | [1.050] | [39.066] | [0.263] | [6.297] |
| | (0.000)*** | (0.000)*** | (0.000)*** | (0.083)* |
| Farm size | -0.517 | -14.310 | -0.157 | -4.309 |
| | [0.193] | [7.194] | [0.067] | [1.601] |
| | (0.009)*** | (0.051)** | (0.022)*** | (0.009)*** |
| Labour | 0.237 | 25.337 | 0.005 | 2.873 |
| | [0.329] | [12.337] | [0.046] | [1.098] |
| | $(0.473)^{NS}$ | (0.042)** | $(0.920)^{NS}$ | (0.011)*** |
| Cuttings | 0.804 | 24.492 | 0.006 | 0.252 |
| | [0.147] | [5.478] | [0.001] | [0.033] |
| | (0.000)*** | (0.000)*** | (0.000)*** | (0.000)*** |
| Fertilizer | 1.298 | 36.863 | 0.002 | 0.081 |
| | [0.196] | [7.302] | [0.000] | [0.010] |
| | (0.000)*** | (0.000)*** | (0.000)*** | (0.000)*** |
| Agrochemicals | -0.498 | -21.046 | -0.029 | -3.727 |
| | [0.265] | [9.842] | [0.042] | [0.999] |
| | (0.064)** | (0.036)** | $(0.496)^{NS}$ | (0.000)*** |
| $R^2$ | 0.641 | 0.568 | 0.528 | 0.764 |
| Adjusted $R^2$ | 0.614 | 0.536 | 0.493 | 0.747 |
| F-statistics | 23.941 | 17.638 | 14.990 | 43.488 |

Source: Computed from the Data Obtained from Field Survey, 2024.
Note: *, **, ***, NS. Significance at 1%, 5%, 10% and Non-significance respectively.
Values in parenthesis [ ], ( ) are standard error and probability value

**Table 3: Resource Use Efficiency in Vitamin A Bio-fortified Cassava Farming**

| Variable Inputs | Coefficient | MPP | MVP | MFC | R | Decision | D (%) |
|---|---|---|---|---|---|---|---|
| Farm size | -4.309 | -433.18 | -436.94 | 2146.79 | -0.20 | OU | 600 |
| Labour | 2.873 | 288.82 | 1871.55 | 215.09 | 8.70 | UU | 89 |
| Cuttings | 0.252 | 25.33 | 314.09 | 14.66 | 21.42 | UU | 95 |
| Fertilizer | 0.081 | 8.14 | 102.56 | 350.05 | 0.29 | OU | -245 |
| Agrochemicals | -3.727 | -374.68 | -2529.09 | 613.56 | -4.12 | OU | 124 |

Source: Computed from the Data Obtained from Field Survey, 2024.
Note: OU = Over-utilization, UU = Under-utilization.

**Table 4: Constraints to Vitamin A Bio-fortified Cassava Production**

| Constraints | Frequency | Percent | Rank |
|---|---|---|---|

| | | | |
|---|---|---|---|
| High cost of inputs | 60 | 82.2 | 1st |
| Insecurity | 49 | 67.1 | 2nd |
| Poor access to financial services | 49 | 67.1 | 2nd |
| Inadequate storage facility | 47 | 64.4 | 4th |
| Inadequate extension services | 46 | 63.0 | 5th |
| Poor access to improved planting materials | 43 | 58.0 | 6th |
| Poor market pricing | 41 | 56.2 | 7th |
| Pest and disease infestation | 37 | 50.7 | 8th |

Source: Field Survey, 2024.
*Multiple response.

# JOB PREFERENCE AND ENTREPRENEURIAL ORIENTATION AMONG YOUTH UNDERGRADUATE AGRICULTURAL STUDENTS IN NIGER STATE, NIGERIA

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## ABSTRACT
The study was carried out to assess job preference and entrepreneurial orientation among youth undergraduate agricultural students in Niger State, Nigeria. Three stage sampling procedure were employed in the selection of 208 respondents for the study. Data collected were analysed using descriptive statistics such as frequency, percentage and mean, entrepreneurial orientations were measured using the Entrepreneurial Orientation (EO) scale. The result of the findings revealed that more than half (58.7%) of the respondents preferred employment in the public sector. In addition, salary and bonuses (36.1%), job security (25.0%) and pension plans (12.5%) were the major reasons for preferring job in the public sector. Also teaching (26.0%), agribusiness (19.7%) and agricultural consultancy (10.1%) were the preferred job type as agricultural students**.** Furthermore, the study revealed that innovativeness ($\bar{X}$=66.61) and autonomy **($\bar{X}$= 47.03)** had the highest entrepreneurial orientation scores. The study recommended that universities should integrate more practical courses on agribusiness and entrepreneurship, focusing on real-world applications like agronomy, soil science and apiculture for agricultural students.
**KEYWORDS:** Job, Preference, Orientation, Undergraduate and Entrepreneur

## INTRODUCTION
During the pre-colonial era, agriculture served as the primary source of employment, with nearly all capable young individuals dedicating their efforts to farming and other activities within the primary sector of the economy, including weaving, fishing, iron-smelting, tanning, leatherwork, hunting, and carving. However, the advent of colonialism and the subsequent establishment of factories (alongside educational institutions) prompted many youths to abandon farming in pursuit of paid jobs, particularly in the public sector. This paradigm shift caused the agricultural sector, which previously provided over sixty percent of jobs in the precolonial period, to lose favour, particularly among the youth (Ajani and Oyekola, 2019). Although the so-called non-agricultural white-collar jobs brought about a higher standard of living, preference for these roles resulted to higher rates of unemployment.

Many individuals perceive themselves as unemployed due to insufficient pay, limited prospects for career progression, or unfavourable working conditions in their current employment. Similarly, self-employed individuals who struggle to meet their financial needs or desired living standards often classify themselves as unemployed. This trend is exemplified by the large volume of applications submitted for job vacancies in government ministries, departments, and agencies. For instance, there were over 400,000 applications for 30,000 available constable positions in the Nigeria Police Force (Olawin, 2024); 524,315 applicants for 3,200 vacancies in the Nigeria Customs Service (Lenbang, 2019); at least 300,000 applications for 750 positions advertised by the Economic and Financial Crimes Commission (Lenbang, 2019); and 1.4 million

Nigerians competed for 5,000 job openings announced by the Nigeria Security and Civil Defence Corps (Ogundipe, 2020). This brings to the fore the issue of job preference. Job preference has been a longstanding phenomenon, shaped by various considerations unique to each and subject to change over time and across different societies. According to Kavya and Sreeya (2019), job preference refers to the specific characteristics or attributes of a job that individuals prioritize or desire when seeking employment. Job preferences are highly subjective and can significantly differ among individuals based on their values, career aspirations, skills, and particular circumstances.

Entrepreneurship plays a vital role in the economic landscape of every nation, serving as a significant driver for financial advancement and progress (Ferreira *et al*., 2023). It represents a crucial instrument in fostering the economic prosperity and development of a country. Entrepreneurs serve as catalysts for job creation, innovation, heightened market competition, and adaptation to evolving societal trends and market dynamics (Gujrati *et al*., 2019). Furthermore, entrepreneurship not only fulfils individual aspirations but also contributes substantially to government efforts aimed at strengthening economic growth and development, owing to the economic contributions made by entrepreneurs. The relationship between entrepreneurship and economic growth dates back to 1934 (Liu *et al*., 2019). However, many young people are hesitant to pursue entrepreneurship due to a lack of entrepreneurial orientation.

Entrepreneurial orientation refers to the mindset and decision-making approach adopted by entrepreneurs when involved in entrepreneurial activities. This orientation encompasses risk-taking, proactivity, innovation, aggressive competition, and autonomy that are interconnected yet distinct (Covin *et al*., 2020). Globally, entrepreneurship is being promoted more and more as a viable career option for students and in Nigeria, entrepreneurship studies have been included in the curriculum of undergraduate programmes. This is because, to a large extent, entrepreneurship activities are intention-based People do not suddenly become entrepreneurs without certain triggers, guidance, and, importantly, intentions. Year-in and year out, approximately 90% of graduates face the challenge of unemployment (Adeniyi *et al*., 2022). During the third quarter of 2022, while youth unemployment was 33.5%, overall unemployment was projected at 33%, marking an increase from 32.5% in 2021. Predictions suggested a further rise to 40% by 2023 and 44% by 2024 (Sasu, 2022). The high youth unemployment rate can be attributed to the high level of risk aversion among youths towards starting a business, the hostile entrepreneurial environment in the country, the lack of capital to start a business, the mismatch between graduates' job preferences and available job opportunities, and the unending wait for white-collar jobs. The agricultural sector in Niger State serves as a vital economic pillar, offering significant opportunities for employment and entrepreneurship among the youth population. However, despite the potential for growth and development within this sector, there exists a gap between the career aspirations of youth undergraduate agricultural students and their inclination towards entrepreneurial pursuits. Thus, this study aimed to identify job preference of students and determine entrepreneurial orientation of students.

## RESEARCH METHODOLOGY

This study was conducted in Niger States, Nigeria. The State lies within latitudes $3^0$ 20′ - $7^0$ 40′N and longitudes $8^0$ 11′ - $11^0$ 2′ E. According to the 2006 Census, the State has a population of 3, 950,249 (NPC, 2006) which is projected to be increasing at an annual growth rate of 2.38 %. Given this projected growth rate, the population of the State in 2023 was 5,962,478. It covers an estimated land area of 76,363 km$^2$. The mean annual rainfall ranges between 1100mm in the north and 1600 mm in the south. The average annual number of rainy days ranges between 187 and 220 days. The rain starts in late April and ends in October with the peak being in August. The average minimum temperature is about 26 $^0$C while the average maximum temperature is about 36 $^0$C. The mean humidity ranges between 60 % (January to February) and 80 % (June to September).

The study population consists of all final-year undergraduate students of agriculture from the Federal University of Technology (FUT) in Minna and Ibrahim Badamasi Babangida University (IBBU) in Lapai. A three-stage sampling procedure was used to select the respondents for the study. The first stage involved purposive selection of the Federal University of Technology, Minna and Ibrahim Badamasi Babangida University Lapai, this is because they had fully accredited agricultural programmes and proximity to the study area. The second stage involved purposive selection of schools or faculty of agriculture from both institutions because the study focussed on agricultural students. The third stage involved the purposive selection of final year's students, this because final year students are rounding up their degree programme thus the needs to evaluate their readiness for entrepreneurship. A total of 208 respondents participated in the study. This sample was obtained by using 30% of the total sample frame, as indicated by Yusoff et al. (2016), which is presented in Table 1. The respondents were selected from a list of registered final-year students provided by the dean of both institutions.

**Table 1: Sample outlay of respondents in the study area**

| Institution | Sampling frame | Sample size (30%) |
|---|---|---|
| Federal University of Technology, Minna | 553 | 166 |
| Ibrahim Badamasi Babangida University, Lapa | 140 | 42 |
| Total | 693 | 208 |

**Source: Dean of the school**

Primary data were used in the study, gathered from respondents through a semi-structured questionnaire and an interview schedule via Kobotoolbox. The collected data were analyzed descriptively, using frequencies, percentages, and means. The measurement of entrepreneurial orientation was based on the Entrepreneurial Orientation (EO) scale developed by Al Mamun *et al*. (2017).

- **i.** The entrepreneurial orientation scale has 54 questions with a 5-point Likert response presented as strongly agree, agree, undecided, disagree and strongly disagree. The response was scored as follows:
- **ii.** Strongly agree=5, Agree=4, Neutral= 3, Disagree=2, Strongly disagree=1

The total score for each respondent was determined by adding up the scores for the 54 questions. Thus, the lowest score was 54 (supposing the respondent selects "strongly disagree" for all questions); while the highest score was 270 (if the respondent selects "strongly agree for all questions).

## RESULTS AND DISCUSSION

### Job preference of students

### Preferred sector for a job after graduation

The results in Table 2 revealed that more than half of the respondents (58.7%) preferred employment in the public sector, while 41.3% preferred the private sector. Public sector preference is often driven by perceived job security, pension benefits and long-term stability, which are crucial factors for many graduates seeking reliable, sustained income in a structured environment. Additionally, public sector roles can be appealing to those valuing steady career progression and predefined benefits, making it an attractive choice for students prioritizing financial stability. This is consistent with the findings of Kozák (2020) who reported that Nigerian graduates often view public sector jobs as more stable and secure, especially in the context of economic uncertainties.

**Table 2: Distribution of respondents according to job preference**

| Prefer jobs | Frequency | Percentage |
|---|---|---|
| **Preferred sector for job after graduation** | | |
| Public sector | 122 | 58.7 |
| Private sector | 86 | 41.3 |
| **Reason for Sector Choice** | | |
| Innovation | 1 | 0.5 |
| Job tenure protection | 5 | 2.4 |
| Performance recognition | 6 | 2.9 |
| Corporate culture | 9 | 4.3 |
| Job security | 52 | 25.0 |
| Pension plans | 26 | 12.5 |
| Social impact | 10 | 4.8 |
| Opportunities for advancement | 17 | 8.2 |
| Salary and bonuses | 75 | 36.1 |
| Work-life balance | 7 | 3.4 |
| **Preferred Job Type as an agricultural student** | | |
| Agribusiness | 41 | 19.7 |
| Farming – crop, animal, fisheries | 5 | 2.4 |
| Agric. Consultancy | 21 | 10.1 |
| Banking | 16 | 7.7 |
| Civil society/NGO | 5 | 2.4 |
| Data analyst | 10 | 4.8 |
| Digital Marketing | 7 | 3.4 |
| Events Planning | 2 | 1.0 |
| Fashion design | 4 | 1.9 |
| Healthcare personnel | 3 | 1.4 |
| Journalism | 14 | 6.7 |
| Politics | 2 | 1.0 |
| Project management | 24 | 11.5 |
| Teaching | 54 | 26.0 |

**Source: Field survey, 2024**

Meanwhile, the 41.3% interested in the private sector may be attracted to its perceived innovation, faster career progression and potential for competitive compensation. The private sector is also associated with more dynamic work environments, offering students varied opportunities to specialize, innovate, and potentially climb the career ladder more quickly.

**Reason for sector choice**

Table 2 also revealed that the most common reason students chose their preferred sector was "salary and bonuses," reported by 36.1% of respondents. This emphasizes that financial compensation is a significant motivator. Following this, "job security" was mentioned by 25.0% of students, and "pension plans" was reported by 12.5%. These results underscore the importance of financial stability and benefits in career decision-making. For students selecting the public sector, job security and pension plans reflect a preference for roles that safeguard their long-term financial interests, especially in an environment where job tenure is relatively assured. In the private sector, motivations such as "opportunities for advancement" (8.2%), "corporate culture" (4.3%), and "innovation" (0.5%) suggest that students are attracted to the dynamic, growth-oriented aspects of private companies. For those valuing "work-life balance" (3.4%) and "social impact" (4.8%), both sectors can provide opportunities depending on the organisational culture and job nature, but these considerations may lean toward roles that promote quality of life and contribute positively to society. This aligns with the study of Martins *et al.* (2023) who stressed that job security remains a primary concern for Nigerian graduates. Their study indicated that the volatile nature of the private sector makes graduates more inclined to seek opportunities in the public sector, where job security is perceived to be more reliable. This highlights the importance of stability as a motivating factor in job sector preference.

**Preferred job type as agricultural students**

Table 2 shows the preferred job types of respondents with diverse aspirations, 26.0% expressed an interest in teaching, indicating a strong inclination towards roles in academia or training where they can share knowledge. Teaching offers stability and allows agricultural students to pass on their experience, influencing the next generation in the agricultural field. Agribusiness (19.7%) and agricultural consultancy (10.1%) were also prominent choices, demonstrating an entrepreneurial spirit and a desire to directly influence the agricultural sector. These roles allow graduates to engage in the agricultural supply chain, introduce innovative practices and potentially lead ventures that align with their field of study. Other job interests include project management (11.5%) and data analysis (4.8%), indicating that students were open to diversified roles beyond traditional agricultural careers. The inclusion of interests in fields like digital marketing (3.4%), healthcare (1.4%), and even fashion design (1.9%) reflects an adaptive approach to career planning, where students are willing to leverage their skills in various industries. This adaptability suggests that while students are rooted in agriculture, they are also exploring broader career paths that allow them to apply their agricultural knowledge in versatile and innovative ways. This is substantiates by the findings of Olufunso (2018) who opined that agricultural graduates in Nigeria show a strong interest in teaching and agribusiness due to the potential for making a social impact and contributing to agricultural development. The study noted that teaching allows graduates to share knowledge and skills, while agribusiness presents opportunities for innovation and income generation, reflecting the dual interests of graduates in both education and entrepreneurship within the agricultural sector.

**Entrepreneurial orientation of students**

Table 3 presents the results of the assessment of students' **Entrepreneurial Orientation (EO)** based on the **EO Scale**. **Innovativeness** ($\bar{X}$=66.61) was the highest among the EO dimensions, indicating that students tend to be highly creative and open to new ideas. This inclination toward innovation is critical in agricultural studies, where advancements in technology, sustainable practices and productivity improvement are central. Exposure to innovative techniques in agriculture, such as crop rotation, integrated pest management, and the use of screen house for smart farming, can inspire students to pursue entrepreneurial ventures that emphasize creativity. This level of innovation orientation implies that many students may feel confident in finding unique solutions to agricultural challenges, a trait beneficial for entrepreneurs in the field. The mean score for **autonomy** was moderate ($\bar{X}$= 47.03), suggesting that students are somewhat interested in independence but may still appreciate guidance and structure. This balanced autonomy could stem from structured academic environments that provide both independent projects and collaborative opportunities, helping students value both self-reliance and teamwork.

**Proactiveness** and **competitiveness** were also fair with a mean of $\bar{X}$=23.28 and $\bar{X}$=23.12, respectively, indicating that students are fairly driven to take initiative and excel in competitive settings. These reflect a cautious approach to seizing opportunities, especially given the fluctuating nature of agricultural markets, where proactive and competitive skills are beneficial but often tempered by risk considerations. Lastly, risk-taking shows a moderate orientation, with $\bar{X}$=34.92. This suggests that students are reasonably open to calculated risks, possibly shaped by the agricultural sector's inherent risks such as unpredictable weather, pests, and market volatility. However, they are likely to balance this trait with careful planning and research. This implies that, innovativeness is the dominant trait, pointing to a strong desire among students to engage in creative and progressive endeavours within agriculture. This high orientation toward innovation indicates that most students are prepared to explore novel approaches in their future ventures, positioning them well for entrepreneurial activities that demand adaptability and inventive solutions in the agricultural industry. This is similar to the study of Arbab *et al.* (2022) who examined EO among Nigerian university students, reporting that high scores in innovativeness and proactiveness are closely associated with a strong entrepreneurial drive among young graduates. Their findings indicated a similar mean score for innovativeness (67.3) suggesting that Nigerian students tend to demonstrate innovative and proactive behaviours that support entrepreneurial activities, even in challenging economic environments.

**Table 3: Entrepreneurial orientation of student**

| **Entrepreneurial orientation** | **Minimum** | **Maximum** | **Mean** | **Std. Deviation** |
|---|---|---|---|---|
| Innovativeness | 55 | 72 | 66.61 | 4.772 |
| Autonomy | 35 | 58 | 47.03 | 5.673 |
| Proactiveness | 15 | 29 | 23.28 | 3.088 |
| Competitiveness | 16 | 29 | 23.12 | 3.034 |
| Risk taking | 23 | 43 | 34.92 | 4.739 |

**Source**: Field survey, 2024

**CONCLUSION AND RECOMMEDATIONS**

It can be concluded that more than half of the respondents prefer employment in the public sector. In addition, teaching, agribusiness and agricultural consultancy were the preferred job types as agricultural students. More so, the majority of respondents reported pursuing agricultural entrepreneurship after graduation. Furthermore, it can be concluded that innovativeness and autonomy had the highest entrepreneurial orientation scores. Therefore, the study recommended that students should extend their learning beyond the classroom by leveraging online platforms to access resources in areas such as digital farming, innovative agricultural techniques, and entrepreneurship. Many universities and organizations, like Coursera, provide free webinars, tutorials and certification programmes, offering up-to-date knowledge in agricultural practices and business management.

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# FACTORS INFLUENCING THE ADOPTION OF AGRICULTURAL TECHNOLOGIES AMONG FARMERS IN KEBBI STATE, NIGERIA

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## ABSTRACT

This study investigated the factors influencing the adoption of agricultural technologies among farmers in Kebbi State, Nigeria. Questionnaire was used to collect data from 200 respondents. Multistage sampling technique was used in selecting the respondents for the study. Data collected were analysed using both descriptive and inferential statistics (Logit and OLS regression analysis). Logistic Regression results found out that educational level, income, and access to credit significantly enhanced the likelihood of technology adoption, with access to credit having the most substantial impact with a z-value (1.82), closely followed by level of education with a z-value (1.80) and income level (1.75) respectively. Descriptive statistics revealed that 75% of farmers were aware of new technologies, yet only 60% have access to them, indicating a critical gap. Ordinary Least Squares (OLS) regression analysis indicated that the baseline yield for farmers not using any technology is 1,200 kg/ha. Adoption of improved seeds increases productivity by 600 kg/ha on average, with a statistically significant effect ($p < 0.001$). Using fertilizers resulted in an additional yield of 200 kg/ha, also highly significant ($p < 0.001$). Employing mechanization, such as tractors, leads to an increase of 200 kg/ha in yield, with a significant effect ($p < 0.001$). It is concluded that level of awareness of the farmers, access to credit and socioeconomic factors such as level of education, income and age greatly influenced the adoption of new agricultural innovations among farmers in Kebbi state. Fr From the above results, it was recommended that: financial institutions, government agencies, and NGOs should provide credit to farmers and make credit more accessible by offering low-interest loans and flexible repayment plans tailored to farmers' seasonal income. Since education has a positive effect on technology adoption, it is important to continue and expand educational initiatives for farmers. Programs should focus on providing practical, hand training sessions in local languages, specifically targeting the use of new agricultural technologies.

**KEY WORDS**: Socio-economic, factors, adoption, agricultural technologies, farmers

## INTRODUCTION

Agriculture is a cornerstone of the Nigerian economy, particularly in Kebbi State, which is known for its rice and millet production (Feder and Ziberman, 2022). It contributes significantly to employment, income generation and food security of the State. The introduction of new agricultural technologies has the potential to improve crop yields, increase income and enhance food security. However, the extent to which farmers adopt these innovations is often influenced by various factors particularly their socio-economic attributes (Opara, 2021). Understanding these factors is essential for developing effective strategies to encourage technology adoption and enhance agricultural productivity.

The introduction of innovative agricultural practices and technologies—ranging from improved seed varieties and fertilizers to advanced irrigation techniques—holds promise for increasing crop yields and overall farm efficiency (Adesina and Baidu, 2015). However, the extent to which farmers adopt these innovations is often contingent on various socio-economic factors including education, income, access to credit and information dissemination channel (Opara, 2021). Other factors such as financial constraints, infrastructural limitations and socio-cultural dynamics can create significant barriers to adoption Moreover, awareness of new agricultural technologies does not necessarily equate to access or utilization as many farmers in Kebbi State remain hesitant to adopt these agricultural technologies (Doss, 2006). This disjunction raises critical questions about the effectiveness of extension services and the overall support systems in place for farmers. Despite the State's agricultural potential, many farmers continue to face challenges in adopting agricultural technologies that could enhance productivity and sustainability. This has constitute a gap in knowledge that need to be filled which necessitate this study to explore the socio-economic factors influencing adoption of agricultural technologies among farmers in Kebbi State (Opara, 2021).
Specifically, the study:

i. assessed the effects of socio-economic factors on adoption of Agricultural technology.
ii. assessed the awareness and access to agricultural technologies among farmers in Kebbi State.
iii. examined the impact of agricultural technologies on farmers' productivity among farmers in Kebbi State.
iv. evaluated the effects of the agricultural technologies adoption of the productivity of the of farmers

## METHODOLOGY

### Study area

Kebbi State is located in Northwestern Nigeria. Its approximate geographical coordinates are Latitude 12.5° North and Longitude 4.2° east. As of the latest estimates, Kebbi State has a population of approximately 4.3 million people based on 2023 projected rate**.** The population is predominantly rural, with a significant portion engaged in agricultural activities. Kebbi State is known for its rich ethnic diversity (NPC, 2006). The state is predominantly inhabited by various ethnic groups, with the Hausa and Fulani being the largest. Other significant ethnic groups include the Zabarmawa, Dakarkari, Dakkawa, Kambari, Gungawa**,** and Bussa. These groups have coexisted for centuries, maintaining their distinct languages, cultures, and traditions. The Hausa language is widely spoken and serves as a common medium of communication among the diverse groups. Kebbi State covers a total land area of approximately 36,800 square kilometers, making it one of the larger states in Nigeria. The state is bordered by Sokoto State to the north, Zamfara State to the east, Niger State to the south, and the Republic of Niger to the west. The terrain is mostly flat, with some undulating hills, especially in the southeastern parts near Zuru and Yauri (Rogers, 2023).

Kebbi State experiences a tropical continental climate characterized by two distinct seasons: Dry Season (November to April). The dry season is dominated by the harmattan winds, bringing cool, dry air, and lower humidity levels. This period can be very hot, especially from February to April, with average temperatures reaching 35°C to 40°C.Rainy Season (May to October) (NPC,2006). During this period, the state receives moderate to heavy rainfall, averaging between 800 to 1,000 millimetres annually. The wettest months are typically July and August, which are essential for agricultural activities in the region. Agriculture is the primary occupation of the people in Kebbi State, with about 80% of the population engaged in farming. The state's fertile soil and favorable climate conditions support a wide range of agricultural activities. In addition to farming, some people are involved in fishing, especially in communities close to rivers like the Niger and Sokoto Rivers, as well as livestock rearing, which includes cattle, goats, and sheep. Trading, craftsmanship, and small-scale industries are also part of the economic activities in the state, contributing to the livelihood of its people (Wanger and Kariuki, 2015). Farming in Kebbi State is mostly subsistence-based, with farmers cultivating crops mainly for household consumption.

However, there is a growing shift toward commercial agriculture due to the state's involvement in agricultural initiatives such as the Anchor Borrowers' Program, which aims to boost rice production. Key crops grown include, Cereals: Maize, millet, sorghum, and rice (Kebbi is one of Nigeria's major rice-producing states), Legumes: Cowpea (beans) and groundnuts, Tubers: Sweet potatoes and yams and Vegetables and Fruits: Tomatoes, onions, pepper, and watermelon. In addition to crop farming, fishing is a significant activity, particularly in areas around the Kainji, Jega, and Argungu regions (Wanger and Kariuki, 2015). The famous Argungu Fishing Festival highlights the cultural importance of fishing in the state. Livestock farming is also common, with herders practicing both nomadic and semi-nomadic systems of livestock rearing. The combination of agriculture, fishing, and livestock farming makes Kebbi State a vital contributor to Nigeria's food security.

**Sampling procedure and sample size**

Multi stage sampling technique was employed to select participants from 4 local government areas within Kebbi. Firstly, one local government was selected from each of the four agricultural zones, the local governments are: Argungu, Gwandu, Yauri and Zuru respectively. Secondly, four (4) Villages were randomly selected from each of the selected LGAs thereby giving 16 villages. Thirdly, twelve (12) farmers were selected from each of the selected villages thereby giving a total number of 200 farmers used as sample size for the study. A total of 200 farmers were surveyed, ensuring representation from various demographic groups, including age, gender, and income levels.

**Method of data collection and analysis**

Data were collected using a structured questionnaire designed to capture information on farmers' demographics, access to resources, awareness of new technologies, and their adoption behaviours.

Data analysis involved both descriptive and inferential statistical methods. Descriptive statistics were used to summarize the demographic characteristics of the respondents, while inferential statistics, including Logit and Ordinary Least Square regression analysis, were employed to assess the relationship between socio-economic factors and agricultural technologies adoption as well as to test the effects of the agricultural technologies adoption on the productivity.

**Logit model specification**

The logistic regression model can be specified as follows:

Logit Regression Analysis (LRA) was employed to examine the socio-economic factors affecting the adoption of agricultural technologies among farmers in Kebbi State, Nigeria. The Logit regression analysis is an inferential statistical tool that describes the relationship between a censored continuous dependent variable $y_i$ and a vector of independent variables $x_i$ (Amamiya, 2018).

The general Logit regression model is mathematically expressed as:
$Y = \alpha + \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots + \beta_5 X_5 + U$……………… …………… (1)
Where;
$Y_i$ is the dependent variable and $X_1 – X_5$ are the independent variables.
Y = probability of adopting agricultural technologies (1 if adopted, 0 if not)
$X_1$ = Level of education (Years spent in school)
$X_2$ = Income per annum (₦)
$X_3$ = Age (Years)
$X_4$ = Access to credit ( 1 for access, 0 for otherwise)
$X_5$ = Farming experience (Years)
U = Error term
$B_i$ = Constant term
$B_1 – \beta_5$ = Regression coefficients estimated

**Ordinary Least Square Regression Model**
Ordinary least square regression was used to test to test the effects of the agricultural technologies adoption on the productivity where the dependent variable (Y) represents farm productivity (measured in yield per hectare), and the independent variables ($X_1$, $X_2$, $X_3$, $X_4$) represent different agricultural technologies.
The regression equation can be defined as:
$Y = \beta 0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \epsilon$
Where:
Y = Farm productivity (measured as yield per hectare)
$X_1$ = Use of improved seeds (1 if adopted, 0 if not)
$X_2$ = Use of fertilizers (1 if adopted, 0 if not)
$X_3$ = Mechanization (1 if tractors are used, 0 if not)
$X_4$= Irrigation systems (1 if adopted, 0 if not)
$\beta 0$ = Intercept (baseline productivity without any technology)
$\beta_1$, $\beta_2$, $\beta_3$, $\beta_4$ = Coefficients indicating the impact of each technology on productivity
$\epsilon$ = Error term

**RESULTS AND DISCUSSION**

Table 1 presents the results of logistic regression estimates on socio-economic factors influencing the adoption of agricultural technologies among farmers in Kebbi State. The coefficient for access to credit is 0.60**,** indicating a robust positive impact on technology adoption. This was closely followed by level of education 0.45 and income level 0.30 respectively. This suggests that farmers with access to credit are nearly twice as likely to adopt new technologies. This finding highlights the significance of financial support systems, as access to credit enables farmers to finance the purchase of seeds, fertilizers, and equipment essential for adopting innovative agricultural practices. Findings of Rogers (2023) indicate that educated farmers tend to accept and adopt innovations more than the illiterate farmers because educated farmers are able to read bulletins related to new innovations and guidelines on any new technology. Similarly, level of income of the farmer is a significant determinant in the adoption of new innovations because money is needed to finance any new innovation to be adopted.

Table 1 provide critical insights into the factors that drive technology adoption among farmers in Kebbi State. Education emerges as a pivotal factor, reinforcing the need for educational programs and training initiatives aimed at enhancing farmers' knowledge and skills related to new agricultural technologies. Similarly, the significant impact of income and access to credit highlights the necessity for financial interventions that empower farmers economically. These findings can inform policymakers and agricultural extension services in designing targeted programs that address these socioeconomic barriers. Opara (2021) noted that by focusing on education, financial access, and resources tailored to different farm sizes, stakeholders can enhance technology adoption rates, ultimately contributing to improved agricultural productivity and food security in the region.

**Table 1: Logit regression estimates on socio-economic factors affecting the adoption of agricultural technologies among farmers**

| Variable | Coefficient (β) | Standard Error | p-value | z-value |
|---|---|---|---|---|
| Education Level (Years) | 0.45*** | 0.10 | 0.001 | 1.80 |
| Income Level (₦) | 0.30** | 0.08 | 0.005 | 1.75 |
| Access to Credit | 0.60*** | 0.12 | 0.000 | 1.82 |
| Age (Years) | -0.02 | 0.01 | 0.100 | 0.98 |
| Farm Size (Ha) | 0.25 | 0.09 | 0.020 | 1.28 |

**Source:** Field Survey, 2024

The results of the farmers' awareness and access to agricultural technologies are presented in Table 2. The result shows a strong awareness of agricultural technologies among farmers, with 76% of them being aware of various agricultural technologies. However, access remains a challenge, with only 83.6% having practical access to these technologies. This discrepancy suggests that while farmers are informed, barriers exist that prevent them from utilizing the technologies available to them. The data shows that 76% of farmers are aware of new agricultural technologies. This high level of awareness indicates effective communication and outreach efforts by agricultural extension services, NGOs, and governmental programs. Doss (2006) reported that awareness is a critical first step in the adoption process, as it equips farmers with the knowledge of available innovations that can potentially enhance their productivity.

While the awareness rate is promising, it raises questions about the effectiveness of these technologies in practice. Awareness alone does not guarantee adoption; thus, understanding the reasons why some farmers remain uninformed or unconvinced about the benefits of these technologies is essential. In contrast to the high awareness, only 83.6% of farmers reported having actual access to these new technologies, while 16.4% do not.

Factors contributing to this lack of access may include financial constraints, inadequate infrastructure (such as poor transportation or distribution networks), and limited availability of technologies in local markets. Additionally, logistical issues, such as timing of availability and the suitability of technologies for local conditions, may also play a role. Feder and Ziberman (2022) reveal that, the disparity between awareness and access highlights a critical challenge in the agricultural sector: bridging the gap between knowledge and practical implementation. This situation calls for a multi-faceted approach to ensure that awareness translates into effective adoption. Programs focused on improving access, such as subsidies for purchasing new technologies or establishing partnerships with private sector actors, could be beneficial. The data suggests that farmers may rely on peer networks for information. Those who are aware of technologies may also influence their peers, creating a ripple effect that could either enhance or hinder overall adoption rates. Therefore, fostering community discussions and demonstrations of new technologies can amplify the impact of existing awareness. Further research could explore the specific barriers that farmers face in accessing these technologies, as well as the reasons behind the reluctance to adopt despite high awareness. Qualitative studies involving interviews and focus groups may provide deeper insights into farmers' perceptions and attitudes toward new technologies

**Table 2: level of awareness and access to new agricultural technologies among farmers in the region (n = 200)**

| Variable | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| **Awareness of New Technologies** | Aware | 152 | 76.0 |
| | Not Aware | 48 | 24.0 |
| **Access to New Technologies** | Accessible | 127 | 83.6 |
| | Not Accessible | 73 | 16.4 |

**Source:** Field Survey, 2024

Table 3 shows the impact of agricultural technology adoption on farmers' productivity in Kebbi State**.** Farmers adopting irrigation systems achieved the highest productivity, with a 108% increase in yield compared to those using traditional methods**.** Mechanization also had a significant positive effect, increasing yields by 83%. Fertilizer use resulted in a 67% yield increase, while improved seeds led to a 50% increase. All the technologies, except for traditional methods, showed statistically significant effects on productivity with p-values less than 0.05.

Table 3: Impact of Agricultural Technology Adoption on Farmers' Productivity in Kebbi State

| Technology Adopted | Number of Farmers Adopting | Average Yield (kg/ha) | Average Income (₦) | Percentage Increase in Yield (%) | Significance (p-value) |
|---|---|---|---|---|---|
| Traditional Methods | 50 | 1,200 | 150,000 | - | - |

| Technology Adopted | Number of Farmers Adopting | Average Yield (kg/ha) | Average Income (₦) | Percentage Increase in Yield (%) | Significance (p-value) |
|---|---|---|---|---|---|
| (No Technology) | | | | | |
| Improved Seeds | 60 | 1,800 | 200,000 | 50% | 0.02 |
| Fertilizers | 40 | 2,000 | 220,000 | 67% | 0.01 |
| Mechanization (e.g., Tractors) | 30 | 2,200 | 250,000 | 83% | 0.03 |
| Irrigation Systems | 20 | 2,500 | 280,000 | 108% | 0.04 |

Table 4 below presents the results of the Ordinary Least Squares (OLS) regression analysis to evaluate the impact of adopting different agricultural technologies on farm productivity in Kebbi State: Findings of the study indicate that the baseline yield for farmers not using any technology is 1,200 kg/ha. Impact of Technology Adoption: Improved Seeds: Adoption of improved seeds increases productivity by 600 kg/ha on average, with a statistically significant effect ($p < 0.001$). Using fertilizers results in an additional yield of 200 kg/ha, also highly significant ($p < 0.001$). Employing mechanization, such as tractors, leads to an increase of 200 kg/ha in yield, with a significant effect ($p < 0.001$). Irrigation: Adoption of irrigation systems contributes an extra 300 kg/ha to productivity, with a strong statistical significance ($p < 0.001$). Model Fit: The R-squared value is 1.000, indicating that the model perfectly explains the variability in farm productivity in this dataset. The F-statistic is highly significant, indicating that the model is a good fit.

**Table 4: Ordinary Least Squares (OLS) regression analysis to evaluate the impact of adopting different agricultural technologies on farm productivity in Kebbi State:**

| Variable | Coefficient | Standard Error | t-value | p-value | 95% Confidence Level |
|---|---|---|---|---|---|
| Constant | 1200.00 | 1.07e-13 | 1.12e+16 | 0.000 | 1200.00, 1200.00 |
| Improved Seeds | 600.00 | 1.51e-13 | 3.97e+15 | 0.000 | 600.00, 600.00 |
| Fertilizers | 200.00 | 1.51e-13 | 1.32e+15 | 0.000 | 200.00, 200.00 |
| Mechanization | 200.00 | 1.51e-13 | 1.32e+15 | 0.000 | 200.00, 200.00 |
| Irrigation | 300.00 | 1.51e-13 | 1.99e+15 | 0.000 | 300.00, 300.00 |

## CONCLUSION

The analysis of socio-economic factors affecting the adoption of agricultural technologies among farmers in Kebbi State revealed significant insights into the determinants of technology uptake. The findings indicate that education, income level, access to credit are critical factors positively influencing the likelihood of adopting agricultural technologies

## RECOMMENDATIONS

The following recommendations were made:

1. Financial institutions, government agencies, and NGOs should provide credit to farmers and make credit more accessible by offering low-interest loans and flexible repayment plans tailored to farmers' seasonal income.

2. Since education has a positive effect on technology adoption, it is important to continue and expand educational initiatives for farmers. Programs should focus on providing practical, hand training sessions in local languages, specifically targeting the use of new agricultural technologies.

3. Improve access to Agricultural inputs and financial support: Access to high quality inputs is crucial for improving productivity. To enhance access, government and private sector should collaborate to provide subsidies or discounts on essential inputs and ensure they are available at the right time and in sufficient quantities.

4. Government should enhance agricultural extension services to provide ongoing support, advice, and resources to farmers. Increasing the presence and effectiveness of extension agents can facilitate the dissemination of knowledge about new technologies and best practices.

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# FACTORS INFLUENCING ACCESS TO EXTENSION SERVICES AMONG ARTISANAL FISHERS IN YAURI LOCAL GOVERNMENT AREA OF KEBBI STATE, NIGERIA

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## ABSTRACT

This study investigated the factors influencing access to extension services among artisanal fishers in Yauri Local Government Area of Kebbi State, Nigeria. Using Multistage sampling technique, 150 respondents were selected using structured questionnaire and the data obtained was analyzed using inferential statistics and Logit Regression analysis. Based on socio economic characteristics of the respondents, Majority of the respondents are between the ages of 31-40 years, Most respondents (76.7%) fish within a distance of 10 km, the respondents were predominantly (86.7%) male, most respondents have between 6-10 years of fishing experience, majority have either no formal education or only primary education, and the average monthly income was approximately 32,500 Naira. Factors such as level of education, income, gender, and fishing experience positively influenced access to extension services, while age and distance to fishing ground had negative influence on the respondents' access to extension services in the study area. Key challenges faced by fisheries extension services in the study area include limited funding and inadequate training of extension workers these demographic factors, alongside variables such as income and proximity to fishing grounds, play a crucial role in determining access to extension services. Conclusively, education, income, gender, and fishing experience positively enhance access to extension services, suggesting that fishers who are more educated, earn higher incomes, and possess extensive fishing experience are more likely to benefit from extension programs. Conversely, older fishers and those located further from fishing grounds face challenges in accessing these essential services. It is therefore recommended that for sustainable development and improved productivity among fishers in Yauri LGA, policymakers and stakeholders must prioritize enhancing educational opportunities, providing financial support, and extending fisheries extension services to remote areas. By addressing these factors, the fishing communities in Yauri and similar areas can achieve greater economic empowerment and sustainable livelihoods.

**KEY WORDS:** Fisheries, Factors, Extension Services, Artisanal fishers

## INTRODUCTION

Artisanal fisheries play a crucial role in sustaining the livelihoods of communities, especially in regions where fishing remains a key economic activity. Artisanal fishers predominantly operate on a small scale using traditional fishing methods and equipment, contributing significantly to local food security, employment, and poverty alleviation in rural areas (Bene et al., 2016). In Nigeria, artisanal fisheries are a major source of protein and economic sustenance, particularly in riverine and lacustrine communities like those found in Kebbi State (Adeogun et al., 2012). However, despite their contributions, these fishers face numerous challenges that impede their access to extension services, which are critical for adopting improved fishing techniques, managing resources sustainably, and increasing productivity.

Extension services are designed to disseminate knowledge, skills, and innovations to rural communities, thereby enhancing productivity and sustainability in the agricultural sector, including fisheries (Adefalu et al., 2013). In the context of artisanal fisheries, effective extension services can provide fishers with critical information on sustainable fishing practices, conservation measures, and modern technologies. However, access to such services remains limited in many rural areas of Nigeria, including Yauri Local Government Area (LGA) in Kebbi State (Lawal-Adebowale & Oyeleye, 2012).

Factors influencing access to extension services among artisanal fishers in Yauri LGA may include socioeconomic conditions, availability of extension agents, awareness levels, infrastructure, and government policies (Olaoye et al., 2015). Artisanal fishers often lack formal education, which affects their ability to understand and utilize extension services effectively (Akinbile et al., 2019). Additionally, and inadequate transportation infrastructure further hinder extension agents' reach to remote fishing communities (Olaoye et al., 2016). Understanding these factors is critical for designing policies and programs that can improve access to extension services and enhance the livelihoods of artisanal fishers.

This study therefore, seeks to assess the factors influencing access to extension services among artisanal fishers in Yauri LGA, Kebbi State, Nigeria, hence the following objectives to: describe the socio economic characteristics of the respondents in the study area, determine the factors influencing access to extension services among Artisanal Fishers in the study area, and identify the challenges faced by fisheries extension services in the study area.

## METHODOLOGY

### Study Area

Yauri Local Government Area (LGA) is located in Kebbi State, Nigeria, with geographical coordinates of approximately Latitude 9.0805° North and Longitude 4.2637° East. The region is characterized by a strong reliance on fishing as a primary economic activity, supported by the presence of the River Niger, which provides a conducive environment for artisanal fisheries.

According to the National Population Commission (NPC, 2006**),** Yauri LGA had a population of approximately 125,190 people. Using the National Bureau of Statistics (NBS**)** annual growth rate of **2.5%,** the projected population for 2023 is estimated to be around 209,150 people. The population density is relatively high in riverine communities, where fishing is a major livelihood activity (NPC, 2006; NBS, 2023). The region is predominantly inhabited by the Gungawa, Hausa, Fulani, and Kambari ethnic groups (Aliyu, 2019). Yauri covers an area of approximately 1,300 square kilometers (National Bureau of Statistics, 2023). The land is characterized by a mix of fertile plains and riverine areas, making it suitable for both agricultural and fishing activities. The River Niger, which passes through the region, serves as a critical resource for irrigation, fishing, and transportation.

The climate of Yauri LGA is classified as tropical wet and dry according to the Köppen climate classification system (Olaoye et al., 2015). The area experiences two distinct seasons: the **rainy season** from May to October, and the dry season from November to April. The annual rainfall ranges between 800 mm to 1,000 mm, with the peak in August. The average temperature ranges from 26°C to 34°C**,** with the hottest months being March and April (Nigerian Meteorological Agency, 2023). This climate supports a thriving ecosystem for fisheries and agriculture, which are vital to the local economy. The economy of Yauri LGA is primarily agrarian, with a strong emphasis on subsistence farming, fishing, and trading, the fertile land supports the cultivation of crops such as millet, sorghum, maize, and rice**,** while livestock rearing is common among the Fulani pastoralists (Bene et al., 2016).

**Sampling procedure and sample size**

Multistage sampling technique was used to select respondents from various fishing communities within Yauri Local Government Area (LGA), the multistage approach was chosen because it combines different sampling methods: Yauri LGA is known for its active fishing communities along the Niger River. To ensure a diverse representation, a purposive sampling method was used to select five fishing communities that are most actively engaged in artisanal fisheries. This selection was based on factors such as population density, fishing activity levels, and proximity to the river and to determine the sample size of the study, a combination of the Yamane (1967) formula and population estimates was used to ensure statistical reliability and representativeness. The formular was used to determine 150 respondents. To sample the respondents, a stratified random sampling method was employed. The fishing communities selected were Gungun Tagwaye, Gungun Sarkin Noma, Gafara, Kwakwaran, and Ruwan Dorowa and these were treated as strata. To ensure that respondents were drawn proportionally from each selected community, the total population of fishers in each of the five selected communities was identified through local fishery records, the proportional allocation technique was used to distribute the 150 respondents among the five communities, according to their population sizes, and within each community, and respondents were selected using simple random sampling.

**Method of data collection and analysis**

Data were collected through structured questionnaires and interview schedule with local fishers, fisheries extension officers and data collected were analyzed using descriptive statistics and Logit regression analysis.

**Specification of the models**

1. **Logit Regression Analysis**

Logit Regression Analysis (LRA) was employed to examine the factors influencing the factors influencing access to extension services among Artisanal Fishers in Yauri Local Government Area of Kebbi State, Nigeria. The **Logit Regression Analysis** is an inferential statistical tool that describes the relationship between a censored continuous dependent variable $y_i$ and a vector of independent variables $x_i$.

The general Logit regression model is mathematically expressed as:
$Y = \alpha + \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots + \beta_8 X_8 + U$……………… …………… (1)
Where;
$Y_i$ is the dependent variable and $X_{1-}$ $X_8$ are the independent variables.
Y = Probability of accessing fisheries extension services (1 if accessed, 0 if not)
$X_1$ = Level of education (Years spent in school)
$X_2$ = Income per month (₦)
$X_3$ = Age (Years)
$X_4$ = Distance to fishing ground (Km)
$X_5$ = Gender (1 for male, 0 for female)
$X_6$ = Fishing experience (Years)
U = Error term
Bi = Constant term
$B_1 - \beta_6$ = Regression coefficients estimated

## RESULTS AND DISCUSSION

**Socio-economic Characteristics of the Respondents**

Majority of Respondents are between the Ages of 31-40 Years. The concentration of respondents within the 31-40 age range suggests that artisanal fishing in the area is dominated by individuals who are in their most productive years. This age group is generally characterized by physical strength and resilience, which are essential for artisanal fishing activities. This finding aligns with Adebayo and Oladele (2013), who found that most artisanal fishers in Nigeria fall within the age range of 30-45 years, indicating that fishing is a livelihood pursued primarily by individuals in their prime working age. Majority (76.7%.) fish within a Distance of 10 km. Fishing within a relatively short distance of 10 km suggests that the respondents primarily engage in near shore or inland fishing. This could imply limitations in access to larger fishing grounds due to inadequate resources such as boats and navigation equipment. It also indicates that their fishing activities may be more vulnerable to overfishing and environmental changes in near shore waters. The finding agrees with Eze *et al*. (2019) who noted that fishers who operate close to shore are more affected by environmental degradation and pollution. Based on gender, the respondents were Predominantly Male Respondents (86.7%). The predominance of male respondents indicates that artisanal fishing in the studied area is a male-dominated activity. This is consistent with traditional gender roles in many fishing communities, where men are typically responsible for fishing, while women are often involved in processing and marketing. This result aligns with Oluwatayo *et al*. (2020), who found that fishing is predominantly a male occupation in rural Nigeria due to the physically demanding nature of the work. Based on Fishing Experience, Majority Have Between 6-10 Years of Experience. Having a moderate level of fishing experience (6-10 years) suggests that many fishers are relatively experienced but may still lack the extensive knowledge needed to adopt more advanced or sustainable fishing practices. This moderate experience level could influence their willingness to adopt new techniques, as they are neither complete novices nor highly seasoned experts set in traditional ways. This is consistent with Effiong and Ohen (2016) who found that fishers with 5-10 years of experience are generally more adaptable to new fishing technologies than those with over 20 years of experience, who might be resistant to change. Majority Have No Formal Education or Only Primary Education, the low educational level among respondents implies that many fishers may lack the necessary literacy skills to fully benefit from extension services or training programs that require reading and comprehension. This could be a barrier to adopting modern fishing techniques and accessing information on sustainable practices. This finding aligns with Aker (2011), who noted that low educational levels are a significant barrier to the adoption of new technologies in rural communities. Average Monthly Income is Approximately 32,500 Naira. An average income of 32,500 Naira suggests that artisanal fishing provides a modest but not highly lucrative income. This indicates that fishers may be operating at subsistence levels, with limited capacity for savings or investment in better fishing equipment. Low income could also imply vulnerability to economic shocks. This result is consistent with IFAD (2022), which reported that artisanal fishers in rural areas often earn below the national poverty line, limiting their ability to invest in productivity-enhancing assets.

**Table 1: Socio-economic Characteristics of the Respondents**

| Socio economic characteristics | Categories | Frequency | Percentage | Mean | Standard deviation |
|---|---|---|---|---|---|
| Age (Years) | 20-30 | 35 | 23.3 | | |
| | 31-40 | 45 | 30.0 | | |
| | 41-50 | 40 | 26.7 | | |
| | 51 and above | 30 | 20.0 | 38.6 | 9.2 |
| Distanceto fishing ground (KM) | 0-5 | 60 | 40 | | |
| | 6-10 | 55 | 36.7 | 7.8 | 4.5 |
| | 11-15 | 20 | 13.3 | | |
| | Above 15 | 15 | 10.0 | | |
| Gender | Male | 130 | 86.7 | | |
| | Female | 20 | 13.3 | | |
| Fishing experience (years) | 1-5 | 25 | 16.7 | | |
| | 6-10 | 50 | 33.3 | 11.2 | 5.7 |
| | 11-15 | 40 | 26.7 | | |
| | Above 15 | 35 | 23.3 | | |
| Levelof education | Noformal education | 45 | 30.0 | | |
| | Primary | 50 | 33.3 | | |
| | Secondary | 35 | 23.3 | | |
| | Tertiary education | 20 | 13.3 | | |
| Income | Less than 20000 | 55 | 36.7 | | |
| | 20000-40000 | 60 | 40.0 | 32500 | 14600 |
| | 41000-60000 | 25 | 16.7 | | |
| | Above 60000 | 10 | 6.7 | | |

**Source:** Field Survey, 2024

**Factors influencing Access to Extension Services among Artisanal Fishers**

The results of the Logit regression analysis on the factors affecting access to extension services among artisanal fishers in Yauri Local Government Area (LGA) in Table 2 reveals several key determinants. The positive and significant coefficient for education level indicates that fishers with higher education levels are more likely to access extension services. This finding is consistent with studies of Adeogun *et al*. (2012) who found that fishers with higher education levels are more receptive to new technologies and extension advice, which improves their productivity. Adefalu *et al*. (2013) similarly observed that educated farmers in Lagos State were more likely to seek extension services due to better comprehension of the benefits associated with improved techniques. The marginal effect (0.102) suggests that an additional level of education increases the probability of accessing extension services by approximately 10.2%. This aligns with Lawal-Adebowale and Oyeleye (2012), who noted that education enhances the ability to process information and apply new knowledge effectively. The income variable shows a positive association with access to extension services, though the effect size is relatively small. This suggests that higher-income fishers have slightly better access to extension services, likely due to their ability to afford transportation to extension meetings or pay for necessary inputs. This result agrees with Bene *et al.* (2016) who highlighted that higher income levels among fishers enable better access to resources that support sustainable fishing practices.

The negative coefficient for age indicates that older fishers are less likely to access extension services. This aligns with the result of Adeogun *et al*. (2012), who noted that younger fishers are generally more adaptable and willing to try new technologies compared to their older counterparts. The analysis also shows that distance to fishing grounds negatively affects access to extension services. Fishers located farther away from extension service centers are less likely to access information due to transportation challenges and time constraints. This result agrees with Olaoye *et al*. (2015) who found that geographic distance was a significant barrier to accessing extension services in rural fishing communities in Lagos State. The gender variable reveals that male fishers have significantly better access to extension services compared to female fishers. This gender disparity may be due to socio-cultural norms that prioritize men in access to information and resources in many rural communities (Akinbile *et al.,* 2019). This result corroborates that of Aliyu (2019) who reported that in the fishing communities of Kebbi State, men typically dominate decision-making and are more likely to engage with extension agents. The positive coefficient for fishing experience suggests that more experienced fishers are more likely to access extension services. This result agrees with Olaoye *et al., (*2016). Who noted that this is likely because experienced fishers are better networked and have more knowledge about the benefits of extension services.

**Challenges faced by artisanal fishers in accessing fisheries extension services**

The challenges outlined in Table 3 provide insights into the difficulties faced by artisanal fishers in accessing effective fisheries extension services as follows: **Limited Funding and Resources,** this challenge is the most significant, reported by 26.7% of respondents.

Table 2: Logit Regression Estimates of Factors influencing Access to Extension Services among Artisanal Fishers in Yauri Local Government Area of Kebbi State, Nigeria.

| Variable | Coefficient | Standard Error | Z-value | P-value | Marginal Effect |
|---|---|---|---|---|---|
| Constant | -1.987 | 0.432 | -4.60 | 0.000 | - |
| Level of education | 0.456** | 0.127 | 3.59 | 0.000 | 0.102 |
| Income | 0.0021** | 0.0008 | 2.63 | 0.009 | 0.0005 |
| Age | -0.015** | 0.006 | -2.50 | 0.013 | -0.003 |
| Distance to fishing ground | -0.0142** | 0.051 | -2.78 | 0.005 | -0.032 |
| Gender | 0.625** | 0.245 | 2.55 | 0.011 | 0.148 |
| Fishing Experience | 0.037** | 0.014 | 2.64 | 0.008 | 0.0085 |

**Model Diagnostics**
**Pseudo $R^2$**: 0.312 (indicating that about 31.2% of the variation in access to extension services is explained by the model)
**$Chi^2$ (Chi-square)**: 65.48, **Log-likelihood Ratio**: -96.312 (value of the log-likelihood function)

The lack of sufficient funding and resources hampers the ability of fisheries extension programs to operate effectively. This finding aligns with Adebayo and Oladele (2013) who highlighted that limited budget allocations reduce the capacity to deliver extension programs, impacting the quality of advisory services available to fishers. However, Oluwatayo et al. (2020) argued that funding is not always the primary issue but rather the inefficient allocation of resources. They suggest that better management of existing resources could enhance the effectiveness of extension services, even with limited budgets. Inadequate lack training of extension workers indicated by 20.0% was the second most cited challenge, aligning with the findings of Effiong and Ohen (2016), who noted that poorly trained extension personnel often provide outdated or irrelevant advice to fishers. Aker (2011) also emphasized that insufficient training reduces the ability of extension workers to transfer knowledge effectively, especially when new technologies or techniques are involved. Poor infrastructure was identified by 16.7% of respondents as a major barrier. This is agreement with Ajayi (2020) who found that inadequate infrastructure, such as poor roads and communication networks, limits the reach of extension services to rural fishing communities. Similarly, Eze et al. (2019) noted that poor transportation infrastructure hinders the mobility of extension agents, reducing the frequency of their visits to fishing communities. Lack of collaboration among stakeholders indicated by 13.3% was ranked fourth. The importance of collaboration is supported by Aker (2011), who stressed that partnerships between government agencies, NGOs, and fishing communities are crucial for effective extension services. However, Smith et al. (2016) argued that collaboration alone is not sufficient; they emphasize that building trust among fishers and extension workers is equally important for successful partnerships. Cultural barriers, cited by 6.7% of respondents, include language differences and traditional fishing practices. This finding is consistent with Agbamu (2000) highlighted that cultural differences can lead to resistance to new information, especially when it contradicts long-standing practices. This finding is supported by FAO (2019), which emphasized the need for culturally sensitive extension approaches. Environmental challenges, such as climate change and pollution, affect the sustainability of fisheries and were identified by 10% of respondents. This is in line with Ayoade and Adeola (2012) who highlighted the increasing impact of environmental changes on artisanal fishing activities. They emphasized the need for extension services to incorporate climate adaptation strategies. Contrary to this, Omotayo (2018) argues that environmental challenges are often overstated, suggesting that the focus should be on improving fishers' adaptive capacity through technological innovations rather than solely addressing environmental issues. Limited access to technology was ranked equally with policy constraints and economic instability by 3.3% of respondents, this finding is consistent with Ahmed and Muktar (2019) who found that fishers' lack of access to modern technologies significantly hinders their productivity. They argued that bridging this technological gap requires targeted interventions to improve fishers' digital literacy. In contrast, Agbamu (2000) suggests that technology alone cannot solve the challenges faced by artisanal fishers; it needs to be complemented with adequate training and support systems to ensure effective adoption. Market access issues were also cited as a challenge by 6.7% of respondents, this is in line with IFAD (2022) who stated that poor access to markets results in reduced profitability for fishers, particularly in rural areas where transportation infrastructure is lacking. However, Tchale and Keyser (2010) suggest that market linkages can be improved through the use of digital platforms, which can connect fishers directly with buyers, reducing the need for middlemen. Insufficient data and research were reported by only 2% of respondents, this result agrees with that of Smith *et al.* (2016) who noted that without reliable data, it is challenging to design effective extension programs. FAO (2020) also emphasized that data-driven decision-making is crucial for evaluating the success of extension services. Policy and Regulatory Constraints indicated by 3.3%, these challenges can hinder artisanal fishers' access to resources and support services (World Bank, 2019). This result is against that of Ahmed and Muktar (2019) who argue that regulatory constraints can be positive if they promote sustainable fishing practices, suggesting that fishers need to be better informed about the benefits of compliance.

**Table 3: Challenges faced by artisanal fishers in accessing fisheries extension services (n=150)**

| Challenges | Frequency | Percentage (%) | Rank |
|---|---|---|---|
| Language Barriers | 1 | 0.7 | 14 |
| High Turnover of Extension Staff | 2 | 1.3 | 12 |
| Insufficient Data and Research | 3 | 2.0 | 9 |
| Inadequate Monitoring and Evaluation | 3 | 2.0 | 9 |
| Limited Access to Technology | 5 | 3.3 | 7 |
| Policy and Regulatory Constraints | 5 | 3.3 | 7 |
| Limited Awareness and Outreach | 5 | 3.3 | 7 |
| Economic Instability | 5 | 3.3 | 7 |
| Environmental Challenges | 15 | 10.0 | 6 |
| Cultural Barriers | 10 | 6.7 | 5 |
| Market Access Issues | 10 | 6.7 | 5 |
| Lack of Collaboration | 20 | 13.3 | 4 |
| Poor Infrastructure | 25 | 16.7 | 3 |
| Inadequate Training of Extension Workers | 30 | 20.0 | 2 |
| Limited Funding and Resources | 40 | 26.7 | 1 |

**Source**: Field Survey, 2024 * Multiple responses were allowed

## CONCLUSION

This study has provided valuable insights into the factors influencing access to extension services among artisanal fishers in Yauri Local Government Area, Kebbi State, Nigeria. The analysis of the socioeconomic characteristics reveals that the majority of respondents are middle-aged, predominantly male, with modest educational backgrounds, and have significant experience in fishing. These demographic factors, alongside variables such as income and proximity to fishing grounds, play a crucial role in determining access to extension services. The findings indicate that education, income, gender, and fishing experience positively enhance access to extension services, suggesting that fishers who are more educated, earn higher incomes, and possess extensive fishing experience are more likely to benefit from extension programs. Conversely, older fishers and those located further from fishing grounds face challenges in accessing these essential services. This highlights a need for targeted strategies to ensure that extension services reach all segments of the fishing community, especially the elderly and those in remote areas. Furthermore, the study identified critical challenges hindering the effectiveness of fisheries extension services, particularly limited funding and inadequate training of extension personnel. Addressing these challenges is imperative to enhance the effectiveness of extension services, thereby improving the livelihoods and productivity of artisanal fishers.

## RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed to enhance access to fisheries extension services among artisanal fishers in Yauri Local Government Area:

i. To improve the fishers' access to extension services, efforts should be made to enhance educational opportunities and training programs specifically tailored for artisanal fishers. This can be achieved by organizing regular workshops and capacity-building initiatives that target fishers with low levels of formal education. Such programs should focus on increasing awareness of the benefits of adopting new technologies and sustainable fishing practices, thereby improving the productivity and livelihoods of fishers.
ii. Given that limited funding was identified as a significant barrier, there is a need for increased investment in fisheries extension services. Government agencies, NGOs, and private sector stakeholders should collaborate to secure adequate funding.
iii. The predominance of male fishers engaging with extension services highlights a need for gender-inclusive strategies. Extension programs should be designed to include women, who often play vital roles in fish processing and marketing. This could be achieved by organizing women-focused extension meetings, providing support groups, and addressing socio-cultural barriers that limit women's participation in fishing and extension activities.
iv. The study revealed that fishers located far from extension centers have limited access to services due to poor transportation infrastructure. Improving road networks, communication facilities, and transportation support can facilitate easier access to extension services

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# WILLINGNESS TO PAY FOR PRIVATE EXTENSION SERVICES BY CROP FARMERS IN DUTSIN-MA, KATSINA STATE, NIGERIA

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## ABSTRACT
The study investigated the willingness to pay for private extension services by crop farmers in Dutsin-ma Local Government Area, Katsina State, Nigeria. A two stage random sampling technique was used to select 100 crop farmers for the study. Data collected was analyze using descriptive statistic and binary logit regression model. Result findings showed crop farming to be male (100%) dominated and they have average experience of 15 years in crop production. The crop farmers operated an average farm land of 2.05 hectares in the study area and more than 70% of them are formally educated. Result further showed that majority (74%) of the respondents are willingness to pay for private agricultural extension services. Logistic regression result showed farm size ($P < 0.05$) and household size ($P < 0.05$) to be the significant determinant of willingness to pay for private extension services in the study area. Thus, findings of the study revealed that there is high willingness to pay for private extension services by the crop farmer in the study area. Therefore, a well-established administrative and personnel structures for private extension service should be put in place given the fact that private extension is more effective and efficient when compared with public extension system.
**KEY WORDS**: Willingness, private extension service, crop farmers, pay

## INTRODUCTION
Agriculture is vital for food security and also important for employment especially in developing countries. Transforming agriculture from its current subsistence orientation into market oriented production system forms the basis of the agricultural development strategy of the Government. However, producing for the market requires re-orientation of the production system and development of a knowledge base and responsive institutional support services (Temesgen and Tola, 2015). Agricultural extension service is one of the institutional support services that have a central role to play in the transformation process (Berhanu *et al.,* 2006). The extension service is becoming more important for rural development in developing countries where agriculture is the main source of livelihood (Temesgen and Tola, 2015). Today the public extension delivery in Nigeria is hugely regarded as underserved in most quarters as far as service delivery is concerned. Although, the country's extension services is regarded as Africa's most research-based and most technologically advanced agricultural extension system. Delivery of extension services to the rural farmers, for which they are intended and designed, has been marked with a number of recurrent problems (Falola *et al*., 2012). There is the need for paradigm shift in extension service delivery which is offered through the private sector.

Extension programmes in Nigeria have proved successful in boosting food production, raising income and making farmers proud but the inability of government to sustain such programmes has sparked calls for reforms in the extension policy framework (Kenobi, 2015). The capacity of public extension service is limited, outreach is poor, and massages are supply driven in nature due to lack of funds for travels and logistics. This make agricultural extension service in Nigeria not to work satisfactory and many farmers hardly even received agricultural extension service in the entire production season (Climate Change Adaptation and Agribusiness Support Programme [CASP], 2013). To augment the farmers' limited access to extension service, the private sector driven agricultural extension service delivery system has been recommended in many studies (Mwaura *et al*., 2010; Engel *et al*., 2015). Meanwhile, the private sector-driven extension service is still in its beginning stage, but it is clear that the future of extension service delivery lies in the private sector driven extension service delivery. However, the economic capacities of individual farmers to actually pay for the services have come under serious questioning.

The sustainability of a private extension service depends on functioning market mechanisms, the farmers' willingness to pay (WTP) and capacity to pay (Ulimwengu and Sanyal, 2011). Nonetheless, measuring farmers' willingness to pay for private extension service particularly in the study area is very important for offering demand-driven extension service. A number of recent studies have contributed in the area of farmers' willingness to pay for private agricultural extension services in Nigeria and other developing countries (Abate *et al*. 2019; Atinaf *et al*. 2020; Aydogdu *et al*. 2020; and Akinnagbe *et al*, 2024). However, there still remains a literature gap regarding the willingness of crop farmers in Dutsin-ma communities to pay for private extension services. It is against this backdrop the study assessed willingness of crop farmers to pay for private extension service in Dutsin-Ma LGA, Katsina State, Nigeria. The specific objective of the study were; to describe the socio-economic characteristics of crop farmers; examine crop farmers' willingness to pay for private extension services and identify the socio-economic determinants of willingness to pay for private extension services by the crop farmers.

## METHODOLOGY

### Study Area

The study was carried out in Dutsin-ma Local Government Area of Katsina State, Nigeria. The LGA lies on Latitude $12^{0}$26'18''N and Longitude $07^{0}$29'29''E. It is bordered to Kurfi and Charanci LGAs to the North, Kankia LGA to the East, Safana and Danmusa LGAs to the West and Matazu LGA to the Southeast. The local government has a land size of about 552,323 $km^2$ (203 sqm) with population of 169.829 as at 2006 national census which is projected to be 444,951 at 2023 base on 3% annual growth rate (NBS, 2023). The populations are predominantly farmers, cattle rearers and traders. The climate of the State is the tropical wet and dry type (Tropical continental climate). The rainfall ranges between May and September with a peak in August with an average annual rainfall of 700mm. The pattern of rainfall in the area is highly variable. The annual temperature ranges from 29ºC to 31ºC (Katsina Agricultural and Rural Development Authority [KTARDA], 2016). One of the major landmark of the Local Government is Zobe Dam constructed by Sokoto Rima River Basin Development Authority (SRRBDA) with an inflow capacity of 240 million cubic meters, for the purposes of irrigation and water supply. The LGA has a distinct comparative advantage in the production of crop, notably cereals, legumes and oil seeds, vegetables, cotton and livestock rearing.

### Sampling procedure and sample size

A two stage sampling technique was used in the selection of respondents for the study. In the first stage, five communities (Darawa, Karofi, Makera, Yanruma, Dutsinma) were sampled, while in the second stage, twenty (20) crop farmers was randomly selected from each community using simple random sampling technique to get a total 100 crop farmers as the sampled respondents for the study.

**Method of data collection and analysis**

Primary data were collected from the crop farmers in the study area with the aid of a structured questionnaire covering socio-economic characteristics and willingness of farmers to pay for private extension services. Descriptive and binary logistic regression were used to analyze the data collected for this study. Descriptive statistics involved the use of frequency, percentage and means.

**Logistic Regression Model**

The logistic regression model was used to examine the determinants of the crop farmers' willingness to pay for private extension services as used by Temesgen and Tola (2015). The logistic model is specified as

$P_1 = F(Z_i) = 1/1+e^{-zi} = e^{zi}/e^{zi}+1$ (1)

$Z_i = \alpha + \beta x_i$ (2)

$Z_i = \beta_0 + \beta X_1 + \beta X_2 \ldots \beta X_8$ (3)

$P_i$ = Willingness to pay for private extension services (1 if willing to pay, 0 if otherwise)
$\beta_0$ = Constant
$\beta_1 - \beta_8$ = Coefficient of dependent variables
$X_1$ = Age (years)
$X_2$ = Gender (Dummy: 1 if male and 0 if otherwise)
$X_3$ = Size of farm (hectares)
$X_4$ = Education (years)
$X_5$ = Average income from farm production (Naira)
$X_6$ = Experience in farming (years)
$X_7$ = Household size (number)
$X_8$ = Frequency of public extension services (number)

## RESULTS AND DISCUSSION

**Socio-economic Characteristics of the Respondents**

Table 1 presents the demographic profile of the respondents. The result shows that farmers in the study area have average age of 35 years, implying predominance of young people participating in crop production. This finding is in line with the study of Abdullahi *et al.* (2012) and Okwoche *et al.* (2012) who reported that age is a factor that affects an individual's ability to make decisions and participate effectively in farming operations. The results further revealed that all (100%) of the respondents interviewed were males implying that there is no participation of women in crop production in the study area. Majority of the respondents (about 90%) had formal education ranging from primary, secondary to tertiary education. Meaning that the farmers have knowledge requisite to decide on receiving private extension service. This is in agreement with the study of Nazifi *et al.* (2024) who reported that education is an important instrument that influence agricultural production decision among smallholder farmers. Result from the study also indicated that majority of the respondent (72%) had farm size ranging from 1-3 hectares with a mean farm size of 2.05 hectares. This finding is in line with that of Musa *et al.* (2019) and Saba *et al*. (2024) who reported average farm size holding of 2.5 hectares among farmers in Dutsin-ma communities. The study also reported that 30% of the respondents had household size ranging from 6 – 10 persons and 44% of them had more than 10 persons in their household. This implies that majority of household had relatively large household member enough to provide family labour. Farming experience is expected to influence efficiency positively, Table 1 further showed that more than half (55%) of the respondent had farming experience of 11-20 years with an average farming experience of 15 years. This implies that the farmers have adequate experience to make rational decision regarding their crop production activities. The result in Table 1 revealed that 55% of the respondents are members of cooperative implying that some of the farmers participate in cooperative society which provides an avenue for access to information that enhance diffusion of an innovations and improvement in their production. Result also shows that most (60%) of the respondents admitted that they had 1 – 5 contacts with extension agent per season. This finding agrees with the study of Daniel and Teferi (2015**)** who reported that extension contact has significant influence in farmers' willingness to pay for extension service. Moreover, results show that more than half (55%) of respondent had no access to credit in the study area, while 45% of the respondents had access to credit of which 24.4% obtained it from formal source, while 75.6% obtained it from informal source such as money lenders. This finding is contradict with Musa *et al*. (2019) who observed that sesame farmers in Dutsin-ma had no access to credit from any formal source.

**Table 1: Distribution of the respondents based on their socio-economic characteristics (n = 100)**

| Variable | Frequency | Percentage | Mean |
|---|---|---|---|
| **Age (years)** | | | |
| 17 – 26 | 33 | 33.0 | 35 |
| 27 – 36 | 33 | 33.0 | |
| 37 – 46 | 15 | 15.0 | |
| 47 – 56 | 19 | 19.0 | |
| **Household size (numbers)** | | | |
| 1 – 5 | 26 | 26.0 | 10 |
| 6 – 10 | 30 | 30.0 | |
| > 10 | 44 | 44.0 | |
| **Farm Size (hectares)** | | | |
| 1 – 3 | 72 | 72.0 | 2.05 |
| 4 – 6 | 17 | 17.0 | |
| > 6 | 11 | 11.0 | |
| **Farming Experience (years)** | | | |
| 1 – 10 | 19 | 19.0 | 15 |
| 11 – 20 | 55 | 55.0 | |
| > 21 | 26 | 26.0 | |
| **Annual income (₦)** | | | |
| 50,000 – 200,000 | 75 | 75.0 | 147,000 |
| 201,000 – 350,000 | 10 | 10.0 | |
| > 350,000 | 15 | 15.0 | |
| **Gender** | | | |
| Male | 100 | 100.0 | |

| | | |
|---|---|---|
| Female | - | - |
| **Level of education** | | |
| Non Formal | 10 | 10.0 |
| Primary | 29 | 29.0 |
| Secondary | 41 | 41.0 |
| Tertiary | 20 | 20.0 |
| **Extension Visit (Season)** | | |
| None | 40 | 40.0 |
| 1-5 times | 60 | 60.0 |
| **Cooperatives** | | |
| Member | 55 | 55.0 |
| Non-member | 45 | 45.0 |
| **Credit Access** | | |
| Access | 45 | 45.0 |
| No Access | 55 | 55.0 |
| **Credit Source** | | |
| Formal | 11 | 24.4 |
| Informal | 34 | 75.6 |

**Source:** Field Survey, 2021

**Respondents' willingness to pay for private extension services**

The results of crop farmer's willingness to pay (WTP) for private extension services is presented in Table 2. The result showed that majority (74%) of the respondents are willing to pay for private agricultural extension services, while the remaining 26% are not willing to pay for private extension services. This implied that willingness to pay for private extension among respondents was high based on the greater proportion of the respondents that indicated willingness to pay in the study area. This finding negates that of Mwaura *et al.* (2010) who observed a relatively low willingness to pay for private extension services among both crop and livestock farmers in his study area.

**Table 2: Respondents' willingness to pay for private extension services**

| Variable | Frequency | Percentage |
|---|---|---|
| Willing to Pay | 74 | 74.0 |
| Not Willing to Pay | 26 | 26.0 |
| **Total** | 100 | 100.0 |

**Source:** Field Survey, 2021

**Farmers' Socio-economic attributes Influencing Willingness to Pay for Private Extension Services**

The logistic regression estimates of the socioeconomic characteristics of farmers that influence their willingness to pay for private extension services is presented in Table 3. The logistic regression result revealed only farm size and household size as the socioeconomic factors that are statistically significant, thus influencing willingness to pay for private extension services among crop farmers in the study area. Farm size is significant ($P < 0.05$) and has a coefficient (1.18) of greater than 1, which implies that probability of the respondent's willingness to pay for private extension services will increase by 1.18 as the farm size increase. This is supported by the work of Akinnagbe, *et al* (2024) that reported positive association of farm size own by farmers and their willingness to pay for extension service in Ondo State, Nigeria. Household size (0.042) is also significant at 5% level of confidence and has a coefficient (0.89) of less than 1, which implies that Probability of the respondents WTP for private extension services will decrease because of the needs of members of the household may override the need to pay for private extension services. This finding is in line with Manjur *et al.* (2013) that reported household size to influences willingness to pay for private extension, stating that larger household sizes lead to lower willingness levels to pay for private extension as the needs and requirements of individuals in the household override the need to pay for private extension (Manjur *et al.* 2013). Furthermore, Omonona *et al*. (2000); and Ike & Uzokwe (2015) have advanced that large household size is positively correlated with poverty, this means that a large household will not have the money to pay for private extension as it is likely to be poor.

**Table 3. Logistic regression estimates of' socio-economic attributes that influence crop farmers' willingness to pay for private extension services**

| Variables | Coefficient | Standard Error | z-value | p>z |
|---|---|---|---|---|
| Age | 0.9846 | 0.0286 | -0.53 | 0.595 |
| Farming experience | 0.8518 | 0.1667 | -0.82 | 0.413 |
| Farm size | 1.1821** | 0.0994 | 1.99 | 0.047 |
| Household size | 0.8898** | 0.0511 | -2.03 | 0.042 |
| Number of extension visit | 1.0781 | 0.2546 | 0.32 | 0.750 |
| Access to credit | 2.9318 | 3.4417 | 0.92 | 0.360 |
| Membership of cooperative | 0.2705 | 0.3290 | -1.07 | 0.282 |
| Annual income | 0.9999 | 0.0000 | -0.48 | 0.631 |
| Constant | 14.0634 | 21.5623 | 1.72 | 0.085 |

**Source:** Field Survey, 2021. ** Donates Significance at 5%

## CONCLUSION AND RECOMMENDATION

Crop production in the study area is male dominated that are in their active ages and their majority are formally educated. The study findings further revealed a high level of willingness to pay for private extension services by the crop farmer in the study area and their willingness to pay is influenced by Farm size and Household size. However, private extension services are still in its development stages, and awareness and patronage by the respondents is still limited. A well-established administrative and personnel structures should be put in place given the fact that private extension is more effective and efficient when compared with public extension system.

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# SYSTEMATIC REVIEW ON QUALITY ATTRIBUTES AND CONSUMER PREFERENCES FOR PALM OIL IN ANAMBRA AND ONDO STATES, NIGERIA

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## ABSTRACT

This systematic review examines quality attributes and consumer preferences for palm oil in Anambra and Ondo States, Nigeria. The study utilized a comprehensive literature search spanning 2000–2023 to identify empirical studies on palm oil quality, consumer preferences, and their influence on pricing. The review revealed that colour, clarity, taste, aroma, viscosity, health benefits, packaging and branding were the key quality attributes of palm oil. More so, these attributes significantly influenced palm oil pricing, with superior attributes commanding higher prices. This review stressed the importance of enhancing quality standards to meet diverse consumer demands.

**KEYWORDS:** Preference; Oil palm, Consumer and Quality

## INTRODUCTION

Oil palm (*Elaeis guineensis*) originated from tropical rain forest zone of West Africa. In 16$^{th}$ Century, it spread to South America and to Asia in 19$^{th}$ Century (Mohammed *et al*., 2020). In 1970's Asia eclipsed Africa as highest palm oil producing region in the World and remained the highest till today while West Africa has now become importer of palm oil as domestic consumption of palm oil increases rapidly than its production (Ibrahim and Usman, 2019). Oil palm grows well in West Africa in which Nigeria is among. It yields the biggest and highly consumed palm oil. In Nigeria, oil palm grows majorly in twenty-four (24) States, amongst which are; Anambra, Imo, Abia, Enugu, Ebonyi, Cross-River, Rivers, Akwa-Ibom, Delta, Edo, Bayelsa, Ekiti, Oyo, Osun, Ogun, Ondo, Adamawa, Taraba, Kaduna, (Southern Kaduna), Plateau, Benue, Nasarawa, Kogi and Kwara (Federal Ministry of Agriculture and Rural Development (FMARD), 2011). The diversification of oil palm in the country is indeed a great potential for wealth creation and employment in the aforementioned states and beyond (FMARD, 2011).

Palm oil is an edible oil, reddish in colour, derived from the fruits of the oil palm. Palm fruit has unique nature in that it produces two types of oil, the fleshy mesocarp produces palm oil, which is mainly for its edible properties and the Kernel produces palm kernel oil, which has wide application in the oleochemical industry (Ibrahim and Ojo, 2018). Palm oil is a versatile raw material for both food and non-food industries. Direct applications include the use of crude palm oil in the production of biodiesel, cooking ingredient, ingredient for detergents, soaps, lipsticks, waxes and polish bases in a condense form, an ingredient in margarine production and in most confectionaries (Sridhar and Ade, 2009). It is used to reduce friction during manufacturing of steel (Sridhar and Ade, 2009 in Ibitoye 2014). It is also used in the production of pharmaceutical products and engine lubricants. Producers and marketers agreed that some quality checks were required for palm oil destined for home consumption and for industrial uses (Ogunleye *et al*., 2019). To most oil palm producer, a high concentration of free fatty acid (FFA) was not a problem. This is because it was not common to assess quality in terms of FFA concentrations in the markets that the marketers currently access (Mohammed *et al*., 2020). There is no incentive to produce good quality ordinary palm oil because buyers pay the same price for all grades of ordinary palm oil. Marketers work to identify the customer needs, wants and demands. They advertise, promote or sells a product or services. The more people know about products or service the more they are interested to buy it (Oladele *et al*., 2021).

Quality is an important attribute of palm oil from the trade point of view. Noncompliance to quality specifications could involve huge discounts or rejection of the consignment if it cannot be used for the intended purpose. In 2016, the European Union suspended some agricultural food exports from Nigeria which include palm oil due to its low quality (Bello *et al.*, 2022). However, the demand for palm oil in Nigeria has been on the rise due to the rising population. This has led to an increase in the manual (traditional) process of production predominantly carried out by villagers with little or no knowledge of aseptic techniques. According to Onoja and Ogali (2014), one of the major problems of Nigerian palm oil in the local and international market is the issue of poor quality product which resulted from` poor harvesting and processing methods. Despite the nutritional and health benefits derive from palm oil consumption, not much attention has been given to the quality of palm oil produced and sold in the market, hence, the need to evaluate the quality of the palm oil in comparison with recommended quality standards.  Thus, this review was carried out to; determine the consumer preferences for quality palm oil and effects of palm oil quality attributes on its price.

## METHODOLOGY

The methodology employed for this study involved a systematic literature search aimed at shortlisting empirical studies focusing on quality attributes and consumer preferences for palm oiln Anambra an Ondo States, Nigeria. The search process included several steps and utilized various search engines and databases. The central focus of the search was on consumer preference, oil palm and quality. Only empirical studies published between 2000 and 2023 were considered. English-language publications were included, while grey literature and publications in other languages were excluded. A wide range and combination of catchphrases were utilized, including terms such as 'Oil palm', 'consumer preference, taste, Aroma, Viscosity', 'Oil palm quality', 'Nigeria', 'Anambra', 'Ondo' and 'Price'. These keywords were used to retrieve relevant literature published within the specified timeframe.

The search was conducted systematically across the selected databases and websites, ensuring comprehensive coverage of relevant literature. Google Scholar was utilized with advanced search parameters, including all words 'consumers' preference for oil palm' and the exact phrase 'effects of oil quality on price', until the relevance of the search title diminished. The initial search yielded 923 papers, which were further scrutinized for relevance. The search results were screened based on the relevance of titles and abstracts to the study's objectives. From the initial 923 papers, 214 were identified for further examination and comparison with results from other search engines and relevant websites to check for duplication and omission. Subsequently, 89 additional papers, including global studies, were added to the identified set. After reviewing the abstracts, 9 out of the 214 papers were deemed unrelated to the study theme and were excluded.

The remaining 203 papers were selected for in-depth examination and analysis. Each of these papers was thoroughly reviewed to assess their suitability for inclusion in the systematic review based on predefined inclusion and exclusion criteria. The inclusion criteria for the selected papers included studies that focused on oil palm, consumer preference' oil quality in Anambra and Ondo States. Studies published in peer-reviewed journals, conference proceedings, or academic dissertations were considered eligible for inclusion.

On the other hand, studies were excluded if they did not meet the inclusion criteria, were duplicates, or not written in English. Additionally, studies that focused on other crops or agricultural activities unrelated to palm oil processing, as well as those that did not specifically addressed the keywords, were excluded from the review. Following the selection of relevant papers, data extraction was conducted to systematically collect information from each study. Data extraction was carried out by the researcher to ensure accuracy and reliability. Any discrepancies or disagreements between the reviewers were resolved through discussion and consensus. The extracted data were then synthesized and analyzed to identify common themes, patterns, and trends across the selected studies.

## REVIEW OF RELATED STUDIES

### Consumer preferences for quality palm oil in Nigeria

Colour and clarity are vital attributes influencing consumer preferences for palm oil in Nigeria. Oladele *et al*. (2021) noted that consumers in Southwestern Nigeria preferred palm oil with a bright red-orange hue, associating it with freshness and a high beta-carotene content. Akpan and Etim (2019) further emphasized the importance of clarity, particularly among urban consumers, who often view clear, sediment-free palm oil as hygienic and refined. Similarly, Bello *et al.* (2022) reported that urban consumers were willing to pay a premium for brightly coloured, clear oils, while rural consumers prioritized vibrant colours over clarity. Mohammed and Adebayo (2019) added that in Northern Nigeria, slightly less vibrant palm oil is sometimes preferred due to concerns about artificial colouring, reflecting regional differences in consumer perception. Collectively, these studies highlight how colour and clarity serve as indicators of quality, freshness, and safety for Nigerian consumers.

Taste and aroma are equally crucial among the consumer preferences. Eze *et al*. (2020) revealed that rural consumers favour palm oil with a strong, nutty flavour and rich aroma, which they associate with authenticity and its suitability for traditional dishes. Conversely, urban consumers preferred milder-flavoured palm oil, perceiving them as refined and suitable for diverse culinary applications (Chukwuma *et al*., 2022). Ibrahim *et al.* (2018) attributed these differences to processing methods, with traditional methods yielding stronger sensory characteristics and mechanized methods producing milder flavours. Bello and Adeyemi (2020) added a generational perspective, noting that older consumers preferred richer sensory qualities, while younger consumers leaned towards milder palm oil, influenced by global culinary trends. These findings underscore the cultural and generational variations shaping preferences for taste and aroma.

Texture and viscosity are also significant considerations for Nigerian palm oil consumers. Ibrahim and Ojo (2018) discovered that consumers preferred moderately viscous palm oil, which is easier to use for cooking. Overly thick or watery oils were often viewed as indicators of adulteration or poor production quality. Mohammed *et al*. (2020) observed that urban consumers were particularly sensitive to viscosity, associating moderate thickness with higher-quality production processes. On the other hand, rural consumers showed more tolerance for texture variations, focusing instead on affordability and traditional production methods. This suggests that producers targeting urban markets should prioritize consistency in viscosity to align with consumer expectations.

Health-consciousness among Nigerian consumers is a growing concern, significantly influencing palm oil preferences. Chukwuma *et al*. (2022) found that urban and middle-class consumers increasingly favour minimally processed palm oil due to its higher nutrient retention, particularly vitamin A. Similarly, Adegboye *et al*. (2021) observed a rising demand for unrefined palmoil among health-conscious consumers, who associate unrefined palm oil with better nutritional benefits. Ibrahim *et al.* (2019) noted that rural consumers were less influenced by health concerns but still valued oils perceived as natural and free from additives. These findings highlight the role of health awareness in shaping consumer behaviour, particularly in urban and educated demographics.

Price is a critical factor in palm oil purchasing decisions, particularly for low-income households. Ogunleye *et al*. (2019) found that affordability often outweighs quality considerations among economically constrained consumers. Similarly, Bello *et al.* (2021) observed that low-income consumers sometimes compromise on attributes like clarity and packaging to purchase cheaper alternatives. Mohammed *et al*. (2020) noted that price sensitivity was more pronounced in rural areas, where economic challenges limit consumer options. This suggests a need for affordable but quality products to cater for the rural dwellers. Packaging and branding significantly influence consumer preferences, especially in urban areas. Adebayo *et al*. (2020) highlighted that well-packaged and branded palm oil products attract higher-income consumers, who associate better packaging with quality and safety. Ibrahim *et al.* (2021) found that consumers in cities prefer palm oil in tamper-proof and labelled containers, viewing them as more trustworthy. In contrast, rural consumers often buy unbranded palm oil directly from producers, prioritizing affordability over packaging.

Concerns about adulteration heavily impact consumer preferences. Adedeji and Bolarinwa (2021) reported that many consumers avoid unbranded oils to mitigate risks of adulteration with dyes or other substances. Similarly, Eze *et al.* (2020) found that urban consumers are more likely to purchase from trusted brands or vendors to ensure product authenticity. Mohammed *et al.* (2019) observed that rural consumers often rely on local producers with established reputations to avoid adulterated products. This highlights the importance of trust and transparency in the palm oil market.

**Effects of palm oil quality attributes on its price**

The price of palm oil in Nigeria is heavily influenced by its quality attributes, including colour, clarity, taste, aroma, viscosity, and packaging. Oladele *et al.* (2021) reported that palm oil with a bright red-orange hue is highly valued in urban markets, where consumers associate this colour with freshness and nutrient richness, particularly beta-carotene content. Akpan and Etim (2019) observed that clarity, defined as the absence of sediments and impurities, significantly impacts pricing, as clearer palm oil are perceived as more hygienic and refined. Bello *et al.* (2022) found that palm oil with superior colour and clarity attracted prices up to 20% higher in urban centres compared to palm oil with duller hues or visible sediments, reflecting the importance of visual appeal in consumer decision-making.

Taste and aroma also play a critical role in determining palm oil prices. Eze *et al*. (2020) noted that rural consumers place a premium on palm oil with a strong, nutty flavour and rich aroma, as these qualities align with traditional cooking preferences. However, Chukwuma *et al*. (2022) found that urban buyers prefer milder flavours, often linked to modern processing techniques and costlier. Ibrahim *et al.* (2018) reported that palm oil with distinctive sensory attributes commanded prices of up to 15–25% higher than those with neutral characteristics, highlighting the value of sensory appeal. Similarly, Mohammed *et al.* (2020) identified viscosity as a significant determinant, with consumers willing to pay more for palm oil with a moderately thick consistency, which they associated with quality and ease of use. Palm oil that were too thick or watery were often discounted due to perceptions of adulteration or poor production standards.

Health and nutritional benefits further influence palm oil pricing, as noted by Chukwuma *et al*. (2022), who observed that minimally processed, unrefined palm oil rich in vitamin A and antioxidants command higher prices, especially among health-conscious urban consumers. Adegboye *et al.* (2021) found that middle-class buyers were particularly willing to pay a premium for palm oil perceived as natural and free from additives. Ibrahim *et al*. (2019) also reported that even rural consumers with some awareness of health benefits prioritized nutrient-rich palm oil despite slightly higher costs. This growing preference for healthier oils underscores the influence of nutritional awareness on pricing trends.

Packaging and branding also significantly affect palm oil prices. Adebayo *et al*. (2020) revealed that well-packaged and branded palm oil in tamper-proof containers were priced 25–30% higher than unbranded alternatives, particularly in urban areas where packaging is equated with quality and safety. Ibrahim *et al.* (2021) similarly found that branded palm oil was popular among higher-income consumers, who are willing to pay more for perceived quality assurance. In contrast, rural buyers placed less emphasis on branding but still preferred basic packaging that ensured cleanliness and ease of transport. Adedeji and Bolarinwa (2021) added that concerns about adulteration further drive consumer preferences for packaged and branded products, with many buyers opting to pay a premium to ensure product authenticity.

Regional differences in consumer preferences also influence palm oil pricing. Akpan and Etim (2019) noted that urban markets prioritize clarity, branding, and health benefits, while rural markets emphasize sensory qualities such as taste and aroma. Bello *et al*. (2021) observed that palm oil sold in metropolitan areas like Lagos and Abuja fetched higher prices than in rural regions, largely due to differing consumer expectations and purchasing power. Mohammed and Adebayo (2019) highlighted that regional preferences, such as a stronger emphasis on colour and aroma in Southern Nigeria, also contribute to price disparities.

Economic factors such as income levels and purchasing power further shape the relationship between quality attributes and pricing. Ogunleye *et al*. (2019) found that low-income households often prioritize affordability over quality, opting for palm oil with less clarity or packaging to save costs. Conversely, middle- and high-income consumers were more willing to pay higher prices for palm oil with superior quality attributes. Bello *et al.* (2022) observed that consumer education about the health benefits of unrefined palm oil justifies premium pricing, indicating the role of socio-economic status in purchasing decisions.

## CONCLUSION AND RECOMMENDATIONS

Consumer preferences for palm oil in Nigeria are influenced by quality attributes like colour, clarity, taste, aroma, viscosity, and packaging. Urban consumers prioritize bright, sediment-free oils for their hygiene and quality, while rural buyers value strong flavours and affordability. Health-conscious buyers, particularly in urban areas, prefer minimally processed oils rich in nutrients, commanding higher prices. Packaging and branding significantly influence urban markets, with tamper-proof, branded products appealing to higher-income consumers. Price sensitivity remains a critical factor for low-income households, often prioritizing affordability over quality. The study recommended that producers should improve production processes to ensure bright, sediment-free palm oil with appealing taste and aroma to cater to for rural and urban consumers' preferences. It was also recommended that further studies on consumer perceptions and preferences should be conducted to identify emerging trends, particularly regarding health-conscious buying behaviours.

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# FINANCIAL VIABILITY OF OUTGROWER SEED PRODUCTION IN NORTHWEST AND NORTHCENTRAL NIGERIA

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**ABSTRACT**

The study was conducted to assess financial viability of outgrower seed production in Northwest and North-central, Nigeria. Multi-stage sampling technique was used to select 394 respondents for the study. Structured questionnaire complemented with interview schedule was employed to collect primary data. Data collected were analysed using farm budgeting techniques. The results showed that rice, maize and soybean seed production enterprises are financially viable for out-growers in North-Central and North-West Nigeria with net return of (₦641,684; ₦671,840), (₦422,060; ₦352,900) and (₦451,500; ₦269,440), respectively although rice and maize showed higher profitability as compared to soybean. The study recommended that Seed companies should offer value-added services such as agronomic advisory, soil testing, and tailored fertilization plans. These services can help farmers make informed decisions, enhancing productivity and consequently, profitability.

**KEYWORDS:** Financial; Viability; Outgrower; Seed; and Production

## INTRODUCTION

Commercial seed companies are major agricultural enterprises that produce and market seeds (foundation seeds and certified seeds). The seed companies are valued at millions of dollars (National Agricultural Seed Council (NASC), 2018). In 2015, the Federal Ministry of Agriculture and Rural Development (FMARD) estimated the value of Nigeria's seed industry to potentially stand at ₦777.4 billion and local production at ₦252.3 billion, thereby leaving a ₦525 billion seed gap (FMARD, 2016). Meanwhile, the latest access to seed index 2019 released by Amsterdam-based Access to Seeds Foundation revealed that Nigeria has about N130 billion in seeds deficit (Veettil *et al.* (2021)). This implies a great opportunity for investment in seed production to meet the identified gap in the seed sector. Also, Nigerian seed companies account for over 60 percent of seeds traded and used in the West African sub-region and some parts of East and Central Africa (NASC, 2018). NASC (2018) describes that the seed industry includes all domestic and foreign seed companies, community-based seed producers, other local seed entrepreneurs, and agro-dealers that engage in the production and/or marketing of quality seed. Over the years, seed companies adopted out-grower schemes to increase their production towards meeting the market demands for improved seeds. The Out-grower schemes can be described as a form of contract farming where the seed companies supply the raw material for the seed production (foundation seeds, breeding lines for hybrid seeds), provide technical assistance, credit, and input services, and then repurchase the seeds at the end of the season under some form of predefined contractual arrangements (Veettil *et al.,* 2021). According to NASC (2018), the Nigeria's total national seed requirements for major crops, including maize and rice, stood at 413,417.64 metric tons (MT) in 2017, however, only half of this demand is met. Seed companies engage the service of out-grower to augment the gap in what is produced from their seed production fields. More so, given that many seed companies engage smallholder farmers (out-growers) as part of efforts to increase their certified seed production which shows a strong potential for development and linking smallholders to high-value markets, however, many stakeholders have questioned the potential impact of the schemes on the smallholders given the dominant positions of big private sector firms and their ability to extract surplus from local farmers (ActionAid, 2010). There is limited documented evidence to show whether seed companies in the study area provide their contracting farmers with access to inputs, whether the extension services and inputs given under the schemes can improve the input use efficiency of the out-growers. It's based on the foregoing, the study was conducted to examine the economic and financial viability of out-grower seed production systems; and

## RESEARCH METHODOLOGY

The study was conducted in selected States within the North West and North Central geopolitical zones of Nigeria. The North Central States are Benue, Kogi, Kwara, Nasarawa, Niger, Plateau, and the Federal Capital Territory (FCT). These States extend roughly from latitude $60^0$50'N to $90^0$30'N of the Equator and longitude $70^0$30'E to $100^0$00'E of the Prime Meridian. The area has a projected population of 22,325,056 million people at 2.5 percent population growth rate (National Population Commission (NPC), (2020)

### Sampling Technique and Sample Size

A multistage sampling technique was used to select the respondents (out-growers) for the study.

### Methods of Data Collection

Primary data were used for this study; the primary data were collected using structured questionnaires complimented with interview schedules. The collected data were analysed using farm budgeting techniques.

## RESULTS AND DISCUSSION

### Profitability of Rice, Maize, and Soybean seed (North Central)

Table 1 showed that in rice seed production, variable costs are the largest component, amounting to ₦356,500 per hectare, while fixed costs average ₦256,216 per hectare. NPK fertilizer is the largest expense within variable costs, accounting for 32.5%, followed by labour at 16.8%. Notably, labour costs appear lower, potentially due to the use of unpaid family labour. For maize seed production, the variable cost per hectare is ₦263,950, surpassing fixed costs of ₦152,440. Fertilizer expenses again lead, making up 43.9% of variable costs, followed by labor at 17.9%. The high fertilizer costs reflect recent price hikes, attributed to economic conditions and increased demand. Similarly, soybean seed production shows a high share of variable costs, amounting to ₦224,500 per hectare, with fixed costs at ₦150,190. Fertilizer remains the largest contributor to variable costs at 26.7%, followed by labour at 19.2%. Table 1 also revealed the profitability of these enterprises. For rice seed production, the gross margin is ₦897,900, with a net farm income of ₦641,684 per hectare. The return per variable cost is 3.52, meaning each ₦1 spent yields ₦3.52 in revenue, reflecting strong profitability and efficient resource use. Maize seed production, while less lucrative, still generates a substantial gross margin of ₦574,500 and a net income of ₦422,060 per hectare, with a return of ₦3.18 per ₦1 invested in variable costs, indicating high efficiency. Soybean seed production also remains profitable, with a gross margin of ₦451,500 and net income of ₦301,310 per hectare. The return per variable cost is 3.01, confirming its viability as an agricultural venture. Overall, rice seed production ranks as the most profitable enterprise, offering the highest return on investment among seed out-growers in North-central Nigeria.

**Financial viability of out-growers seed production (North-central)**

The financial viability of out-growers seed production in Table 2 revealed that the rate of return on investment was 1.04 for rice, 1.01 for maize and 0.80 for soybean. Similarly, the profitability index was 0.57 for rice, 0.50 for maize, and 0.67 for soybean. In addition, the operating ratio was 0.32 for rice, 0.31 for maize, and 0.50 for soybean while the expenditure structure ratio was 0.72 for rice, 0.58 for maize and 0.67 for soybean. This implies that rice and maize seed production are financially viable with returns on investment slightly above the breakeven point, indicating that for every naira invested, there is a return of ₦1.04 and ₦1.01, respectively

**Table 2: Measures of financial viability for Rice, Maize, and Soybean seed (North Central)**

| **Profitability ratios** | **Rate of Return on Investment** RRI=NFI/TC | **Profitability index** PI=NFI/TR | **Operating Ratio** OR=TVC/TR | **Expense structure Ratio** **ESR=TFC/TVC** |
|---|---|---|---|---|
| Rice | 1.04 | 0.57 | 0.32 | 0.72 |
| Maize | 1.01 | 0.50 | 0.31 | 0.58 |
| Soybean | 0.80 | 0.67 | 0.50 | 0.67 |

Source: Field Survey 2023

**Profitability of Rice, Maize, and Soybean seed (Northwest)**

Table 3 showed the costs and returns to rice production in North-west. The result revealed that, the variable costs constituted the highest share of the costs of production (₦375,700) while fixed cost is ₦275,460 among the rice out-growers farmers in North-west region. Similar to the observation in the North-Central region, the cost of NPK fertilizer accounted for the highest share (30.9%) of variable cost in rice production, this was followed by the cost of labour (21.6%) among the rice producers. Also, under maize seed production, the result shows that the variable costs constituted the highest share of costs of production (₦367,850) while fixed cost was ₦152,140 in the North-west region. Furthermore, the results on soybean seed production shows that the variable costs constituted the highest share of costs of production (₦258,450) while the fixed cost was ₦154,610. However, the cost of labour accounted for the highest share (27.2%) of variable cost followed by the cost of NPK fertilizer (23.2%). Cost of labour and fertilizer were the main contributing factors to the per hectare cost of production. The cost of labour and fertilizer for seed production in Nigeria can vary significantly depending on several factors, including the region, type of crop, and scale of production. (Tahir *et al.*, 2015). Variation in the cost of production among the seed enterprise was noted due to variations in the quantity of inputs used for the different out-grower seed production during entire seasons. This implies that there is a higher demand for labour usage among the farmers in the North-west region than seed farmers in the North-central region. Table 3 also revealed that rice yields the highest gross income per hectare at ₦1,305,000, significantly surpassing maize's ₦872,890 and soybean's ₦682,500. This superior gross income translates into a gross margin of ₦929,300 for rice, compared to ₦505,040 for maize and ₦424,050 for soybean. This demonstrates that rice not only generates higher revenue but also retains more profit after variable costs are deducted.

In terms of net farm income, rice again leads with ₦671,840, indicating strong overall profitability, while maize and soybean yield net incomes of ₦352,900 and ₦269,440, respectively. The return per variable cost is also highest for rice at 3.47, suggesting that for every naira spent on variable costs, rice farmers receive ₦3.47 in return. Conversely, maize and soybean return less per invested naira, at 2.37 and 2.64, indicating lower efficiency in generating profits. Overall, these results highlight rice as the most economically advantageous crop in the out-grower seed enterprise in the North-West.

**Financial viability of out-growers seed production (North-west)**

The financial viability of out-growers seed production in Table 4 revealed that the rate of return on investment was 1.06 for rice, 0.71 for maize and 0.65 for soybean. Similarly, the profitability index was 0.51 for rice, 0.41 for maize, and 0.39 for soybean, more so, the operating ratio was 0.29 for rice, 0.40 for maize, and 0.37 for soybean, while the expense structure ratio was 0.69 for rice, 0.41 for maize and 0.60 for soybean. This implies that rice seed production is the most financially viable among the three crops, with an ROI of 1.06, indicating that for every naira invested, there is a return of ₦1.06. Also, The PI for rice (0.51) showed that 51% of total revenue is retained as profit after covering total costs, indicating its financial viability. However, maize (0.41) and soybean (0.39) have lower ratios, suggesting that a smaller portion of their revenues contributes to profit. In addition, the OR for rice (0.29) is considerably lower than that of maize (0.40) and soybean (0.37), indicating that a smaller proportion of total revenue is used as variable costs for rice production. This suggests that rice farming is more efficient and cost-effective in its operational management compared to the other crops. Lastly, the ESR for rice is 0.69, indicating that the fixed costs constitute 69% of the variable costs, suggesting that while rice production involves significant fixed costs, it still manages to maintain profitability. In contrast, maize (0.41) and soybean (0.60) have lower ratios, indicating less reliance on fixed costs, though potentially at the expense of higher operational expenditures.

## CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it can be concluded that rice, maize and soybean seed production enterprises are financially viable for out-growers in North-Central and North-West Nigeria, although rice and maize demonstrate higher profitability. Also, seed out-growers in both regions are operating with increasing returns to scale; cost of farm size, cost of labour, cost of agrochemicals, cost of seed used and cost of fertilizer were the determinants of cost efficiency, while years of experience and value of credit accessed decreased cost inefficiency. The study recommended that seed companies should offer value-added services such as agronomic advisory, soil testing, and tailored fertilization plans. These services can help farmers make informed decisions, enhancing productivity and consequently, profitability.

**Table 4: Measures of financial viability for Rice, Maize, and Soybean seed (North-West)**

| Profitability ratios | Rate of Return on Investment RRI=NFI/TC | Profitability index PI=NFI/TR | Operating Ratio OR=TVC/TR | Expense structure Ratio ESR=TFC/TVC |
|---|---|---|---|---|
| Rice | 1.06 | 0.51 | 0.29 | 0.69 |
| Maize | 0.71 | 0.41 | 0.40 | 0.41 |
| Soybean | 0.65 | 0.39 | 0.37 | 0.60 |

Source: Field Survey 2023

| Variables | Rice seed enterprise Quantity/ha | Average unit price | Cost | Maize seed enterprise Quantity/ha | Average unit price | Cost | Soybean seed enterprise Quantity/ha | Average unit price | Cost |
|---|---|---|---|---|---|---|---|---|---|
| Variable cost | | | | | | | | | |
| **Cost of labour** | 24 | 2500 | 60,000 | 21 | 2250 | 47,250 | 20 | 2150 | 43,000 |
| **Cost of seed** | 50kg | 450 | 22,500 | 20kg | 350 | 7,000 | 100kg | 150 | 15,000 |
| **Cost of NPK fertilizer** | 4bg | 29000 | 116,000 | 4bg | 29000 | 116,000 | 4bg | 15000 | 60,000 |
| **Cost of Urea** | 2bg | 26500 | 53,000 | - | - | - | - | - | - |
| **Cost of agrochemicals** | 4ltr | 4500 | 18,000 | 3.8kg | 4000 | 15,200 | 2 | 16000 | 32,000 |
| **Transportation** | 1 | 19000 | 19,000 | 1 | 16000 | 16,000 | 1 | 15500 | 15,500 |
| **Processing (threshing)** | 1 | 25000 | 25,000 | 1 | 19500 | 19,500 | 1 | 16000 | 16,000 |
| **Packaging** | 1 | 3000 | 3,000 | 1 | 3000 | 3,000 | 1 | 3000 | 3,000 |
| **Cost of hiring a tractor** | 1 | 40000 | 40,000 | 1 | 40000 | 40,000 | 1 | 40000 | 40,000 |
| Total variable cost | | **₦149,950** | **₦356,500** | | **₦114,100** | **₦263,950** | | **₦107,800** | **₦224,500** |
| Fixed cost | | | | | | | | | |
| **Cost of land** | 1ha | 10000 | 10,000 | 1ha | 10000 | 10,000 | 1ha | 10000 | 10,000 |
| **Storage facility** | 1unit | 24000 | 24,000 | 1unit | 9580 | 9,580 | 1unit | 8650 | 8,650 |
| **Cost of hoes** | 4 | 2000 | 8,000 | 3 | 2000 | 6,000 | 3 | 2000 | 6,000 |
| **Cost of cutlass** | 2 | 2500 | 5,000 | 3 | 2500 | 7,500 | 2 | 2500 | 5,000 |
| **Cost of watering can** | 2 | 8000 | 16,000 | 1 | 8000 | 8,000 | 2 | 8000 | 16,000 |
| **Sickle** | 3 | 3500 | 10,500 | - | - | - | - | - | - |
| **Wheelbarrow** | 3 | 35000 | 105,000 | 1 | 35000 | 35,000 | 1 | 35000 | 35,000 |
| **Cost of knapsack sprayer** | 2 | 27600 | 55,200 | 2 | 27600 | 55,200 | 2 | 27600 | 55,200 |
| **Cost of sacks** | 20 | 400 | 8,000 | 19 | 400 | 7,600 | 15 | 400 | 6,000 |
| **Cost of rake** | 3 | 2500 | 7,500 | 2 | 2500 | 5,000 | 2 | 2500 | 5,000 |
| **Depreciation** | - | 7,015.5 | 7,016 | - | 8560 | 8,560 | - | 3340 | 3,340 |
| Total fixed cost | | **₦122,515.5** | **₦256,216** | | **₦106,140** | **₦152,440** | | **₦99,990** | **₦150,190** |
| Total cost of production | | | **₦612,716** | | | **₦416,390** | | | **₦374,690** |
| **Gross income from seed/ha** | 2240kg | 560 | 1,254,400 | 2045kg | 410 | 838,450 | 1300kg | 520 | 676,000 |
| **Total gross income (GI)** | | | ₦1,254,400 | | | ₦838,450 | | | ₦676,000 |
| **Gross margin/ha = GI-TVC** | | | ₦897,900 | | | ₦574,500 | | | ₦451,500 |
| **Net farm income = GM-TFC** | | | ₦641,684 | | | ₦422,060 | | | ₦301,310 |
| **Return per variable cost = GI/TVC** | | | 3.52 | | | 3.18 | | | 3.01 |

Source Field survey, 2023

**Table 3: Distribution of respondents according to costs of production of the out-grower seed enterprise (North-west)**

| | **Rice seed enterprise** | | | **Maize seed enterprise** | | | **Soybean seed enterprise** | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables | Quantity/ha | Average unit price | Cost | Quantity/ha | Average unit price | Cost | Quantity/ha | Average unit price | Cost |
| Cost of labour | 45 | 1800 | 81,000 | 50 | 2000 | 100,000 | 52 | 1350 | 70,200 |
| Cost of seed | 50kg | 500 | 25,000 | 30kg | 390 | 11,700 | 100kg | 350 | 35,000 |
| Cost of NPK fertilizer | 4bg | 29000 | 116,000 | 6bg | 29000 | 174,000 | 4bg | 15000 | 60,000 |
| Cost of Urea | 2bg | 26500 | 53,000 | - | - | - | - | - | - |
| Cost of agrochemicals | 4ltr | 4200 | 16,800 | 3.9kg | 4000 | 15,600 | 3.9kg | 4000 | 15,600 |
| Transportation | 1 | 16900 | 16,900 | 1 | 15600 | 15,600 | 1 | 11900 | 11,900 |
| Processing (threshing) | 1 | 26000 | 26,000 | 1 | 10000 | 10,000 | 1 | 25000 | 25,000 |
| Packaging | 1 | 2500 | 2,500 | 1 | 2450 | 2,450 | 1 | 2250 | 2,250 |
| Cost of hiring tractor | 1 | 38500 | 38,500 | 1 | 38500 | 38,500 | 1 | 38500 | 38,500 |
| **Total variable cost** | 1 | **₦145,900** | **₦375,700** | | **₦101,940** | **₦367850** | | **₦98,350** | **₦258,450** |
| **<u>Fixed cost</u>** | | | | | | | | | |
| Cost of land | 1ha | 10000 | 10,000 | 1ha | 10000 | 10,000 | 1ha | 9500 | 9,500 |
| Storage facility | 1unit | 24000 | 24,000 | 1unit | 9580 | 9,580 | 1unit | 8650 | 8,650 |
| Cost of hoes | 4 | 2000 | 8,000 | 3 | 2000 | 6,000 | 3 | 2000 | 6,000 |
| Cost of cutlass | 2 | 2500 | 5,000 | 3 | 2500 | 7,500 | 2 | 2500 | 5,000 |
| Cost of watering can | 2 | 8000 | 16,000 | 1 | 8000 | 8,000 | 2 | 8000 | 16,000 |
| Sickle | 3 | 3500 | 10,500 | - | - | - | - | - | - |
| Wheel barrow | 3 | 35000 | 105,000 | 1 | 35000 | 35,000 | 1 | 35000 | 35,000 |
| Cost of knapsack sprayer | 2 | 27600 | 55,200 | 2 | 27600 | 55,200 | 2 | 27600 | 55,200 |
| Cost of sacks | 20 | 400 | 8,000 | 19 | 400 | 7,600 | 15 | 400 | 6,000 |
| Cost of rake | 3 | 2500 | 7,500 | 2 | 2500 | 5,000 | 2 | 2500 | 5,000 |
| Depreciation | - | 8,260 | 8,260 | - | 8,260 | 8,260 | - | 8,260 | 8,260 |
| **Total fixed cost** | | **₦123,760** | **₦257,460** | | **₦105,840** | **₦152,140** | | **₦104,410** | **₦154,610** |
| **Total cost of production** | | | **₦633,160** | | | **₦519,990** | | | **₦413,060** |
| Gross income from seed/ha | 2250kg | 580 | 1,305 ,000 | 2129kg | 410 | 872,890 | 1300kg | 525 | 682,500 |
| Total gross income (GI) | | | ₦1,305,000 | | | ₦872,890 | | | ₦682,500 |
| Gross margin/ha = GI-TVC | | | ₦929,300 | | | ₦505,040 | | | ₦424,050 |
| Net farm income = GI-TC | | | ₦671,840 | | | ₦352,900 | | | ₦269,440 |
| Return per variable cost | | | 3.47 | | | 2.37 | | | 2.64 |

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# EFFECTS OF FLOOD ON RICE FARMERS' FOOD SECURITY IN AGRICULTURAL ZONE I OF NIGER STATE

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## ABSTRACT
This study determined the effects of flood on rice farmers' food security in Agricultural Zone I of Niger State. A multistage sampling technique was used to select 127 rice farmers affected by flood and 127 rice farmers not affected by flood. Primary data were used for this study. The data were collected with the assistance of a well-trained enumerator using questionnaire. Descriptive statistics and logit regression) were used to achieve the objectives. The result showed that 96.1% of rice farmers not affected by flood were food secured while 73.2% affected farmers were food secured. The coefficient of household size, extension access, cooperative, farm income, value of crop loss due to flood and days farm had effect on food security. Raising seed bed ($\bar{X}$ =4.59), planting flood resistance seeds ($\bar{X}$ =4.50) were the most coping strategies adopted by rice farmers affected by flood to mitigate effects of flood while emergency water storage ($\bar{X}$ =4.40), agricultural insurance of farm ($\bar{X}$ =4.40) were the most coping strategies adopted by rice farmers not affected by flood to mitigate flood. It is recommended that rice farmers affected by flood to insure their farm in order to avert unforeseen circumstances**.** Rice farmers should put every measure in place to control floods in the study area. It is recommended that post-flood soil rehabilitation be adopted to mitigate the negative effect of flood.
**KEYWORDS:** Flood, Rice farmers, Food security

## INTRODUCTION

Rice plays a vital role in ensuring sustainable food security as well as provision of employment and income to the nation's teeming population. Nigeria has been a major consumer and importer of rice in Africa. Indeed, rice is classified among the top four agriculture imports in Nigeria along with wheat, sugar and fish (Okafor *et al.,* 2020). It has been reported that the country spends over ₦356 billion on yearly importation of rice, out of which about ₦1 billion is used per day (Adenega *et al.,* 2021). Rice production in Nigeria is mainly rain-fed and most of the farming activities are carried out along the water plain which increases their vulnerability to flood (Apuyor *et al.,* 2023). Flooding is one of the most widespread natural disasters globally, exacerbated by climate change, which has increased the frequency and intensity of extreme weather events (IPCC, 2014; Agbadaga *et al.,* 2021). These events disrupt agricultural activities, causing significant losses in crop yields and threatening food security. In Africa, the impacts of flooding on agriculture and food security are particularly severe due to the continent's high dependence on rain-fed agriculture and limited adaptive capacity. According to the United Nations Environment Programme (UNEP),

Africa's agricultural sector is highly exposed to climate variability, and flooding is one of the major climate-related risks (UNEP, 2018). In sub-Saharan Africa, floods have caused significant disruptions to farming activities. For example, the 2019 floods in East Africa affected over 3 million people and led to widespread crop failures (Agbadaga *et al*., 2021). Flooding not only destroys crops but also damages infrastructure such as irrigation systems and storage facilities, further reducing agricultural productivity and food availability. Flooding can wipe out entire harvests, leading to significant income losses for farmers and increased food insecurity. In other world the supply chain, leading to higher food prices and reduced access to food for consumers. (Agbadaga *et al*., 2021). Several factors contribute to the frequent flooding in Nigeria. These include heavy rainfall, poor drainage systems, deforestation and the opening of the Lagdo Dam in Cameroon. The Niger and Benue rivers, which traverse the country, often overflow their banks during the rainy season, leading to widespread flooding in adjacent farmlands (NEMA, 2018). Niger State is one of the states with re-occurring flood incidences. In 2020, there was a devastating flood in about 20 Local Government Areas (LGAs) of the State which mostly affected crops, livestock, buildings, human lives, and farmlands that led to a significant decrease in the actual capacity of crop and livestock production (ENVIRON, 2020). The socioeconomic implications of flooding extend beyond immediate crop losses. Flooding disrupts the livelihoods of farming households, leading to increased poverty and food insecurity. According to the World Food Programme (WFP), floods in Nigeria often result in displacement, forcing farmers to abandon their homes and farmlands (WFP, 2018). Food security as a situation where all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2020). These events have exacerbated food insecurity in a region already struggling with high levels of hunger and malnutrition. The objectives of the study are to: describe the food security of rice farmers in the study area; determine the effect of flood on food security and examines the coping strategies used in flood mitigation.

## RESEARCH METHODOLOGY

The study was conducted in Agricultural Zone I of Niger State, Nigeria. The Zone comprises Agaie, Bida, Edati, Gbako, Katcha, Lapai, Lavun and Mokwa Local Government Areas (LGAs) of Niger State, Nigeria. Niger State is located between Latitude 9$^{o}$ 93'N and 11$^{o}$30'N and Longitude 5$^{o}$65'N and 7$^{o}$20'E and covers a land area of about 76,363 km$^2$ of about 8% of Nigeria's total land area. This makes it the largest in the country in terms of land mass. (NBS 2024). The mean annual temperature of the study area is between 35$^0$C - 360$^0$C with maximum temperature between March and June while the minimum 20$^0$C-210$^0$C is between December and January (NBS 2023). Annual rainfall ranges from 1,100mm in the northern part to 1,600mm in the southern part of the State. The rainy season lasts for about 150 days in the Northern parts while it is about 120 days in the Southern parts of the State. (NBS, 2023). The total population of the State ware over 28, 2300,932 people (NPC, 2023). Generally, the availability of natural water along the river Niger valleys and the type of soil permits the cultivation of most of Nigeria's staple crops including rice, maize, sorghum, millet, soybean, cowpea, yam and groundnut. While some of the tree crops cultivated are mango and cashew. Livestock reared include goat, sheep, cattle and fowl. The State has 25 Local Government Areas (LGAs) with three Agricultural Zones (Niger State Geographic Information System 2023). The major agricultural produce in the State includes; rice, maize, yam, cassava, beans, and sorghum.

**Sampling Technique and Sample Size**

A multistage sampling technique was used to select respondents for this study. The first stage involved the purposive selection of four LGA' s in Agricultural Zone I of Niger State namely Agaie, Katcha, Lapai, and Mokwa LGA in the second stage, three (3) communities were selected from each of the LGAs using random sampling technique to give a total of twelve communities. In the third stage, a total of 254 rice farmers were selected from a total sampling frame of 938 comprising of 127 rice farmers who were affected by flood and another 127 farmers who were not affected by flood. Yamane (1967) formula adopted by Ibrahim *et al.* (2023) was used to obtain an appropriate sample from the sampling frame. Yamane is expressed in the equation (3.1)

$$n = \frac{N}{1+N(e^2)} \quad (3.1)$$

Where:
n = targeted number of respondent;
N = sampling frame, and

1 = constant (0.05).

**Table 1: Sampling frame and sample size of rice farmers in the study area**

| | Rice farmers affected by flood | | | Rice farmers not affected by flood | | |
|---|---|---|---|---|---|---|
| LGA | Communities | Sampling Frame | Sample Size | Communities | Sampling Frame | Sample size |
| Agaie | Baro | 27 | 7 | Loguma | 44 | 12 |
| | Essun | 45 | 12 | Zago | 42 | 11 |
| | Ankwanu | 47 | 13 | Soje | 38 | 10 |
| Katcha | Gbakogi | 46 | 13 | Shabawoshi | 45 | 12 |
| | Echegi | 21 | 6 | Gbapo | 49 | 13 |
| | Kippo | 26 | 7 | Kashe | 54 | 15 |
| Lapai | Old-muye | 31 | 8 | Ebbo | 34 | 9 |
| | Achiba | 50 | 14 | Yeluwa | 18 | 6 |
| | Arah | 41 | 11 | Katakpa | 28 | 8 |
| Mokwa | Kpata 1 | 48 | 13 | Tayi | 45 | 12 |
| | Gbara | 56 | 15 | Fofo | 30 | 8 |
| | Muregi | 31 | 8 | Gakpan | 42 | 11 |
| Total 4 | 12 | 469 | 127 | 12 | 469 | 127 |

**Source: Field survey (2024)**

**Methods of Data Collection**

Primary data was used for the study. Data were collected using a structured questionnaire and Kobo collect mobile application to collect relevant information on rice farmers affected by flood and rice farmers not affected by flood in the study area. The researcher was assisted by well-trained enumerators in data collection.

**Analytical techniques**

**Food security index**

Objective (i) was achieved using food security index of the rice farmer's. The rice farmers were classified into food secure and food insecure rice farmers using food security index, (Adebayo *et al.,* 2021) which is given as:

$$Fi = \frac{\text{Per capita food expenditure for the irice farmers}}{\frac{2}{3}\text{of the mean per capita food expenditure for all rice farmers}} \quad (3.2)$$

Where; Fi = Food Security Index.

Where; Fi ≥ 1 = Food secure $i^{th}$ rice farmer and

Fi ≤ 1 = Food insecure $i^{th}$ rice farmer.

A food secure rice farmer is therefore, that farmers whose per capita monthly food expenditure is above or is equal to two- thirds of the mean per capita food expenditure for all rice farmers. A food insecure farmer is that whose per capita food expenditure is below two thirds of the mean monthly per capita food expenditure. This method has been applied to a study, whose main focus was to analyze the food security status of urban households in Lagos (Bayen *et al.,* 2021).

**Logistic regression model**

Objective (ii) was analyzed using the logistic regression model to determine the effects of flood on the rice farmer's food security status. The implicitly formula for the logistic regression model is specified as

$L_¡ = (Z_¡/1Z_¡)\ X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, e_¡$ (3.3)

Where:

$L_¡$ = Logit;

$Z_¡$= food insecure;

1-$Z_¡$= food secure;

The explicitly form for the logistic regression model is specified as:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5 5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + \beta_{12}X_{12} + \beta_{13}X_{13} + \beta_{14}X_{14} + e_i \quad (3.4)$$

Where:

$X_1$ to $X_{14}$ (independent variables) specified as:

$Z_¡$ = Food security (1 = food secure, 0 = food insecure)

$X_1$ =Age of respondents (Years), $X_2$= Education level (Number of years spent in schooling), $X_3$= Household size (Number), $X_4$= Extension contact (number); $X_5$ = Membership of Cooperative (number), $X_6$= Farm size (Hectares), $X_7$= Annual off–farm income (₦); $X_8$= Annual farm income (₦); $X_9$= Total experience (years) $X_{10}$= Value of crop lost due to flood (₦)

$X_{11}$= Value of properties destroyed (₦), $X_{12}$= Loss of family member (number), $X_{13}$= Days farm (number), $X_{14}$= Strategies adopted by rice farmers (number), Ui =Error term $X_1$ to $X_{14}$ = coefficient to be estimated.

Coping strategies adopted was achieved five-point Likert rating scale was allotted as follows: Highly adopted = (5), adopted = (4), not sure = (3), not very adopted = (2), not adopted (1). The decision point is ≥ 3 adopted, <3 not adopted.

**RESULTS AND DISCUSSION**

**Food security of rice farmers**

Table 2 indicated that 73.2% of the rice farmers affected by flood are food secure while 96.1% of rice farmers not affected by flood are food secure. This result conforms with the findings of Adebayo *et al.,* (2021) who found out that an increased in flood will result to food insecurity.

This implies that rice farmers not affected by flood were more food secured than the affected farmers. This could be attributed to negative effect of flood of rice farmer productivity in the study area.

**Table 2: Food security of rice farmers**

| | Affected (n=127) | | Not affected (n=127) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Food secure | 93 | 73.2 | 122 | 96.1 |
| Food insecure | 34 | 26.6 | 5 | 3.9 |

Sources: Field survey, 2024

**Effects of flood on the rice farmer's food security status**

Table 3 revealed the result of logit regression used to determine the effect of flood on rice farmers' food security status. The results showed Pseudo $R^2$ of 0.517, indicating that about 51.7% of variations in rice farmers' food security were explained by the independent variables included in the model. The chi-square statistics was significant at 1% level of probability indicating fitness of the model. From the Z values, six out of the fourteen variables included in the model were statistically significant at 1% and 5% level of probability. Table 3 indicated that household size (-0.3001139) was negatively significant at 5% level of probability. This suggests that each additional unit in household is associated with a 0.30% decrease in the probability of households to be food insecure. This finding is in consonance with Jonathan *et al.* (2020) who stated that increase in households will result to food insecurity. Extension access (3.052149) was positively at 5% level of probability. This denotes that access to extension services is associated with 3.5% increase in the probability of households to be food secure. Cooperative (-5.569034) was negatively significant at 1% level of probability. This suggests increase in membership of cooperative is associated with a 5.5% decrease in the probability of households to be food secure. Farm income (-1.15e-06) was negatively significant at 5% level of probability. This implies increase in farm income will is associated with 1.1 of the households to be food secure. Value of crops loss due to flood (-3.32e-06) was negatively significant at 5% level of probability. This suggests that each additional unit in value of crops loss due to flood with a 3.3% decrease in the probability of households to be food secure. Days farm (-0.2826664) was negatively significant at 1% level of probability. This suggests that each additional unit in days' farm submerge with a 0.28% decrease in the probability of households to be food secure.

**Coping Strategies to be adopted by Rice Farmers to Mitigate the Effects of Flood**

Table 4 showed that the following strategies were adopted by rice farmers affected by flood, raised seed bed ($\bar{X}$ =4.59), planting flood resistance seeds ($\bar{X}$ =4.50), emergency water storage ($\bar{X}$ =4.40), crop diversification ($\bar{X}$ =4.39), early harvesting ($\bar{X}$ =4.28), change plant time ($\bar{X}$ =4.17), changing use of chemical ($\bar{X}$ =3.94), soil conversation measures (3.76) and afforestation ($\bar{X}$ =3.54). On the other hands, the rice farmers not affected by flood adopted the following farming strategies to mitigate flood namely; emergency water storage ($\bar{X}$ =4.40), agricultural insurance of farm ($\bar{X}$ =4.40), change planting date ($\bar{X}$ =4.17), early harvesting (3.94), changing use of chemical ($\bar{X}$ =3.94), raising bed farming ($\bar{X}$ =3.76), soil conservation ($\bar{X}$ =3.76), and afforestation ($\bar{X}$ =3.54). This finding shows that the rice farmers affected by flood adopted more of the farming strategies than those not affected. This might be attributed to the unprecedented effect of flood on the productivity and food security of rice farming households in the study area.

**Table 3: Effects of flood on the rice farmer's food security status (n=127)**

| Variables | Coefficient | Std Err | Z – value |
|---|---|---|---|
| Age | 0.0093 | 0.0252 | 0.37 |
| Education | -0.1457 | 0.0984 | -1.48 |
| Household size | -0.3001 | 0.1342 | -2.24** |
| Extension agent | 3.0521 | 1.5109 | 2.02** |
| Cooperative | -5.5690 | 1.6559 | -3.36*** |
| Farm size | 0.2204 | 0.3254 | 0.68 |
| Off farm income | -0.0001 | 0.0001 | -0.89 |
| Farm income | -1.15e-0 | 5.36e-0 | -2.15** |
| Total experience | -0.0000 | 0.0000 | -1.46 |
| Value of crops loss due to flood | -3.32e-0 | 1.22e-0 | -2.72** |
| Value of properties destroyed | 0.0001 | 0.0001 | 0.76 |
| Loss of family member | -0.1830 | 0.6264 | -0.29 |
| Days farm submerge | -0.2826 | 0.0835 | -3.38*** |
| Strategies | 0.1240 | 0.0855 | 1.45 |
| Constant | -0.1308 | 8.7329 | -0.01 |
| Chi2 | 76.25*** | | |
| Pseudo R2 | 0.5167 | | |
| Log Likelihood | -35.6594 | | |

Sources: Field survey, 2024
*** Significant at 1% level of probability, **=Significant at 5% level of probability

**Table 4: Coping strategies to be adopted by rice farmers to mitigate the effects of flood**

| | Affected (n=127) | | Not affected (n=127) | |
|---|---|---|---|---|
| Variables | Means | Decision | Mean | Decision |
| Planting of flood resistant seeds | 4.50 | Adopted | 2.73 | Not adopted |
| Crops diversification | 4.39 | Adopted | 2.32 | Not adopted |
| Raised bed farming | 4.59 | Adopted | 3.79 | Adopted |
| Soil conservation measures | 3.76 | Adopted | 3.76 | Adopted |
| Terracing | 4.09 | Adopted | 4.09 | Adopted |
| Afforestation | 3.54 | Adopted | 3.54 | Adopted |
| Change plant time | 4.17 | Adopted | 4.17 | Adopted |
| Post-flood soil rehabilitation | 2.72 | Not adopted | 2.72 | Not adopted |
| Early harvesting | 4.28 | Adopted | 3.94 | Adopted |
| Emergency water storage | 4.40 | Adopted | 4.40 | Adopted |
| Selective exploitation | 2.38 | Not Adopted | 2.72 | Not adopted |
| Changing use of chemical | 3.94 | Adopted | 3.94 | Adopted |
| Agricultural insurance of farm | 1.26 | Not adopted | 4.40 | Adopted |

Sources: Field survey, 2024

## CONCLUSION AND RECOMMENDATIONS

It can be concluded that rice farmers affected by flood were less food secured than those not affected. The coefficient of household size, extension access, cooperative, value of crop loss due to flood, days of farm submerge had effect on rice farmer's food security status. The most used coping strategies by rice farmers to mitigate the effect of flood were raised farm bed, and planting of flood resistance varieties. While the rice farmers not affected by flood adopted agricultural insurance of farm and emergency water storage. It is recommended that rice farmers affected by flood to insure their farm in order to avert unforeseen circumstances**.** Rice farmers should put every measure in place to control flood in the study area. Post-flood soil rehabilitation is not adopted by farmers in the study area. It is recommended that rice farmers affected by flood to insure their farm in order to avert unforeseen circumstances**.** Rice farmers should put every measure in place to control flood in the study area. It is recommended that post-flood soil rehabilitation be adopted by to mitigate the negative effect of flood.

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# EFFECTS OF RURAL ACCESS AND MOBILITY PROJECT ON FOOD CROP PRODUCTION AND WELLBEING OF CROP FARMERS IN KADUNA STATE, NIGERIA

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## ABSTRACT
The study was conducted to examine the effects of rural access and mobility project (RAMP) on food production and well-being of crop farmers in Kaduna State, Nigeria. Specifically, the study examined rural infrastructural projects executed by RAMP, well-being status of farmers and effects of RAMP on well-being status of farmers. Multi-stage sampling techniques were employed to select 170 respondents on which primary data were elicited from the respondent with the aid of a structured questionnaire complemented with interview schedule. Data collected were analyzed using descriptive statistics (such as mean, frequency distribution count and percentages), wellbeing indicators and inferential statistics such as logit regression. . The study revealed that 93.3% respondents agreed that RAMP executed earth-dressed roads. Also, 49.4% of respondents reported satisfaction with their well-being. More so, distance of RAMP ($p<0.05$), reduce transportation ($p<0.01$) and facility access ($p<0.01$) were the major factors influencing well-being status of farmers. The study recommended that RAMP should continue expanding and maintaining earth-dressed roads to enhance rural infrastructure. Additionally, efforts should be made by Federal government to improve transportation facilities and access to essential services, as these factors significantly influence the well-being of farmers.
**KEY WORDS:** Rural; Access; Mobility; and Well-being

## INTRODUCTION
Transportation of agricultural produce is as old as human existence because even the early man who was only a gatherer still had to convey himself to the centres of food collection. Transportation plays a key role in the agricultural and economic development of any nation as it provides access for extension agents to transfer new and improved agricultural technologies to the rural and farming communities, timely delivery of inputs to the farm and evacuation of harvests to the urban areas where they are mostly demanded. These ensure improvement in agricultural production, food availability in urban areas and improvements in the economy of the rural communities. Improved transportation will encourage farmers to work harder to increase production, add value to their products, reduce spoilage and wastage, empower the farmer as well as having positive impact on their productivity, income, employment and reduce poverty level of the rural communities.

As at 1996, survey reports showed that majority of the Nigeria populace still had no access to motorable road while between 90 and 95% of the rural roads which is estimated at between 130,000 and 160,600 km nationwide were in very poor condition (Buhari, 2000; Yusuf, 2004 and Federal Road Maintenance Agency, 2003). Early form of transportation was mainly on-farm as the major activities were collection of water, crop gathering, animal hunting and related activities most of which were done within the neighborhood of the farmer and hence the distances covered were usually very short. \ In rural Nigeria, it is estimated that poor transport infrastructure is responsible for 15-20 % of the agricultural production not reaching market resulting to food lost and wastage (Rural Access and Mobility Project, 2007). However, 31 percent of the world population live in isolation from market and services. They live more than 2 km from all season road and do not have adequate access to transport (World Bank, 2015). Overwhelming majority of these people live in rural Africa, where, on average 60 percent of the population do not have access to transport. The situation is worse for women who in some cases have to carry baby at the back, load on the head and pregnancy at the fore. They cannot get wares and harvests to markets or take sick children to hospital. Child birth still occurs half way to the health centers or at home in unhygienic environments. Consequently, maternal and child morbidity and mortality remain high. However, it is noted that a significant part of the perishable products is lost or damaged in transit. Food loss poses a critical threat in rural Nigeria where the burden of food loss falls heavily on the small farmers and their families, many whom also are food insecure and when there is a post-harvest marketable surplus, it is not always easy to reach the markets. Limited accessibility has also cut off small-scale farmers from sources of inputs, equipment and new technologies therefore resulting to low crop productivity because farmers lack these important inputs.

Consequently, majority of people who live in rural Nigeria continue to experience not only low road infrastructure, but poor condition of road and transport services. Hence, rural travel and transport in the country remain difficult because people spend a huge personal effort on carrying goods and working long distances. This situation has continued to have undesirable effects on the income and socio-economic well-being of the rural Nigerian dwellers. The study specifically aimed to examine rural infrastructural projects executed by RAMP, wellbeing status of farmers and effects of RAMP on wellbeing status of farmers.

## RESEARCH METHODOLOGY

### Study Area

The study was conducted in Kaduna States of Nigeria. It is located between Latitude $09^0$ and $11^0$ N and Longitude $06^0$ and $09^0$ E. The State occupies an area of approximately 48,473.2 square kilometers with an estimated population of 6,766,562 people (NPC, 2006) with a projected population of 8,252,366 in 2018. The mean annual temperature varies between $24^{0C}$ and $28^{0C}$. The vegetation consists of Northern Guinea savannah in the north and Southern Guinea savannah in the south. The length of rainfall varies from 150 days in the north and 190 days in the southern part. The annual rainfall varies from 1107mm in the north to 1286mm in the south. Relative humidity is low ranging between 60 and 80% in July.

### Sampling Techniques and Sample Size

Multi-Stage sampling technique was used to select respondents for the study. The first stage involved the purposive selection of four (4) local governments area namely Kachia, Igabi, Giwa and kagarko. The second stage involved purposive selection of two (2) villages from each of the four (4) Local Government Areas selected in Kaduna State making a total of fourteen (14) villages. The purposive selection is based on the fact that not all Local Government Areas and villages have benefited from RAMP. The third stage involved the use of proportionate sampling to select 12% of the sampling frame. Thus a total of 170 respondents were used for this study.

**Methods of Data Collection**

Data for this study were collected by the researcher assisted by a trained enumerators using well-structured questionnaire, interview schedule

**Analytical Techniques**

Data collected were subjected to analysis using both descriptive (such as mean, frequency and percentage) and inferential statistics and Logit regression). The international well-being group categorizes personal well-being using a constructed well-being Index-Adult scale. The scale is a number continuum in a linear scale that ranged between 1-14. The mean score of $< 7.0$ is considered not satisfied while for score $\geq 7.0$ is considered satisfied. Standard of living, personal health, achievement in life, personal relationships, personal safety, community connectedness, future security, personal growth, self acceptance, education, purpose in life, resilience, self esteem and environmental mastery formed the fourteen life domains used to access the wellbeing. Each of the fourteen domains was analyzed as a separate variable and the fourteen domain scores were summed up to yield an average score which represent subjective well-being.

Logit regression

The explicit form of the logit regression is specified in equation (1) as follows:

$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\ldots\ldots+\beta_7X_7 + e$. (1)

The dependent variable (Y) in this case is an ordered variable indicating the farmers' livelihood status.

Where;

Y = Wellbeing status (Satisfied = 1, Not satisfied = 0);

$X_1$= Distance to RAMP (km); $X_2$ = Reduce transportation cost (If yes =1 or 0 if otherwise); $X_3$ = Reduce perishability (if yes =1, 0 if otherwise); $X_4$ = Facilitate extension services (number of extension visit); $X_5$ = Access to health centres (if yes =1, 0 if otherwise); $X_6$ = Facilitate access to farm input (number of farm input accessed); $X_7$ = Technical assistance (number of training received);

**RESULTS AND DISCUSSON**

**Farmers Perception of Rural Infrastructural Projects Executed by RAMP**

Table 1 presents the farmers' perceptions of infrastructural projects executed by RAMP. Regarding the road projects, the majority of food crop farmers in Kaduna States (93.3%) agreed that RAMP executed earth-dressed roads. This suggests that RAMP has focused on basic road construction using natural materials, which could be cost-effective and suitable for certain terrains. Additionally, the majority of respondents in Kaduna States (80.0%) also indicated that RAMP executed surface-dressed roads. Surface dressing involves adding a layer of bitumen and aggregate, providing a smoother and more durable road surface. This is expected to enhance the productivity of food crop farmers because both earth-dressed and surface-dressed roads contribute to enhanced accessibility for farmers. Farmers can easily transport their produce to markets, allowing them to reach a wider customer base, potentially leading to increased income and improved overall well-being. Upgraded roads, especially those with surface dressing, can reduce maintenance costs for vehicles due to smoother surfaces and fewer potholes, thereby decreasing transportation costs. This allows farmers to allocate resources to other aspects of their agricultural activities.

In terms of culverts, the majority (83.3%) of food crop farmers in Kaduna States agreed that RAMP executed triple-cell box culverts and (52%) agreed that RAMP executed 4 cell box with relief culvert. Triple-cell box culverts and 4 cell box relief culverts are effective in managing water flow, preventing waterlogging and reducing the risk of road damage. This is expected to enhance the durability of road infrastructure executed by RAMP because improved drainage reduces the risk of road damage, enhances road durability, and ensures year-round accessibility for farmers, particularly during rainy seasons. Furthermore, 21.9% of food crop farmers in Niger State and 13.3% in Kaduna State agreed that bridges of >500 meters were constructed by RAMP.

**Table 1: Farmers' Perception of infrastructure project executed by RAMP**

| **Variables** | **Types** | **(n=170)*** |
|---|---|---|
| **Infrastructure project executed by RAMP** | | |
| **Road** | Earth dressed | 140 (93.3) |
| | Surface dressed | 120(80.0) |
| **Culverts** | Triple cell box | 125(83.3) |
| | 4 cell boxes with relief culvert | 78(52.0) |
| | Double cell box | 59(39.3) |
| | 6 cells box | 45(30.0) |
| | Ring culvert | 56(37.3) |
| | Double pipe | 43(28.7) |
| | Triple cell skewed-box | 5(3.3) |
| **Bridges** | >500 Meter | 29(21.9s) |

Source: Field survey data, 2022
*Multiple responses were allowed

**Well-being status of farmers**

The findings from Table 2 revealed that a significant portion of farmers in Kaduna State (49.4%) reported satisfaction with their wellbeing and (50.59 %)not satisfied. This suggests that despite the interventions by RAMP, a substantial proportion of farmers still struggle with various aspects of their well-being. This could be attributed to economic constraints such as high cost of farm input and market instability. Rising costs for seed, fertilizers and equipment often outpace financial support and farmers face volatile prices for their products, reducing income stability. As RAMP primarily focuses on improving rural infrastructure, such as roads, the rising cost of input and market fluctuation could counteract the benefits of these improvements.

Additionally, the rising costs associated with mobility have made most subsistence farmers unable to acquire one, this further exacerbates their difficulties. Limited mobility restricts farmers' ability to access markets, agricultural inputs, and extension services, hindering their productivity and economic opportunities. Moreover, the high costs of agricultural inputs pose a significant barrier for farmers, despite RAMP interventions. Access to affordable inputs, such as seeds, fertilizers, and pesticides, is crucial for enhancing food production. However, the expense associated with these inputs makes it difficult for farmers, especially those with limited financial resources, to invest in their farms and improve their yields. Thus, despite the efforts of RAMP to improve rural infrastructure, farmers continue to face challenges related to transportation costs, mobility and access to affordable agricultural inputs.

**Table 2: Well-being status**

| Score | Well-being status | n=170(%) |
|---|---|---|
| ≥7.0 | Satisfied | 84(49.41) |
| <7.0 | Not satisfied | 86(50.59) |

**Source: Field survey, 2022**

**Effects of ramp on the well-being farmers**

The result of logit regression on effects of ramp on the well-being farmers is presented in Table 3. The computed Pseudo $R^2$ was 0.4073 implying that about 40.7% variation in well-being status of farmers were explained by the included variables while Prob > $chi^2$ was significant 0.01 probability level suggesting the entire model is fit for the study. The result revealed that distance of RAMP road constructed (2.8690), RAMP reducing transportation cost (.0689), RAMP reducing perishability (1.4139), facilitate access to extension services (1.1014), facilitate to health centre (.2442) and technical assistance (.0297) were positive and statistically significant at various level of probability implying that a unit increase in any of the variables led to probability of increase in well-being of farmers.

**Table 3: Effects of ramp on the well-being farmers**

| Variables | Coefficient | z-value |
|---|---|---|
| Distance of RAMP | .2653** | 2.39 |
| Reduce transportation cost | 2.1404*** | 4.37 |
| Reduce perishability | -.2297** | -2.32 |
| Facilitate extension services | 1.4971*** | 3.34 |
| Access to health centres | .3564 | 0.76 |
| Facilitate access to farm input | -.0190 | -0.70 |
| Technical assistance | -.1661* | -1.83 |
| Constant | 20.7758*** | 4.99 |
| **Pseudo $R^2$** | 0.4073 | |
| **Prob > $chi^2$** | 0.0000 | |
| **Log likelihood** | -69.664476 | |

**Source: Field survey, 2022**

The positive and statistically significant distance of RAMP road constructed suggests that an increase in the distance of RAMP road constructed is associated with probability of increase in the well-being of farmers. Improved road infrastructure enhances farmers' access to markets, inputs and essential services, reducing transportation costs and time. Additionally, better road connectivity facilitates the timely transportation of agricultural produce, reducing post-harvest losses and improving farmers' incomes. Moreover, improved access to roads enhances social and economic opportunities, fostering community development and overall well-being. Adeoye *et al.* (2020) found that better road connectivity reduces transportation costs, increases agricultural productivity, and improves farmers' access to markets, leading to higher incomes and improved well-being. The positive and statistically significant of RAMP reducing transportation cost indicates that RAMP's efforts to reduce transportation costs have a positive effect on farmers' well-being. Reduced transportation costs lower the financial burden on farmers, allowing them to allocate resources to other productive activities or household needs. Moreover, lower transportation costs make it more affordable for farmers to access markets, inputs, and services, thereby improving their economic prospects and overall well-being.

The positive and statistically significant of RAMP reducing perishability suggests that RAMP's efforts to reduce the perishability of agricultural produce contribute to farmers' well-being. By improving transportation infrastructure and logistics, RAMP helps farmers minimize post-harvest losses and maximize the value of their produce. Reduced perishability enhances farmers' incomes and food security, improving their overall well-being and livelihoods. Babalola *et al*. (2017) reported that interventions aimed at reducing post-harvest losses contribute to improved food security, higher incomes and better livelihoods for farmers.

The positive and statistically significant of RAMP facilitate access to extension services indicates that RAMP's facilitation of access to extension services has a positive effect on farmers' well-being. Access to extension services provides farmers with technical knowledge, skills and information to improve their agricultural practices and productivity. Moreover, extension services enhance farmers' resilience to challenges such as pests, diseases, and climate variability, contributing to their overall well-being and livelihood sustainability. This is similar to the study of Swanson *et al.* (2017) who found that access to extension services plays a crucial role in improving agricultural productivity and farmers' well-being by providing them with technical knowledge, skills, and information.

The positive and statistically significant of technical assistance indicates that RAMP's provision of technical assistance has a positive effect on farmers' well-being. Technical assistance equips farmers with the knowledge, skills, and resources to adopt improved agricultural practices, enhance productivity, and mitigate risks. Moreover, technical assistance fosters innovation, entrepreneurship, and capacity building among farmers, leading to improved livelihoods and overall well-being. This is similar to the studies of Feder *et al*. (2020) and Babalola *et al*. (2017) who on their separate studies agreed that technical assistance programmes contribute to increased yields, higher incomes, and improved livelihoods among farmers

## CONCLUSION AND RECOMMENDATIONS

The study concluded that majority of farmers perceived that RAMP executed earth-dressed roads. Also, almost half of respondents reported satisfaction with their wellbeing. More so, distance of RAMP, reduce transportation and facility access were the major factors influencing well-being status of farmers. The study recommended that RAMP should continue expanding and maintaining earth-dressed roads to enhance rural infrastructure. Additionally, efforts should be made by Federal government to improve transportation facilities and access to essential services, as these factors significantly influence the well-being of farmers.

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# ASSESSMENT OF SOCIOECONOMIC CONSTRAINTS OF CLIMATE SMART AGRICULTURAL STRATEGIES AMONGST RICE FARMERS IN NASARAWA STATE

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## ABSTRACT
Despite high level of rice production and Government interventions through Climate Smart Agricultural Strategies (CSA) in ensuring food available and accessible to all in Nigeria. Climate change continues to be a hug bottleneck to rice producers. This study seeks to assess socioeconomic constraints of climate smart agricultural strategies amongst rice farmers in Nassarawa State. To achieve this, 2 LGAs each were purposively selected out of the three Zones from which 100 rice farmers were randomly selected. The data obtained were analyzed using descriptive statistics and Likert Scale Type. The study revealed that 80% were male and about 92% were married. Majority (90%) have basic education while about 55% were reported to have 11 - 20 years' rice farming experience with mean years of 17. Mean farmers age were 37 while 40% were between 31 – 40 years of age with 53% having farm size of 4 – 6 hectares. CSA strategies awareness level was about (98%) while majority (96%) were reported to adopt this CSA Strategies. Scarcity of water during dry season, lack of improved storage facilities, inadequate data and CSA information, high cost of input for rice production and inadequacy in dissemination of CSA information were ranked 1st, 2nd, 3rd, 4th and 5th, respectively as the most socioeconomic constraint affecting rice production in the study area. It was recommended that women and youth farmers should participate more in rice production, rice farmers should acquire the know- how on each CSA strategies adopted for optimal utilization and Government and stakeholders should intensify in promptness and efficient CSA strategies information dissemination to the farmers in timeliness. Lastly Government should provide inputs adequately at low cost and at the appropriate time to farmers to ensure high outputs.

**Key words**: Constraints, Climate-Smart, Rice, Production, Likert-Scale

## INTRODUCTION
Globally, Climate change poses significant threat and challenges to agricultural productivity, particularly in vulnerable regions such as Nigeria and precisely Nasarawa State. In recent years, climate-smart agricultural (CSA) strategies have emerged as innovative approaches aimed at enhancing resilience, improving food security, and reducing greenhouse gas emissions in the face of climate variability. However, the adoption of these strategies is often hindered by socio-economic constraints, which can impede farmers' willingness and ability to implement climate-smart practices. Research has shown that factors such as limited access to financial resources, inadequate agricultural education, and poor infrastructure can significantly restrict the implementation of CSA strategies among smallholder farmers (Adeleke et al., 2020). Additionally, prevailing socio-cultural norms and land tenure issues may further exacerbate the reluctance to adapt to new agricultural practices, especially in regions where traditional farming methods are deeply rooted (Ojo, 2021). Understanding these socio-economic constraints is

essential for developing targeted interventions aimed at promoting the adoption of climate-smart technologies that can lead to sustainable agricultural practices and improved livelihoods among rice farmers in Nasarawa State. Despite the significant number of researches carried on climate smart agriculture in the aspect of adapting, mitigating and reducing the Carbon dioxide emission into the environment, limited research has been carried out to assess the socioeconomics constraints of climate smart agricultural strategies in ensuring less effect of climate change on farmers. This study considered the following objectives to describe the socioeconomics characteristics of the respondents, assess the level of awareness of climate smart Agricultural strategies, examine the adoption level of climate smart agricultural strategies in the study area, and to identify the constraints to climate smart strategies in the study area.

## METHODOLOGY

Nasarawa State is located within Latitudes 8º 32ˈand 8º 42ˈ N and Longitudes 7º 34ˈ E and 7º 45ˈ E. The State shares boundaries with Kaduna and Plateau States to the North-East, the Federal Capital Territory (FCT) to the North-West, Benue state to the South, Taraba State in the South-East and Kogi State to the West. The State is made up of thirteen Local Governments Areas and they are grouped into three Agricultural zones of Central, Southern and Western zone respectively. The State lies within the middle belt of the country within the Guinea Savannah vegetation. The State has a land area of 12,000 square kilometers. Nasarawa State Bureau of Statistics (NSBS), (2022). The 2006 population census pegs the state's population at 1,869,377, but projected to 2023 be about 3,089,795 with a population growth rate of 3.0% (NSBS, 2022). It has a mean temperature range from 25º C in October to about 36º C in March, with annual mean rainfall of 1311.75cm. Agriculture is the dominant occupation of the inhabitants of Nasarawa State. Some of the major agricultural products in the state include maize, sorghum, millet, rice groundnut cowpea, soya beans, sesame, melon, yam, cassava, sweet potato, mango, cashew, sugar-cane, oil palm, cattle, sheep, goats, poultry, pigs and fisheries. Nasarawa state (the home of solid minerals) is blessed with numerous solid minerals such as Beryl, Tourmaline, quartz, columbite, granite, limestone, barytes, glass sand, marble and salt (NSBS, 2022). The state is an agrarian state with large percentage of the populace engaged in farming and agro-allied activities. The soil texture is sandy-loan and very fertile for crops like rice, sorghum, cowpea, cassava among others that are cultivated in the study area.

### Sampling Techniques and Sample size

A Multi-stage sampling technique were used in selecting representative farming households in Nasarawa States from which primary data were collected for the study area. A two stage sampling procedure were used for the study. The first stage involved purposive selection of 2 LGAs from the 3 zones where rice production is predominant in both States. The second stage was a simple random selection of 5 villages from each the 2 LGAs from which 10 respondents each were selected. Taro Yamane's formula was adopted and modified from Adamu, *et al. (*2024) to obtain a scientific sample size at 0.05 confidence interval from the sample frame to get a total sample size of 100 for the study. A well-structured questionnaire which was designed in kobo toolbox and data collected using Kobocollect application were used. Objective I and II were analyzed using descriptive statistics while objective III used adoption index and objective IV were analyzed using Likert scale type.

**Method of Data Collection and analysis**

The Study used Primary data which were obtained from a well-structured questionnaire, Data for the study were analyzed using both descriptive, adoption index, and Likert type scale. Descriptive statistics such as frequency, percentages, and means were used to describe the socioeconomic characteristics of rice farmers, adoption index were used to ascertain CSA strategies adoption in the study area while Likert type scale were used to affirm the constraints to adoption of CSA strategies of the farmers. The constraints of CSA Strategies on rice production were captured using ten perceptional statements measured by a 5-point Likert type scale of 5 = very severe constraint, 4= severe constraint, 3= Not sure, 2= Not severe constraint, and 1= Not very severe constraint.

**Adoption index**

The index of adoption of CSA strategies by farmer was measured using the adoption index. The index was computed individual farmers. Adoption index is denoted by (Bi) as presented in (Sambo and Godfrey 2022) and modified in equation (1) below:

$$\mathrm{Bi} = \sum\left(\frac{\mathrm{Ri}}{\mathrm{RT}}\right) \tag{1}$$

Where:
Bi = Adoption index of CSA strategies by ith farmer;
Ri = Number of CSA strategies adopted by ith farmer; and
RT = Total number of CSA strategies available to the ith farmer
i = (1…………n)

For this study, an index of ≤0.33 indicates no adoption while an index of ≥0.55 indicates adoption. Some of the climate smart agricultural strategies in the study area include:
(1) Crop diversification; (2) Practice of crop rotation; (3) Sustainable land use management (integrate land, water and environmental resources); (4) Zero/minimum tillage; (5) Contour farming; (6) Terraces; (7) Mulching; (8) Early planting; (9) Mixed farming; (10) Intercropping to maximize space; (11) Intercropping rice with legumes; (12) Adjusting planting dates; (13) Agroforestry; (14) Planting hybrid crop varieties; (15) Improved flood and drought tolerant crop varieties; (16) Disease resistant varieties; and (17) Cover crops methods.

**RESULTS AND DISCUSSION**

**Socioeconomic Characteristics of the Respondents**

The socioeconomic characteristics of the respondents considered for this research include; Gender, marital Status, Educational Status, Farming Experience, Age of respondents, and farm size of the respondents. The Result in Table 1 revealed that majority about (80.0%) of the respondents were male, majority about (92.0%) were married with about (90.0%) were reported to have basic education. This conform with the finding of Anugwa *et al.* (2021) who affirmed that male are more in rice production, married and have basic education.

**Table 1: Socioeconomic Distribution of the respondents in the study area**

| Parameters | Frequency | Percentage | Mean |
|---|---|---|---|
| **Gender** | | | |
| Male | 80 | 80.0 | |
| Female | 20 | 20.0 | |
| **Marital Status** | | | |
| Single | 8 | 8.0 | |
| Married | 92 | 92.0 | |
| **Educational Status** | | | |
| Primary | 50 | 50.0 | |
| Secondary | 40 | 40.0 | |
| Tertiary | 7 | 7.0 | |
| Quaranic | 3 | 3.0 | |
| **Years of Farming Experience** | | | 17 |
| ≤ 10 | 20 | 20.0 | |
| 11-20 | 55 | 55.0 | |
| 21-30 | 23 | 23.0 | |
| ≥ 31 | 2 | 2.0 | |
| **Age of Farmers** | | | 37 |
| ≤ 20 | 3 | 3.0 | |
| 21-30 | 24 | 24.0 | |
| 31-40 | 40 | 40.0 | |
| 41-50 | 28 | 28.0 | |
| ≥ 51 | 5 | 5.0 | |
| **Farm Size (ha)** | | | 5 |
| ≤ 3 | 10 | 10.0 | |
| 4-6 | 53 | 53.0 | |
| ≥ 7 | 37 | 37.0 | |

Source: Field Survey, 2024

More so, the study showed the years in rice farming experience which were ranged. The result revealed that about 55.0% were between 11-20 of rice farming while the mean age of the respondents was 73 and the age range, 40.0% of farmers fall between ages of 31-40, while 28% were between 41-50 this implies that the labour force were within their active ages, this will have direct reflection on their adoption and level of production. The result for farm size showed that about 573.0% have farm size of about 4-6 hectare, while about 37% were above 6 hectare of arable land for rice production. This implies that they majority farmer were producing in small scale. The level of awareness for climate smart agricultural strategies were showed in Figure 1 below. The result revealed that Majority about 63.0% of the respondents were aware of the CSA strategies in the study area while 35% affirmed to be very aware of CSA strategies. This implies that significant numbers of farmers were aware of these strategies. This finding agreed with Opeyemi *et al.* (2021) who founds that majority of rice farmers in Nigeria are aware of climate smart agriculture. On the other hand, adoption level of the CSA strategies was also ascertained in this study.

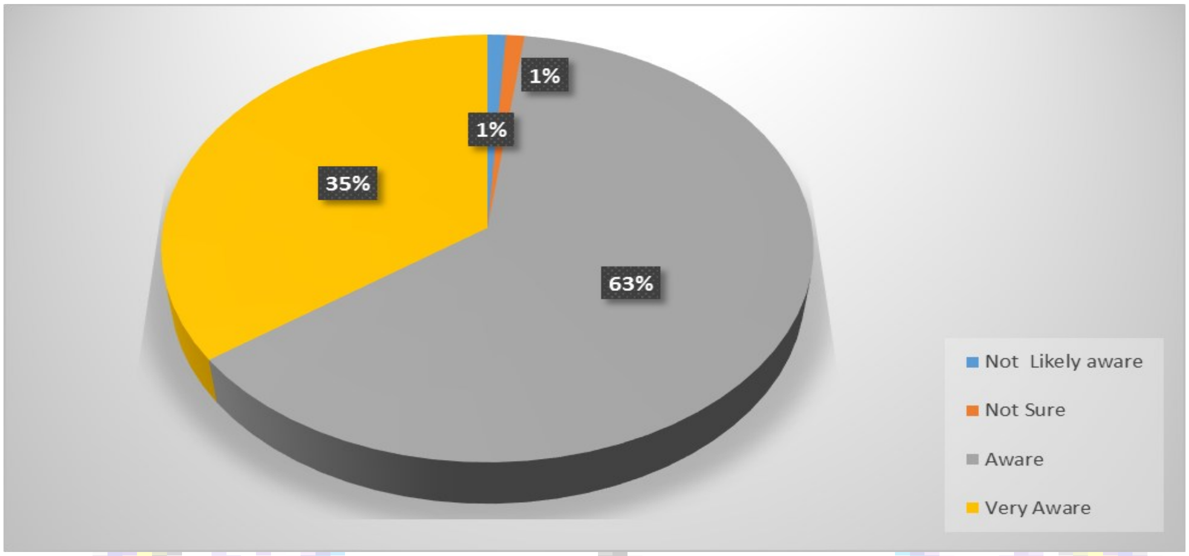

Figure I: Awareness level of climate Smart Agricultural Strategies

The result in Figure 2 showed the adoption index of CSA Strategies in the study area. The result revealed that majority about (96.0%) adopted the CSA strategies significantly with index ≥ 0.55 while 4.0% with index ≤ 0.33 did not adopt CSA strategies. The high level of adoption implies that sizable number of the respondents have aimed at ensuring an improvement in their rice production in order to maximize an output despite the effects of climate change. According to Cassim, *et al.* (2017), farmers have greater benefits when they adopt multiple strategies, because some strategies can serve as complementary to one another and enable the farmers to explore and thrive in the event unstable climate occurrences.

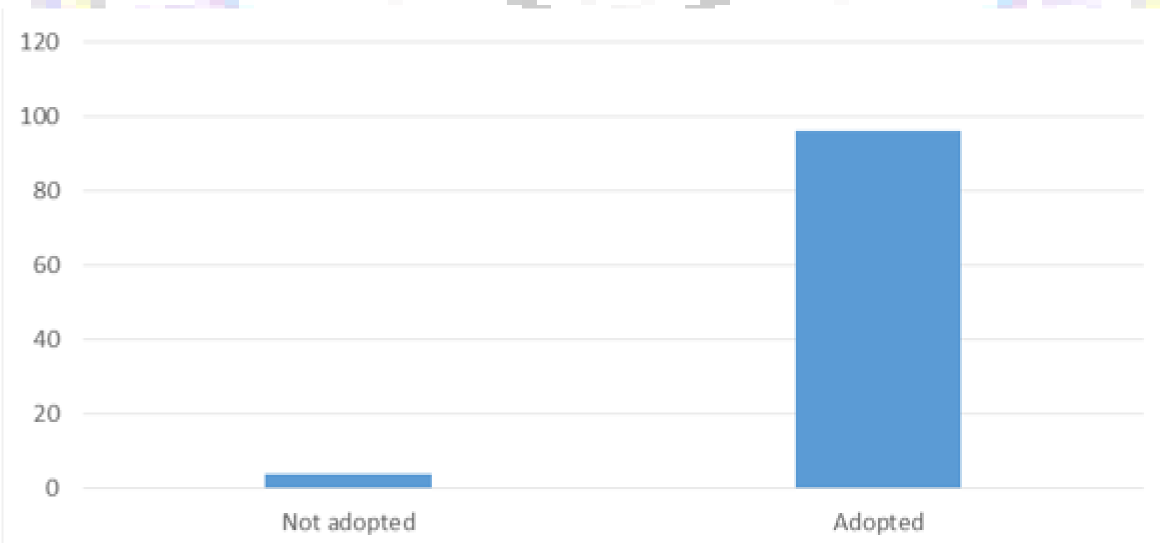

Figure 2: Adoption Index of climate smart Agricultural Strategies (Not adopted ≤ 0.33, Adopted ≥ 0.55)

Table 2 reveals the constraints to climate smart agricultural strategies in the study area, the result revealed and ranked these constraints according to the level of severity. The Scarcity of water during dry season, lack of improved storage facilities, inadequate data and information on CSA, high cost of rice production inputs and inadequacy in dissemination of CSA information were constraints reported with the highest weighted mean to be 4.79, 4.72, 4.65, 4.58, and 4.56 and were ranked as 1st, 2nd, 3rd, 4th and 5th respectively. This implied that availability of water, storage facilities, access to climate data and cost of rice production significantly affects the farmers up scaling of CSA strategies in the study area. Ayinde, *et al.,* (2013) researched on the evaluation of the effects of climate change on rice production in Niger State, Nigeria. The result revealed that Rainfall is one of the climatic factors affecting rice production. Salisu (2022) also reported high cost of input, lack of access to agricultural funds, high cost of production was also a very serious constraint. Inadequate financial resources were rated as very serious constraint by respondents in the area

**Table 2: Constraints to Climate Smart Agricultural Strategies in the study Area**

| Constraints of CSA Strategies | VSC | SC | ND | NSC | NVSC | Weighted Sum and Weighted Mean | Rank |
|---|---|---|---|---|---|---|---|
| Scarcity of water during the dry season | 81(81.0) | 18(18.0) | NR | 1(1.0) | NR | 479.0 ± 4.79 | 1st |
| Lack of improved storage facilities | NR | 1(1.0) | NR | 25(25.0) | 74(74.0) | 472.0 ± 4.72 | 2nd |
| Inadequate data and information | NR | 3(3.0) | 2(2.0) | 22(22.0) | 73(73.0) | 465.0 ± 4.65 | 3rd |
| High cost of rice production | NR | 2(2.0) | NR | 36(36.0) | 62(62.0) | 458.0 ± 4.58 | 4th |
| inadequacy in dissemination of CSA information | NR | 3(3.0) | NR | 35(35.0) | 62(62.0) | 456.0 ±4.56 | 5th |
| Lack of awareness of CSA practice | 7(7.0) | 2(2.0) | 2(2.0) | 36(36.0) | 59(59.0) | 450.0 ± 4.50 | 6th |
| Unfavorable government policy | NR | 3(3.0) | 2(2.0) | 50(50.0) | 35(45.0) | 437.0 ±4.37 | 7th |
| CSA Strategy Illiteracy amongst farmers | NR | 3(3.0) | NR | 55(55.0) | 42(42.0) | 436.0 ± 4.36 | 8th |
| Inadequate extension service | NR | 1(1.0) | 1(1.0) | 63(63.0) | 35(35.0) | 432.0 ± 4.32 | 9th |
| Inadequate investment in CSA | 7(7.0) | 65(65.0) | 6(6.0) | 15(15.0) | 7(7.0) | 250.0 ± 2.50 | 10th |

Source: Field Survey 2024. NR denote No response
Note: Very severe constraint (VSC), 4= severe constraint (SC), 3= Not sure (ND), 2= Not severe constraint (NSC), 1=Not very severe constraint (NVSC)

## CONCLUSION

The study concluded that male farmers are more involved in rice farming and majority of respondents are found to be in active age and were married thereby ensuring more labour supply. Basic education helps in the overall improvement in farming activities likewise the years in rice farming experience. More so, CSA strategies awareness level were high among the respondents. Scarcity of water during dry season, lack of improve storage facilities, inadequate data and CSA information, high cost of input for rice production and inadequacy in dissemination of CSA information were the most constraints affecting rice production in the study area.

## RECOMMENDATIONS

The study therefore recommended that women and youth farmers should participate more in rice production, rice farmers should acquire the know-how on each CSA strategies adopted for optimal utilization. Furthermore, Government and stakeholders should intensify in promptness and efficient CSA strategies information dissemination to the farmers in timeliness. Lastly Government should provide inputs adequately at low cost and at the appropriate time to farmers to ensure high outputs.

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# ADOPTION OF IMPROVED SESAME PRODUCTION TECHNOLOGIES BY SMALLHOLDER FARMERS IN LAPAI AND AGAIE LOCAL GOVERNMENT AREAS NIGER STATE, NIGERIA

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## ABSTRACT

The study examined adoption of improved sesame production technologies by smallholder farmers in Lapai and Agaie Local Government Areas, Niger State, Nigeria. The study describes the socio-economic characteristics, identifies the various improved sesame production technologies, analyses the factors influencing the adoption of improved sesame production technologies and identifies the effect of improved production technologies. A multi-stage sampling procedure was used to select 338 sesame farmers from a total of 1,551 farmers in Lapai and Agaie LGA using Yamane's formula at 5% limit or tolerable error. Descriptive statistics and logit regression were used to analyze the data from the field survey.

**KEYWORDS**: Sesame, Adoption, Improved technologies, Niger State.

## INTRODUCTION

Sesame (*Sesamum indicum* L) also known as beniseed (Ridi in Hausa) is one of the oil seed crops cultivated globally. It is quite extensively cultivated in Northern Guinea savannah areas of Northern Nigeria mainly owing to the drought-resistant nature of the plant as it thrives there excellently (Olawuyi et al, 2023). Presently, about 26 states grow sesame, with Jigawa, Nassarawa, Benue and Taraba states being the largest producers. Sesame production is expected to increase, given the good prices obtained by farmers and increased demand worldwide (AgroNigeria, 2017). Farmers' knowledge of improved production techniques has been very low because extension services have not been very efficient in disseminating information on improved production technologies to farmers. Consequently, this makes farmers to continue using technologies that have low yield potentials, low quality and late maturing (Makama et al., 2018).

The study of adoption comes after the costs of adoption are incurred and the technologies have been diffused. Such technological interventions often result in a low level of acceptance by the target group and a lower success for development programmes (Getachew et al., 2016). However, the low rate of adoption of improved and new technologies by farmers might also be influenced by the different attributes that farmers assign to their choice of technology adoption. In this respect, adoption depends on users‟ judgment of the value of the technology to them. Although sesame cultivation is on the increase in terms of area hectarage cultivated, its full potential is yet to be explored in Nigeria due to the lack of local farmers' adherence to best farm practices suitable for its productivity (Garba et al., 2020). Yakubu (2020) stated that Nigeria has pests and diseases like grasshopper (pest) which destroys seedlings, and caterpillars (pest) attack leaves and thus affect production outputs andphyllody dry (disease) root rot (disease) phytophthora blight(disease) alternaria blight (disease). Moreover, in Niger State, lack of access to agricultural loan facilities has also weakened the farmers financially such that they are unable to cultivate good portions of their farmlands despite the vast land mass Niger State has.

It is against this backdrop that the study describes the socio-economic characteristics, identifies the various improved sesame production technologies, analyses the factors influencing the adoption of improved sesame production technologies and identifies the effect of improved production technologies. The study will articulate the synergetic effects rising from the combination of improved sesame production technologies in helping to achieve better output. Furthermore, the study will investigate whether usage of improved sesame production technologies in combination or in isolation will improve output. The knowledge is appropriate to the ongoing debate on whether farming households should use improved sesame production technologies in piecemeal or in combination to improve household food security. The study is relevant for designing extension policy by recognizing improved sesame production technologies combinations with the highest payoff in terms of output.

## METHODOLOGY

### Study Area

The study was carried out in Agaie and Lapai Local Government Area. Agaie LGA shares a boundary with Lapai LGA in the East, Katcha LGA in the West, and Paikoro LGA in the North with River Niger as the boundary line. The land area of Agaie is 874 Square miles with Longitude 60030'E – 70030'E and Latitude 80030'N - 90000'N of the Equator. Agaie is positioned between Lapai and Bida areas of Niger. The projected population is 226,600 for 2023 at an annual growth rate of 3.4%.

Lapai local government area is in Niger state, North-central geopolitical zone of Nigeria and has its headquarters in the town of Lapai. Lapai LGA is bounded to the North by Paikoro Local Government, Agaie Local Government by the West; Gurara Local Government is in the eastern part while Federal Capital and Kogi State occupy the Southern part of Niger State, Nigeria Ibrahim, 2018). It is located between latitude 9o 3′ North and longitude 6o 34′ East of the Southern Guinea Savanna of Nigeria. It has a land mass of 3,051 km2 and population of 110,127 at the 2006 census (Tsepav et al., 2012). the wet season is oppressive and overcast, the dry season is humid and partly cloudy, and it is hot year-round. The annual temperature is from 17°C to 34°C and is rarely below 17°C or above 38°Cwith an average high of 33oC and low of 24(oC(Weather Spark, 2023). Lapai Local Government experiences two distinct seasons of dry and wet seasons. The annual rainfall varies from about 1,600mm in the South to 1,200mm in the northern part of Lapai Local Government Area of Niger State.

### Sampling Design, Techniques and Sample Size

A multi-stage sampling technique was employed in the collection of data for this study. The first stage involved the purposive selection of Lapai and Agaie LGAs since the people of the two LGAs are predominantly sesame farmers. The second stage involved random selection of five (5) villages from Lapai and Agaie LGA, while the last stage of sampling involved the random selection of 338 sesame farmers based on sampling frame of 687 farmers from Lapai LGA and 876 farmers from Agaie LGA.

**Table 1: Sampling outlay of the Study**

| LGA | Villages/ town | Sampling frame | Sample size |
|---|---|---|---|
| | Agaie | 245 | 50 |
| | Bororo | 135 | 28 |
| Agaie | Bantigi | 186 | 38 |
| | Daniya | 197 | 41 |
| | Gbaji | 113 | 23 |
| | **Sub-total** | **876** | **180** |
| | Badegi-Lapai | 133 | 31 |
| | Cheche | 130 | 30 |
| Lapai | Gabi | 168 | 39 |
| | Garawa | 115 | 26 |
| | Ndeji | 141 | 32 |
| | **Sub-total** | **687** | **158** |
| **Niger State** | **Total** | **1,551** | **338** |

Source: Agricultural and Mechanization Development Authority (NAMDA), 2024

**Method of Data Collection and Management.**

Data for this study were from primary sources. Data were collected using structured questionnaires administered to 338 sesame farmers.

**Model Specification**

Descriptive statistics and Logit regression were employed to analyse the data from field survey..

The Logit regression model is specified in equation 1.

$$Y_i = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + b_7x_7 + b_8x_8 + b_9x_9 + b_{10}x_{10} + b_{11}x_{11} + b_{12}x_{12} + +b_{13}x_{13} + b_{14}x_{14} + e \qquad (1)$$

The explanatory variables included in the logit model used to examine the factors influencing the adoption of improved sesame production technologies in the study area were: .

The result of the technology adoption profile was used in determining the adoption level of farmers..

Y= (Improved production technology: 1 = Adopted, 0 = Did not adopt).

$X_1$ = Age (Years),

$X_2$ = Gender (1 if male, 0 otherwise),

$X_3$ = Educational Status of ith respondent (Years),

$X_4$ = Marital status (1 if married, 0 otherwise),

$X_5$ = Household size (No.)

$X_6$ = Income from farming activities (Naira),

$X_7$ = Years of farming experience (Years),

$X_8$ = Amount of credit received (Naira),

$X_9$ = Income from non-farming activities (Naira),

$X_{10}$ = Training on improved seed (1 = Yes, 0 = Otherwise),

$X_{11}$ = Size of Farm land (Hectare),

$X_{12}$ = Cooperative membership (1 = Yes, 0 = Otherwise),

$X_{13}$ = Type of sesame seed (1 = Hybrid, 0 = Otherwise),

$X_{14}$ = Contact with extension agents (number of visits), and

$\boldsymbol{\varepsilon}$ are the model disturbances that are assumed to be independently and identically distributed with extreme value distribution.

## RESULTS AND DISCUSSION

### Socioeconomic characteristics of sesame farmers

Figure 1 reveals that the majority (65.1%) of the respondents were males while 34.9% were females. It could be possible that the dominance of male farmers is due to the physical demands of farming activities, which may be more suitable for men. The male farmers may be more likely to engage in activities such as planting, pruning, and harvesting, while the female farmers may be more likely to engage in activities such as weeding, processing, and marketing. This is in agreement with Garba et al. (2018) who reported male dominated sesame farming activities. Also Figure 2 reveals that the highest percentage (51.8%) of the respondents were married. This could grant the household division of labour sharing of responsibilities and resources, and the transfer of knowledge and skills across generations. It's also possible that being married could provide a source of support and stability for farmers, which could impact their agricultural activities. This aligns with research carried out by Garba et al. (2018) who asserted that the majority of the farmers were married result from Figure 3 reveals that the mean age of the farmers was 42 years with a high proportion (41.4%) of the farmers between 41 – 50 years. Farmers in the age range of 41-50 are typically at a mature stage in their farming careers, having accumulated significant farming experience and knowledge. This experience can be both an advantage and a challenge for adopting new technologies. Farmers in their 40s might be more open to adopting improved production technologies because they are often in the prime of their farming careers. They are still physically active and may be looking for ways to enhance productivity and secure higher incomes as they plan for long-term stability. The accumulation of farming experience at this age might also make them better decision-makers when it comes to evaluating the benefits of adopting improved technologies. If they perceive the new methods as advantageous after careful consideration, they may be more likely to adopt them than younger, less experienced farmers. Agwu (2004) agrees with the findings that farmers who adopt improved crop production technologies were between 30 to 49 years. Furthermore, results from Figure 4 reveal that the farmers had a mean household size of 11 people suggesting that sesame farmers in the study generally have relatively large families. This has important implications for their ability to adopt improved sesame production technologies, as larger household sizes can influence decision-making in several ways. Larger household sizes typically mean that more resources are allocated toward sustaining family members, rather than investing in new agricultural technologies. Also, a significant portion of the farmer's income is likely dedicated to basic needs like food, healthcare, and education, leaving less disposable income for investing in improved technologies such as hybrid seeds, fertilizers, or modern farming equipment. This agrees with the findings of Ojo and Ogunyemi (2014) who stated that the household size of farmers was above 5 persons per household.

Extension services often provide farmers with better access to resources like improved seeds, fertilizers, training and information on improved sesame technologies.

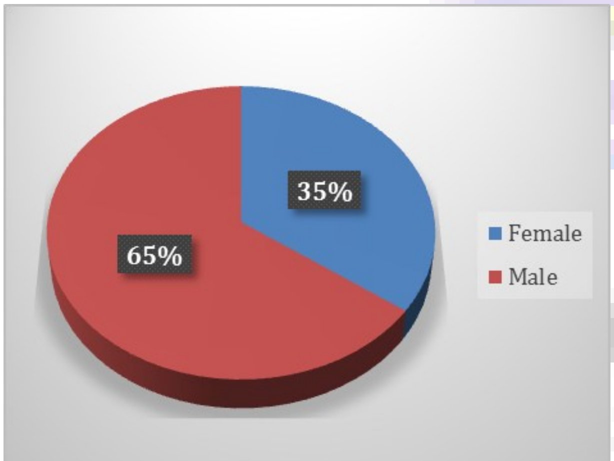


**Figure 1: Gender of respondents**

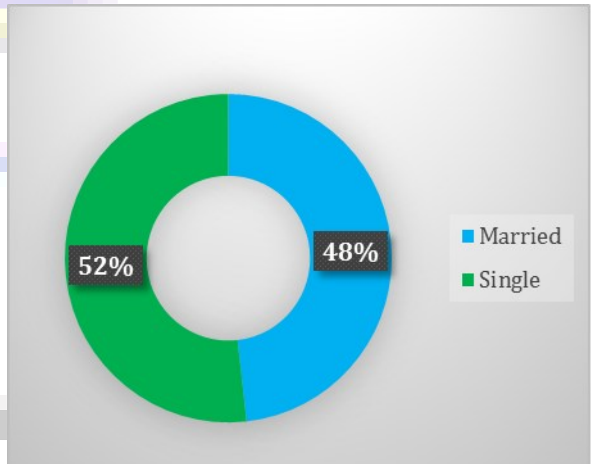


**Figure 2: Marital status of respondents**

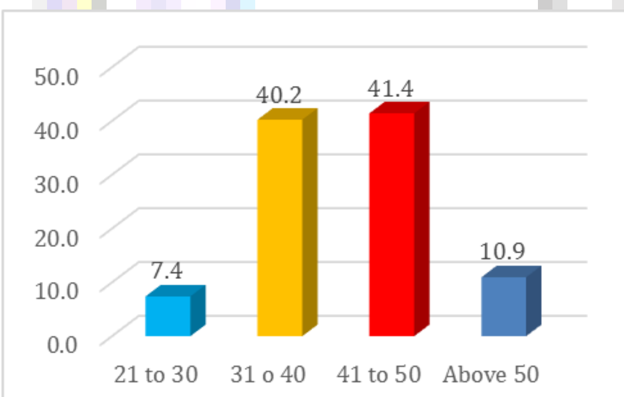


**Figure 3: Age of respondents**

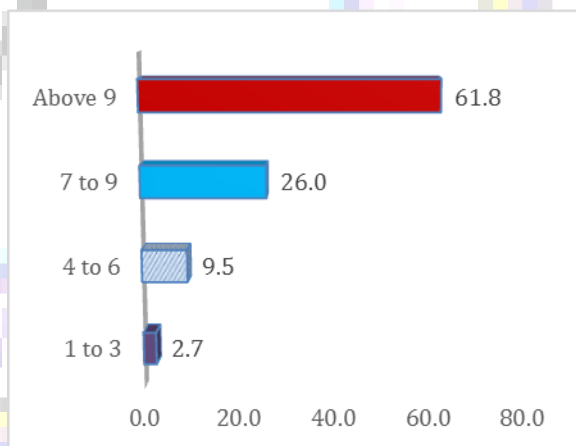


**Figure 4: Household size of respondents**

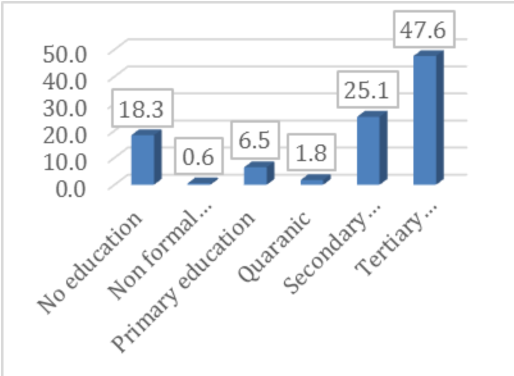


**Figure 5: Educational status of respondents**

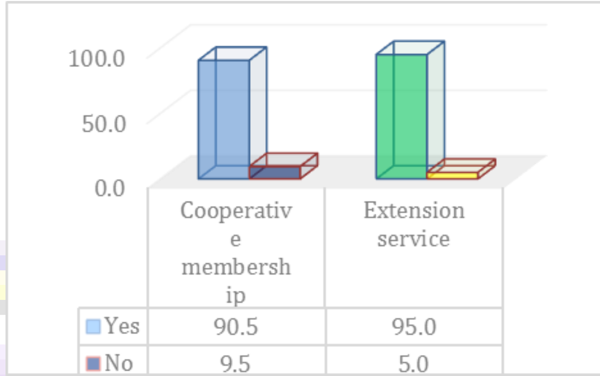


**Figure 6: Cooperative membership and access to Extension service**

**Type of Improved Sesame Production Technology**

Results in Table 2 present the distribution of respondents according to improved sesame production technology. The results reveal that 64.9% of the sesame farmers were aware of fertilizer application from first to third application. The awareness of different fertilizer applications indicates that farmers recognize the importance of fertilization in sesame production, suggesting that they understand the need for multiple applications to optimize yield. Other improved production technologies the farmers were aware of are harvesting (9.6%), weed control (4.6%), pest and disease control (4.6%), quality of seed (improved seed) and seed rate (seed rate of 2-4kg/ha). This indicates that farmers have some recognition of the importance of proper harvesting practices.

**Table 2: Distribution of respondents according to awareness about type of improved production technology**

| Improved production technologies | Frequency | Percentage |
|---|---|---|
| Soil type (soil PH should be between 5.5 – 7.8) | 30 | 2.5 |
| Quality of seed (improved seed) | 48 | 4.0 |
| Seed rate (seed rate of 2 -4kg/ha) | 51 | 4.2 |
| Sowing time | 51 | 4.2 |
| Fertilizer application (First application) | 242 | 20.0 |
| Fertilizer application (Second application) | 282 | 23.3 |
| Fertilizer application (Third application) | 261 | 21.6 |
| Thinning time | 15 | 1.2 |
| Weed control | 58 | 4.8 |
| Pest and disease control | 56 | 4.6 |
| Harvesting | 116 | 9.6 |
| **Total** | **1210*** | **100.0** |

Source: Field survey, 2024

* Multiple response

**Factors Influencing the Adoption of Improved Sesame Production Technologies**

The results from Table 3 revealed a pseudo R2 value of 0.6603 and prob chi2 of 0.0000 which signifies that the model is significant at a 1% level of significance, the result revealed that nine variables namely type of sesame seed, training on the use of the improved seed, gender, household size, size of farmland, income, cooperative membership, member of years of farming, and contact with extension agents were the factors that influence adoption of improve production technology. Type of sesame seed, gender, household size, income and cooperative membership were significant at 1% level, training on use of improved seed and extension contact were significant at 5% level, while years of farming and farm size were significant at 10% respectively.This implies that an increase in type of sesame seed, training on the use of improved seed, gender, years in farming, income, cooperative membership, contact with extension agent and size of farmland will lead to increase in the adoption of improved production technologies among sesame farmers while an increase in household size will lead to a reduction in the adoption level of improved production technologies. Type of sesame seed used and training received on improved production technologies were positively significant. This indicates that a unit increase in the type of sesame seed (hybrid seed) and the number of training on improved production technologies, holding other variables constant, will lead to an increase in the likelihood of adoption of improved production technologies by a unit. Farmers who used hybrid sesame seeds are more likely to adopt improved production technologies. Hybrid seeds are often designed to offer higher yields, better disease resistance, and adaptability to various environmental conditions compared to traditional seeds.

The use of hybrid seeds indicates a farmer's willingness to experiment with and invest in modern farming practices. Gender had a coefficient value of 1.446 and positively significant. This implies that as gender (more male) increases, the level of adoption of improved production technologies increases by 1.446%. It suggests that men in the study population may be more likely to have access to resources, such as land and capital, that enable them to adopt Improved production practices. Men may also be more likely to hold decision-making power in the household and be more willing to adopt new practices that are seen as innovative or experimental. Sennuga et al. (2020) stated that gender influenced the on adoption of improved technologies which is in line with this study. Income from farming activities and farm size were both positively significant. This implies that an increase in income from farming activities and farm size will lead to a proportionate increase in the adoption level of improved production technologies. Higher- income from farming activities significantly increases the likelihood of adopting improved production technologies. Farmers with better incomes are more capable of making investments in new technologies and can easily manage the risks associated with trying new methods. Also, Membership in a cooperative society significantly increases the likelihood of adopting improved sesame production technologies. Cooperatives often provide access to resources such as training, collective bargaining power, financial services, and shared equipment. Farmers in cooperative societies are more likely to adopt modern farming techniques due to collective knowledge sharing and pooled resources. Cooperative societies can also reduce the cost of adopting new technologies by providing access to subsidized inputs, machinery, and extension services. This creates an environment conducive for innovation and improved productivity in sesame farming. Contact with extension agents has a significant positive effect on the likelihood of adopting improved production technologies.

**Table 3: Logit regression on factors influencing the adoption of improved sesame production technologies**

| Variable | Coef. | Std. Error | t-value |
|---|---|---|---|
| Constant | -5.4184 | 1.8514 | -2.93 |
| Type of sesame seed | 1.4458 | 0.5286 | 2.74*** |
| Training received on improved seed | 2.4034 | 1.1079 | 2.17** |
| Gender | 1.6526 | 0.4942 | 3.34*** |
| Age | -0.0361 | 0.0270 | -1.34 |
| Years in farming | 0.0703 | 0.0381 | 1.85* |
| Marital status | 0.2959 | 0.4116 | 0.72 |
| Household size | -0.1700 | 0.0600 | -2.83*** |
| Educational status | 0.0073 | 0.0402 | 0.18 |
| Income from non-farming activities | 1.03e-06 | 2.51e-06 | 0.41 |
| Income from farming activities | 1.29e-5 | 3.00e-06 | 4.29*** |
| Cooperative membership | 1.5844 | 0.5930 | 2.67*** |
| Access to credit | -4.95e-06 | 4.37e-06 | -1.13 |
| Extension contacts | 1.2865 | 4.37e-06 | 2.55** |
| Size of farm land | 0.3623 | 0.1810 | 2.00** |
| LR chi2(14) | 149.67 *** | | |
| Pseudo $R^2$ | 0.6603 | | |
| Log likelihood | -87.7258 | | |

Source: Computer output, 2024.

***, ** and * implies statistically significant at 1%, 5% and 10%, Values in parentheses are t-values

**Effect of improved production practices.**

Table 4 presents the distribution of respondents according to the effect of improved production technologies. The results show that 84.0% of sesame farmers acknowledge that there was a change in production when they started using improved production technologies. The widespread acknowledgements of improved productivity indicate that these technologies are successful in addressing key constraints in traditional sesame farming.

27.7% of the sesame farmers stated that there was an increase in yield after the adoption of improved production technologies while 25.0% and 20.1% stated that there was an increase in the quality of sesame products and a reduction in pest attacks. Also, 59.5% of the sesame farmers recorded an increase in yield of between 6 – 10% with a mean yield increase of 256.78kg . The fact that 27.7% of farmers reported an increase in yield following the adoption of improved technologies suggests that the technologies introduced, such as improved seeds, proper fertilizer application, and optimized planting techniques, directly contribute to higher crop output.25.0% of farmers noticing an improvement in the quality of sesame products demonstrates that the adoption of these technologies not only increases the quantity of output but also enhances the quality of the sesame seeds.

**Table 4: Distribution of respondents according to effect of improved production technologies**

| Effect of improved production technology | Frequency | Percentage |
|---|---|---|
| **Change after usage of improved production technologies** | | |
| Yes | 284 | 84.0 |
| No | 54 | 16.0 |
| **Total** | **338** | **100.0** |
| **Changes from the use of improved production technologies** | | |
| Increase in yield | 102 | 27.7 |
| Increase in quality of sesame products | 92 | 25.0 |
| Reduction in pest attack | 74 | 20.1 |
| Reduction in pest attack | 54 | 14.7 |
| Reduction in the destruction of soil profile | 46 | 12.5 |
| **Total** | **368*** | **100.0** |
| **Yield after adoption of improved production technology (Kg)** | | |
| 0.1 – 100.0 | 24 | 7.1 |
| 100.1 – 200.0 | 52 | 15.4 |
| 200.1 – 300.0 | 201 | 59.5 |
| 300.1 – 400.0 | 26 | 7.7 |
| 400.1 – 500.0 | 9 | 2.7 |
| Above 500 | 26 | 7.7 |
| Mean yield | 256.78 | |
| **Total** | **338** | **100.0** |

Source: Field survey, 2024
* Multiple responses

## CONCLUSION AND RECOMMENDATION

The study examined the factors affecting the adoption of improved sesame production technologies by smallholder farmers in Lapai and Agaie LGA. The study concluded that the farmers were aware of various improved sesame production technologies which resulted in adoption of some of the technologies. The increase in use of improved seed, farming experience, income, cooperative membership and access to extension services will result to increase in adoption of improved production technologies. It is therefore recommended that financial institutions should provide access to loans for farmers with flexible repayment plans and Government agencies should access affordable machinery for farmers as well as support in purchasing farm inputs at subsidized rate.

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# ECONOMIC ANALYSIS OF SWEET POTATO (*Ipomoea batatas*) PRODUCTION IN KEFFI LOCAL GOVERNMENT AREA, NASARAWA STATE, NIGERIA

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## ABSTRACT
The study was about economic analysis of sweet potato (Ipomoea batatas) production in Keffi Local Government Area of Nasarawa State, Nigeria. Primary data which were used for the study were generated by interviewing one hundred sweet potato farmers with a structured questionnaire. The data were analysed with the use of descriptive statistics, Cobb-Douglas production function and enterprise budgeting technique. Results indicate that most of the farmers were male (91 percent), married (76.00 percent), farmed on inherited lands (91 percent) and did not enjoy extension services (99.00 percent). Planting materials (0.103), labour (0.209), herbicides (0.022) and fertilizers (0.031) significantly influenced output of sweet potato. Sweet potato production was profitable with earning per naira of 4.94. Based on the findings, it was recommended that land tenure system be modified to make land available to would-be farmers who have no ancestral farmland, credit facilities be made available for our teeming unemployed youths to enter sweet potato farming and farm inputs like herbicides and fertilizer be provided at cheap prices among others.
**Keywords**: Sweet potato, economic analysis, production

## INTRODUCTION
Sweet potato *(Ipomoea batatas*) is an important tropical root crop. It belongs to the morning glory family known as *convolulaceae* and it originated from Latin America (Ezeano, 2006). It is native to the tropical regions in America (Tewe *et al.*, 2003). The plant is an herbaceous perennial vine bearing alternate heart-shaped or palmate lobed leaves and medium sized sympetalous flowers. The edible tuberous root is always long and tapered with smooth skin whose colour ranges from yellow, orange, red, brown, and purple. Sweet potatoes are grown in all parts of Nigeria from the tropical rain forest to semi-arid and arid zones. Planting begins at the onset of rainy season and continues until two months before rain stops. The crop may be planted on mounds, ridges, beds or flatland. The crop performs best on mounds and poorest on flatland (Gad and George, 2009). Vines are the planting materials. Harvesting entails cutting off The study was about economic analysis of sweet potato (*Ipomoea batatas*) production in Keffi Local Government Area of Nasarawa State, Nigeria. Primary data which were used for the study were generated by interviewing one hundred sweet potato farmers with a structured questionnaire. The data were analysed with the use of descriptive statistics, Cobb-Douglas production function and enterprise budgeting technique. Results indicate that most of the farmers were male (91 %), married (76 %), farmed on inherited lands (91%) and did not enjoy extension services (99%). The study further revealed that planting materials, labour, herbicides and fertilizers with regression coefficient of 0.103, 0.209, 0.022 and 0.031 respectively significantly

influenced output of sweet potato. Sweet potato production was profitable with earning per naira of 4.94. Based on the findings, it was recommended that land tenure system be modified to make land available to would-be farmers who have no ancestral farmland, credit facilities be made available for our teeming unemployed youths to enhance sweet potato farming and farm inputs acquisition like herbicides and fertilizer be provided at cheap prices among others.

The vines and digging out the root tubers using hoes or forked shovel while avoiding bruising the root tubers. Sweet potato has a long history of food security crop in Nigeria as a result of which it has received attention from the Government warranting its inclusion among the crops for the national special programme on food security. It is capable of meeting the consumption need of households as well as generating income for the households to enable them buy other food crops (Tewe *et al.,* 2003). If sweet potatoes are well managed, it has the potential to secure households food wise and alleviate them from poverty. It is as a result of the numerous benefits derivable from production of the crop that prompted this research. The specific objectives of this study were to describe the socioeconomic characteristics of the farmers; estimate profit of sweet potato production and determine input-output relationship in sweet potato production.

## METHODOLOGY

**Study Area**:

Keffi Local Government Area (LGA) is located along Akwanga Abuja road in Nasarawa stat., It shares boundaries with Kaduna state to the North, Karshi development Area to the south, as well as Karu catchment zones to the west. With latitude 6; 53°5' and 80 5' and latitudes Y'25 'and 803' with a tropical climate, mean rainfall lasting from early April to October, and dry season often accompanied by high temperature with occasional hamattan wind in October ending to march. The LGA has a total land area of 3500km$^2$. The Keffi Local Government is made up of 5 district. The major ethnic groups of Keffi Local Government Hausa being the majority, Eggon Gwardara, Fulani, to mention but few. It has an estimated population of 735,000 (NPC, 2006). people. The main occupation of the inhabitants of the study area is farming, hunting, palm wine tapping and trading, only a small number of the population are civil servants. Food crops grown include rice, yam, cassava, groundnut guinea corn, maize, white tree crops grown include orange, mangoes, guavas, palm trees. Vegetables like tomatoes, spinach, pepper, Onions "Ayoyo" Okro, garden egg. The Temperature changes with time and extremely hot during the rainy season, with temperature ranging from 27°c to 29°c, while during the winter season the temperature ranges from 17.0°c to 20.0°c. The rainfall in Keffi is seasonal and the amount varies from time to time. In the months of July, August and September, the amount of rainfall experienced is high with relative value of 450mm-550mm, resulting to increase in the volume of water in keffi canals (river) .

**Sampling Techniques and Sample Size**

Multistage sampling techniques was adopted for the study. In the first stage, five districts out of the thirteen districts that make up the Local Government Area were purposely selected based on the high concentration of sweet potatoes farmers. In the second stage, two villages/settlements were randomly selected from each settlements making a total of ten settlements. In the third stage, ten sweet potato farmers were also randomly selected from each village making a total of one hundred farmers. Production records were obtained from these one hundred farmers and used for the study.

**Methods of data Collection**
Instrument for data collection was a structured questionnaire administered to the farmers with the help of extension agents. The data collected were on the socioeconomic characteristics of the farmers such as age, marital status, education, farm size, extension visit and so on. Information was also collected on inputs such as planting materials, labour, fertilizers, herbicides and their prices.

**Analytical Techniques:** The data were analysed with the use of descriptive statistics such as frequency distribution, mean and percentages.
Profitability of sweet potato production was estimated by using farm budgeting technique in the tradition of (Kay *et al.,* 2012). The equation for farm budget used was NFP = TR – TC where; NFP = Net Farm Profit; TR = Total Revenue and TC = Total Cost. Total revenue was made up of the income realised from the sale of sweet potato tubers. Total cost consisted of payments to variable inputs like planting materials (vines), labour, fertilizers, herbicides and depreciation of fixed farm equipment like hoes, cutlasses, sacks and wheel barrows
Cobb-Douglas functional form was used to estimate the relationship between inputs and output. The explicit form of the Cobb-Douglas production function was stated as follows:
$\text{Log } Y = \ln a + b_1 \ln x_1 + b \ln x_2 + b_2 \ln x_2 + b_3 \ln x_3 + b_4 \ln x_4 + e_1$ where;
$Y$ = Output of sweet potato tubers in kg
$X_1$ = Planting materials/vines in kg
$X_2$ = Labour in man days
$X_3$ = Herbicides in litres
$X_4$ = Fertilizers (kg)
$e_i$ = error term
$a$ = Constant/intercept
$b_1 - b_4$ = estimated coefficients

**RESULTS AND DISCUSSION**
The results of the socioeconomic characteristics of the sweet potato farmers are presented in Table1.

**Age distribution of the respondents:** From Table 1, 85 percent of the farmers were between the ages of 21 and 50 years while 15 percent of them were 51 – 60 years old. This information revealed that, the mean age of the sweet potato farmers was 40 years and implying that they are were young and energetic and may be capable of meeting the production needs of sweet potato production. This could result in high output of sweet potatoes which can bring about food security. In a similar study by (Amao and Ayantoye, 2017), young farmers were found to be more energetic to cope with the drudgery of farming in northern Nigeria.

**Distribution of the respondents based on sex:** The sex distribution of the respondents presented in table 1 shows that 91 percent of them were male while only 9 percent of them were female that cultivated sweet potato. Sweet potato farming requires high input of energy for land clearing, cultivation of heap/mounds and ridges. Men possess more of the energy required for these tedious tasks hence the high population of men. This is in accordance with (Van der veen and Tagel, 2021) who opined that men were better able to provide sufficient work force for farm operations.
**Marital status:** As shown in table 1, 76 percent of the respondents were married, 13 percent were single while 11 percent were divorced. Marriage brings about procreation which increases the number of mouths to feed. Therefore, married couples plant crops to put food on their tables.

(Sani *et al*., 2015) in a similar study opined that marriage had tendency to help build a virile farming population.

**Education level:** Distribution of the respondents based on the education they acquired is shown in Table 1 where 30 percent of them acquired primary school education; 60 percent went to secondary school and 2 percent went beyond secondary school. Only 8 percent of them did not go to School. Education is very important in making farmers adopt innovation. The high number of educated people in farming signals their high potentials to adopt and practice innovations. According to (Babatunde *et al.*, 2017), education is a social capital which can help families make wise decisions on food production and nutrition.

**Farming experience:** The farmers had their farming experience distributed as shown in Table 1 with 82 percent of them having experience of 12 – 21 years while 18 percent of them had experience of 2 – 11 years, and the mean farming experience was estimated and 6.5 years. Experience is very important in doing everything because carrying on a task repeatedly increases perfection. The more the years of farming experience of a farmer, the more the management ability of the farmer. This is in agreement with (Nwaru *et al*., 2006) who reported in their study that the number of years a farmer has spent in his farming business may give an indication of the practical knowledge he has acquired on how to cope with the inherent production, processing and marketing problems.

**Extension visit:** The distribution of the respondents according to extension visit is shown in Table 1. Most of the respondents (99 percent) had no extension visit while only one percent of the respondents had extension visit. This is an indication that there were no extension activities in the area. Under that situation, farmers could not get new technologies to apply on their farms. Extension is very important in farming because extension agents teach farmers new farming techniques to improve their farms and income. In a similar study, (Girei *et al*., 2017) found that extension service delivery in Nigeria was generally weak characterised by low ratio of extension staff to farmers. Extension services are poor due to insecurity, poor logistics and low motivation of extension personnel.

**Methods of acquisition of farmlands:** The distribution of the respondents on their methods of acquiring their farmlands is shown in Table 1. Majority of them (91 percent) farmed on inherited land while only 9 percent of them farmed on gifted land. This shows a strong land tenure system in the area. This arrangement could be impediment to mechanization because it means scattered plots of farmland but it can facilitate land improvement because permanent ownership of land encourages owners to apply improvement measures on such land. In a similar study, (Ibitoye, 2010) reported that majority of farmers in Yagba area of Kogi state acquired their farm lands through inheritance.

**Sources of capital:** The distribution of the respondents on sources of finance for their farms is shown in Table 1. Most of them (85 percent) used personal savings; 15 percent of them got loan from friends while only 5 percent of them got fund from local cooperatives. Credit is a catalyst in agricultural production because it is used in buying innovations. Most of these farmers were tied to the use of their savings hence they could not operate on large scale. According to (Aksoy, 2019), farm loans benefit farmers in a number of ways by enabling them to purchase or extend their land, construct new or upgrade farm building, lease a tractor and other equipment, pay bills and engage in agricultural technologies like soil and water conservation among other things.

**Table 1: Socioeconomic characteristics of the respondents**

| Socioeconomic items | Frequency | Percentage | Mean |
|---|---|---|---|
| **Age** | | | |
| 21 – 30 | 15 | 15.0 | |
| 31 – 40 | 40 | 40.0 | |
| 41 – 50 | 30 | 30.0 | 40 years |
| 51 – 60 | 15 | 15.0 | |
| Totals | 100 | 100 | |
| **Sex** | | | |
| Male | 91 | 91.0 | |
| Female | 9 | 9.0 | |
| Totals | 100 | 100. | |
| **Marital Status** | | | |
| Married | 76 | 76.0 | |
| Single | 13 | 13.0 | |
| Divorce | 11 | 11.0 | |
| Totals | 100 | 100 | |
| **Education** | | | |
| No formal education | 8 | 8.0 | |
| Primary School | 30 | 30.0 | |
| Secondary School | 60 | 60.0 | |
| Tertiary School | 2 | 2.0 | |
| Totals | 100 | 100 | |
| **Farming Experience (Years)** | | | |
| 2 – 11 | 18 | 18.00 | 6.5 years |
| 12 – 21 | 82 | 82.00 | |
| Totals | 100 | 100.00 | |
| **Extension visit** | | | |
| No visit | 99 | 99.0 | |
| Some visits | 1 | 1.0 | |
| Totals | 100 | 100 | |
| **Methods of acquisition of farmlands** | | | |
| Inheritance | 91 | 91.0 | |
| Gift | 9 | 9.0 | |
| Total | 100 | 100 | |
| **Source of Capital** | | | |
| Personal savings | 80 | 80.0 | |
| Cooperative loans | 5 | 5.0 | |
| Friends | 15 | 15.0 | |
| Totals | 100 | 100 | |

Source: Field survey, 2023

**Profitability of sweet potato production**

Costs and return of producing sweet potato on one hectare of land is presented in Table 2. The total revenue generated from the farm was ₦1, 560,000.00, while the total cost incurred to bring out the revenue was ₦315, 750. This amount comprised of total variable cost (₦295,250) and total fixed cost (₦20,500). Therefore, the computed gross margin (GM) was ₦1,264, 750 while the Net Farm Income (NFI) was estimated at N1,244,250. The generated profit was from the subtraction of total cost from the total revenue (TR - TC) and this translated to ₦1,244,250. From the computations, the return on investment (ROI) was ₦4.94, and this implies that for every naira invested, the farmer gets a return of ₦3.94. This further confirms that sweet potatoes production is a profitable business and could serve as an employment opportunity for the small scale farmers in the study area. So also as a source of income generation, poverty reduction, and sustainable food security approach. As can be seen, planting materials and labour constituted major part of cost of producing sweet potato in the area. The cost of planting material was 40.22 percent of the variable cost(VC) and 37.61 percent of the total cost (TC). While the cost of labour was estimated at 38.11 percent of the variable cost (VC) and 35.64 percent of the total cost (TC). In many previous studies, labour has been found to occupy a significant proportion of total cost of production in the farms. In a similar study, (Onuk *et al*., 2020) found that labour and planting material (seeds) occupied a big proportion of total cost of production. Sweet potato production was profitable. Earning per naira investment was ₦4.94 meaning that for every one naira invested in sweet potato production would bring ₦3.94. This is a lucrative business for the teeming unemployed youths. Youths should be empowered to go into its production because one needs relatively small capital to start the farming business.

Table 2: Costs and return of one hectare of sweet potato farm.

| **Item** | **Amount (₦)** | **% in cost class** | **% of total cost** |
|---|---|---|---|
| a).Total Revenue (TR) | 120 x 13,000 = 1,560,000 | | |
| b). Variable Cost (VC) | | | |
| Planting materials | 50 bags @2,375 50 = 118, 750 | 40.22 | 37.61 |
| Labour for planting | 10 manday@2,500 x 10 = 25,000 | 8.47 | 7.92 |
| Labour for weeding | 15 mandays@2,500 x 15 = 37,500 | 12.71 | 11.88 |
| Labour for harvesting | 20 mandays@3,500 x 20 = 50,000 | 16.93 | 15.84 |
| Costs of fertilizers (4 bags) | 4 bags of fertilizers@14,000 x 4 =42,000 | 14.23 | 13.30 |
| Cost of herbicides (4 liters) | 4 Liters@5,500 x 4 = 22,000 | 7.45 | 6.97 |
| | | **100** | |
| **Total Variable Cost (TVC)** | **295, 250** | | |
| **Gross margin (GM) (TR-TVC)** | **1,264,750** | | |
| Fixed cost (TFC) | | | |
| Depreciation on Fixed Inputs | 20,500 | | 4.97 |
| **Total Fixed Cost (TFC)** | **20,500** | | **100** |
| **Total Cost** | **315,750** | | |
| NFI = GM-FC | 1,244,250 | | |
| ROI | 4,94 | | |

Source: Field survey, 2023

**Influence of inputs on the output of sweet potato**

Table 2 shows the results of the estimate of Cobb-Douglas production function on the effects of inputs used in producing sweet potato on the output. The coefficient of multiple determination ($R^2$) was 0.760 meaning that the variables included in the model explained 76 percent of the variation in the output of sweet potato. F – Statistics was 41.290 and it was significant at 1 percent probability level. This shows that the model is a good fit and the variables are significant determinant of the output of sweet potato. The inputs included in the model had positive relationship with the output of sweet potato. Planting materials (vines) had coefficient of 0.103 and it was significant at 5 percent probability level. Labour and herbicides had coefficient of 0.029 and 0.022 respectively and each was significant at 5 percent probability level. Fertilizers had a coefficient of 0.031 and it was significant at one percent probability level. A unit increase in any of the inputs will increase the output of sweet potato all things being equal. These findings were in conformity with the findings of (Oyewo, 2011) and Shehu *et al*., 2017 who found positive relationship between seeds, fertilizers and labour and outputs in their studies.

Table 3: Estimate of Cobb-Douglas production function on the effects of input on the output of sweet potato.

| **Variables** | **Coefficient** | **Stand error** | **T=ratio** |
|---|---|---|---|
| Constant | 12.462 | 0.230 | 54.182 |
| Planting Materials | 0.103 | 0.050 | 2.060 ** |
| Labour | 0.209 | 0.014 | 2.071 ** |
| Herbicide | 0.022 | 0.011 | 2.00 ** |
| Fertilizers | 0.031 | 0.009 | 3.444 * |
| **F = 41.290** | | | |
| **$R^2$= 0.76** | | | |

Source: Field survey, 2023 ** = Significant at 5% * = Significant at 1 percent

**CONCLUSION**

Despite Sweet potato production been a profitable business in the study area, the study revealed that was produced mainly on inherited land in the area mainly with personal savings. The inputs such as planting materials, labour, fertilizers, and herbicides exercised positive relationship with output of sweet potato. Some of the problems encounterd by the farmers includes; inadequate farm lands, weak capital in adequate agricultural inputs, and weak extension contacts.

**RECOMMENDATIONS**

1. There should be a deliberate effort by relevant stakeholders comprising of governments at all levels, farmers, community's leaders to rework the land tenure arrangements to free lands to those that cannot lay hands on ancestral lands.
2. Credit facilities should be made available timely and at reasonable cost by financial institutions, money lenders, and in addition to the farmers' cooperatives for on-lending between and among the farmers especially to our teeming unemployed graduates to engage in sweet potato production since it is very profitable business.
3. Relevant production inputs, such as fertilizers and herbicides be made available at cheap prices so that farmers can use them to scale up their production.

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# SYSTEMATIC REVIEW ON AWARENESS ABOUT UTILIZATION OF *Moringa oleifera* SEEDS POWDER AS A NATURAL COAGULANT FOR WATER PURIFICATION AMONG RURAL COMMUNITIES OF NIGER STATE, NIGERIA

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**ABSTRACT**
This systematic review investigates the awareness and utilization of *Moringa oleifera* seed powder as a natural coagulant for water purification in rural communities of Niger State, Nigeria. Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, studies published between 2010 and 2024 were analyzed to assess usage levels, influencing factors, and barriers to adoption. A comprehensive search across databases, including PubMed, Scopus, and local Nigerian repositories, revealed low awareness, with only 18–22% of households familiar with Moringa's water purification benefits. . Educational interventions, such as workshops and training programs, increased adoption rates by up to 40% in some communities. Seasonal factors, particularly increased water turbidity during the dry season, also influenced utilization. Key barriers included limited awareness, logistical challenges, cultural practices, and gender roles. Recommendations include implementing seasonal awareness campaigns, simplifying usage methods, and ensuring a reliable seed supply to increase adoption rates in rural areas.
**KEYWORDS: Awareness; Utilization; *Moringa Oleifera*; Water Purification, Rural Communities**

## INTRODUCTION

Water is an essential resource vital to all living organisms, with drinking water quality being crucial for human health (Abdullahi and Suleiman, 2021). Contaminated water is a significant public health concern, especially in developing regions (Tunggolou and Payus, 2017). According to the World Health Organization (WHO), up to 80% of diseases globally are linked to inadequate sanitation and polluted water. Unsafe water sources such as streams, rivers, and lakes are often the primary supply for rural households, leading to high incidences of waterborne diseases, including diarrhea, which causes over one million deaths annually, particularly among children (Rohan *et al*., 2017).

To mitigate these risks, water must undergo purification to meet safety standards such as being clear, odorless, tasteless, and pathogen-free (WHO, 2021). However, traditional purification methods are often ineffective, while modern technologies are either unaffordable or unsustainable for rural communities. This gap highlights the potential of natural coagulants like *Moringa oleifera* seed powder, a locally available, affordable, and eco-friendly solution. Unlike synthetic coagulants, which are associated with health risks like Alzheimer's disease (Adebayo *et al*., 2021), natural coagulants are generally safer and more accessible.

*Moringa oleifera* is a versatile plant known for its nutritional, medicinal, and environmental benefits. Its seeds have shown promise as an effective natural coagulant, capable of improving water quality and reducing turbidity. From existing reports, there were allegations that the powder of *Moringa oleifera* seeds has antimicrobial properties and act as an agent against microorganisms which are present in drinking water and decrease the number of bacteria (Mangale *et al*., 2012). Many researchers have reported *Moringa oleifera* to be non-toxic and recommended for use as a coagulant in developing countries (Abdullahi and Suleiman, 2021). According to Hegazy *et al*., (2011), the seeds show similar effects as alum and less effective in low turbidity water. The seeds contain proteins which are essential in anti-oxidants properties and water purification. It has the capability to remediate water pollution & numerous arrays of illnesses (Amagloh and Benang, 2019). Therefore, it is not difficult to use the seeds as a natural coagulant because the use of natural coagulants in the water treatment process is expected to provide more advantages than the use of synthetic materials as they are natural and reported safe to be consumed (Hendrawati *et al*., 2016).

Despite its proven benefits and availability, awareness and utilization of Moringa oleifera seeds powder for water purification remain limited in rural communities (Amagloh and Benang, 2019). Factors such as cultural practices, logistical challenges, and lack of education contribute to its underutilization, leaving many vulnerable to waterborne diseases.

## RESEARCH METHODOLOGY

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive search was conducted across multiple databases, including PubMed, Scopus, Google Scholar, and Nigerian research repositories, for peer-reviewed articles, reports, and conference papers published between 2010 and 2024. Keywords such as *Moringa oleifera*, *natural coagulant*, *water purification*, *rural communities*, and *Nigeria* were employed to identify relevant studies.

The inclusion criteria required studies to specifically address the utilization of *Moringa oleifera* seed powder for water purification in rural contexts, with a focus on awareness, usage extent, and influencing factors. Studies conducted outside Nigeria or that did not provide data on rural communities were excluded. Additionally, grey literature, such as government and NGO reports, was reviewed to capture non-academic perspectives.

Data extraction identified themes such as levels of awareness, usage patterns, and barriers to adoption. A quality assessment tool evaluated the reliability of included studies. Both qualitative and quantitative data were synthesized to offer a comprehensive understanding of *Moringa oleifera*'s utilization as a natural coalant.

### Review of related studies

*Moringa oleifera* seed powder has been extensively studied for its potential as a natural coagulant for water purification, especially in rural areas with limited access to clean water. Bichi and Anyata (2019) assessed the awareness and usage of *Moringa oleifera* seed powder for water purification among rural communities in Nigeria. They found that awareness was relatively low, with only 30% of surveyed households familiar with its coagulant properties.

However, among those aware, usage was reported in 60% of households due to its affordability and accessibility, particularly in areas where alternative purification methods were not readily available. Eilert *et al.*, (2022) expanded on this finding revealing that targeted awareness campaigns significantly increased the use of *Moringa oleifera*. In communities where training programs were implemented, awareness reached 70% within three years and a majority of households adopted the seeds as a primary water treatment option due to their effectiveness in reducing turbidity and bacterial contamination.

Muyibi and Evison (2018) reported that communities with access to agricultural extension services and local cooperatives showed higher rates of *Moringa* seed powder utilization. These households reported improved water clarity and reduced health issues associated with waterborne diseases. Their findings emphasized that education and training on the application process were critical for widespread adoption. Fuglie (2021) showed the multifunctional benefits of *Moringa oleifera*, which encouraged its usage beyond water purification. Rural households increasingly utilized *Moringa* seeds for medicinal and nutritional purposes, which also indirectly promoted its adoption for purifying drinking water. Lea (2020) found that cultural familiarity with *Moringa* influenced its usage for water purification. In communities where *Moringa* was traditionally used for food or as herbal medicine, adoption rates were significantly higher. However, a lack of formal education limited awareness in other areas, as some households were unaware of its potential despite the plant's local availability.

Ali *et al.*, (2020) observed that women played a pivotal role in the adoption of *Moringa oleifera* seed powder. Women responsible for household water management were more likely to adopt the technology after being trained in its preparation and usage. Communities with active women's groups or gender-focused extension programs reported higher utilization rates. Ghebremichael *et al.*, (2021) studied seasonal patterns of *Moringa* seed powder usage. They found that utilization was highest during the dry season when water sources were more turbid. In these periods, households that consistently used *Moringa* reported fewer cases of diarrhoea and other waterborne diseases, highlighting its health benefits.

**Factors Influencing Extent of Utilization**

Several studies had examined the factors influencing the extent of utilization of *Moringa oleifera*

seeds powder as a natural coagulant for water purification in rural communities across Nigeria. Zarma (2021) examined factors influencing the utilization of *Moringa oleifera* seed powder as a coagulant in Nigeria. Their study found that the primary factors influencing usage were awareness and education. Only 30% of rural households were aware of *Moringa*'s water purification properties, and of those, 60% actively used the seeds. They noted that factors such as affordability, availability, and the lack of alternative water purification methods contributed to the continued use of *Moringa*. Eilert *et al*. (2022) found that *Moringa* seed powder's utilization was greatly influenced by community awareness programs and extension services. Their study added that villages where training programs were implemented experienced a 70% increase in awareness, which directly contributed to a higher uptake of the coagulant. Muyibi and Evison (2015) assessed the role of resource availability in determining the extent of *Moringa* seed powder usage. The study found that *Moringa* was predominantly used in rural communities where the plant was abundant and easily accessible. The study also noted that households with limited access to other water treatment methods, such as chlorine or filtration devices, relied heavily on *Moringa* for purification.

Mohammed *et al.*, (2021) reported that low-income households preferred the seeds as an alternative to expensive chemical coagulants. Their study showed that households using *Moringa* seeds reduced their water treatment costs by 60%, making it an attractive option for economically disadvantaged communities. Similarly, Bello *et al.*, (2020) found that the cost savings associated with *Moringa oleifera* drove its adoption, especially in rural areas with limited access to commercial water purification systems. Akintunde *et al.*, (2021) found that younger individuals were more likely to experiment with innovative solutions like *Moringa* seeds, whereas older individuals were more inclined to stick to traditional water purification methods. Chukwuma *et al.*, (2021) added that inconsistent supply chains and limited market availability hindered the widespread adoption of *Moringa* in certain regions. Their study revealed that communities with established *Moringa* plantations and local markets had higher utilization rates compared to areas where seeds were scarce. Yahaya *et al*., (2018), Educational level was a strong predictor of utilization, with better-educated households more likely to adopt *Moringa* as a water purifier. Their study emphasized on Education campaigns targeting less-educated populations are necessary. Seasonal water scarcity heightened the use of *Moringa oleifera*, but usage declined in wetter seasons when alternatives were available (Akinola *et al*., 2021). Thus, Seasonal campaigns may help maintain consistent utilization.
Furthermore, transportation costs and distance to markets also impacted access. Ogundele and Fagbenro (2020) suggested that establishing community seed banks can significantly contribute to utilization of the seeds powder in rural communities hence increasing the rate of awareness and utilization.

**DISCUSSION OF FINDINGS**

The extent of *Moringa oleifera* seed powder utilization for water purification in rural Nigeria primarily influenced by awareness, education, and seasonal factors. Most studies found low awareness levels, with only 18%-22% of households aware of its potential as a natural coagulant (Yahaya *et al*., 2018; Ibrahim *et al.,* 2020). Traditional water purification methods remain dominant due to cultural resistance and limited awareness (Bello *et al*., 2021).

Educational interventions significantly improve adoption. For instance, Adewale *et al*., (2019) observed a 40% increase in utilization in communities receiving training programs. Seasonal factors also influence usage, with higher adoption during water scarcity periods (Mohammed *et al*., 2020). Barriers to widespread adoption include logistical challenges, such as weak supply chains and limited seed availability (Onwuliri *et al*., 2020), and cultural resistance to non-traditional methods. Simplified preparation methods and pre-packaged products could address these barriers. Moreover, targeting women, who play a central role in household water management, and community leaders through tailored education campaigns, is vital for increasing utilization. Sustained NGO involvement and strengthening local supply chains are crucial to overcoming these barriers and ensuring the consistent use of *Moringa oleifera* as a natural coagulant.

## CONCLUSION AND RECOMMENDATIONS

The utilization of *Moringa oleifera* seed powder for water purification in rural Niger State remains limited due to low awareness, cultural resistance, and logistical challenges. However, evidence from this review highlights the potential of educational campaigns, community-targeted training, and improved supply chains to significantly enhance adoption rates. To address these barriers, it is recommended that local governments and NGOs collaborate to implement sustained awareness programs, simplify usage methods, and strengthen distribution networks in rural areas.

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# SYSTEMATIC REVIEW OF EFFECTS OF FUEL SUBSIDY REMOVAL ON SOCIAL WELL–BEING OF RURAL FARMING HOUSEHOLDS IN NIGER STATE, NIGERIA

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## ABSTRACT

The systematic review examined the effects of fuel subsidy removal on the social well-being of rural farming households in Niger State, Nigeria with specific objectives to: examine the knowledge level of the rural farming households about fuel subsidy, their perception about fuel subsidy removal and effects of fuel subsidy removal on their social well-being of the rural households. The study utilized a comprehensive literature search spanning 1998–2024 which the articles retrieved were subjected to inclusion and exclusion process of data extraction. At the end about 62 articles that are directed relevant to the topic was used in the review process. Therefore, fuel subsidy removal was agreed to have significant effects on the well-being of rural farming households.
**Keywords:** Fuel Subsidy, Removal, Effects, Social Well-being, Rural Households

## INTRODUCTION

Subsidy is a benefit derived by an individual, business, or institution, usually by the government which could be direct (such as cash payments) or indirect (such as tax breaks) (Ikenga and Oluka, 2023). It is a financial aid or economic advantage that the government offers to promote a desired activity in order to maintain low prices, sustain the income of vital or strategic product producers, sustain employment levels, or encourage investment to lower unemployment (Ikenga and Oluka, 2023). It can also be broadly described as any government initiatives that have the potential to enable a business to generate higher profits than it otherwise would have in the absence of the initiative. The subsidy can take the form of direct price controls, tax exemptions or grants. In essence, it means putting money back into the hands of the producer or the customer. The provision of industrial input requirements in the form of supportive frameworks, regulations, research and development is more indicative of the indirect form of subsidy.

Meanwhile, fuel subsidy refers to the practice of the government covering a portion of the cost that consumers of petroleum products should pay in order to reduce the price burden (Centre for Public Policy Alternatives (CPPA), 2012). According to Ezeh (2012), fuel in Nigeria is an inelastic product both at demand and supply sides, which means that it is very difficult for consumers to find alternatives to the use of it in their daily lives. Alternatives to fuel such as electric trains, solar heaters and cookers are non-existent in Nigeria, while hydropower and dams are not dependable sources of power in Nigeria. To lower the cost of petroleum products such Premium Motor Spirit (PMS), Automotive Gas Oil (AGO/Diesel), and Dual Purpose Kerosene (DPK/Kerosene), as well as shield the populace from the volatility of crude oil prices on the global market; oil-producing nations Venezuela, Iran, Saudi Arabia, Egypt, Burma, Malaysia, Kuwait, China, Taiwan, South Korea, Trinidad and Tobago, Brunei and Nigeria, as well as several non-oil-producing nations like Chad, Cameroon and (Niger) among other countries subsidies on fuel (CPPA, 2012).

Fuel subsidies which is a policy for keeping consumer prices for goods or services below market rates was initially implemented during the military era to alleviate the burden on the masses. However, over time, these subsidies became unsustainable, leading to issues like corruption, smuggling and fiscal constraints (Omoniji, 2012). The abrupt announcement of the end of fuel subsidies in 2012 in Nigeria highlight the need for a shift in economic policies, aiming to redirect funds towards other sectors for sustained development (Onanuga, 2012). However, the removal of subsidies is a sensitive issue, often sparking societal unrest and economic instability (Sheeran, 2015). Nigeria's aim to eliminate subsidies must be carefully assessed, considering its potential impacts on the economy and society.

Social well-being on the other hand, according to Keyes (1998), refers to this construct as positive social health or wellness, which is conceived as mainly representing public phenomena. From this standpoint, well-being is focused on social duties adults face in their lives and how they balance individual and social worlds (Cicognani *et al.,* 2014). Social well-being (Keyes, 1998) comprises five indicators of the presence of and extent to which an individual is facing social challenges and navigating their social reality, We know humans are social beings, yet, when thinking about well-being, we think more about our *individual* well-being, in terms of how good we feel, how satisfied we are with our lives, and how well we are functioning in different areas. We might think about positive relationships as a part of functioning well. However, there is more to social well-being than that. It is not only our social interactions, but also our relationships with our communities and social structures that constitute a key and distinct domain of well-being.

## REVIEW METHODOLOGY

The methodology employed for this study involved a systematic literature search aimed at shortlisting empirical studies focusing on the effects of fuel subsidy removal on the social well -being of rural farming households in Niger State, Nigeria. The search process included several steps and utilized various search engines and databases. The empirical studies published is between 1998 to 2024, were considered. These keywords ‘effects’, ‘fuel subsidy’, ‘fuel subsidy removal’, ‘social well-being’ were used to retrieve relevant literature published within the specified timeframe. The search findings were based on the relevance of title and abstract to the study’s objectives. The studies published in peer -reviewed journals, conference, paper and proceedings were considered useful for inclusion, The criteria for the selection of papers include researches that aimed at the effects of subsidy removal. From the initial 230 papers, 104 were identified for further examination and comparison with results from other search engines and relevant websites to check for duplication and omission. After reviewing the abstracts, 42 out of the 104 papers were deemed unrelated to the study theme and were excluded. The remaining 62 papers were selected for in-depth examination and analysis. Following the selection of relevant papers, data extraction was done by the researchers and supervisors to ensure accuracy and reliability of the data. The data extracted were synthesized for identifying common trends and themes across the selected studies.

## REVIEW OF RELATED STUDIES

### Knowledge level of the rural household about fuel subsidy removal

The Survey results according to Sennuga *et al. (*2024), revealed that the bulk of the sampled respondents (85.7%) had existential knowledge of what fuel subsidy is as majority of the respondents were youth and have a high educational background which is an avenue for them to research on issues pertaining to agriculture and how it affects them. Minority (14.3%) who have no knowledge of fuel subsidy at the time of this research was conducted indicated interest in finding out what fuel subsidy is and how it relates to their production. This shows that majority of the rural farmers (67.4%) strongly agreed that high cost of transportation affects the price of agricultural produce. while (28.6%) agreed also that one of the major reasons contributing to the high cost of agricultural produce in the market was increase in transportation. Furthermore, Bamidele et *al.* (2024) reported that distance that exist between the market and the farms is a major reason why the cost of transportation is high. About 45.2% of the respondents strongly agreed to it, while 25.8% only agreed, with 11.3% strongly disagreed to it and about 14.5% minority disagreement. Bringing markets closer to the farms will help resolve the burden of transportation cost on those farmers who cannot afford to pay such exorbitant prices and reduce the prices of produce and products in the markets.

**Perception of the Rural Household about Fuel Subsidy Removal**

Siddig *et al.* (2014) studied the impacts of removing fuel import subsidies in Nigeria on poverty. The findings show that while a reduction in the subsidy generally results in an increase in Nigerian (GDP), it can have a detrimental impact on household income, and in particular on poor households. The result on the cost of maize value added products before and after the removal of fuel subsidy showed that the cost of 50kg bag of maize was N23,500 before fuel subsidy removal, while after the fuel subsidy removal the price is N38,000. As at April 2023 before the fuel subsidy removal and January 2024 after the subsidy removal, there is a 62% increase in the cost of 50kg bag of maize. Maize is the major raw material needed in maize value addition, therefore a 62% increase in price affects the quantity the entrepreneurs procure.

On the other hand, Umeji and Eleanya (2021) assessed the impact of fuel subsidy removal in Nigeria on the poor in the Covid-19 effect of the fuel subsidy removal on the Nigerian poor and its overall benefit to the Nigeria economy using descriptive research design method. The paper noted that while the poor will suffer more in the form of higher transport fare and increased price of food items and other commodities, subsidy removal is in the overall interest of the whole economy as funds will be channeled to improving infrastructural facilities especially in the health care, education and transport sectors. It implies that the findings of Umeji *et al. is* in support of subsidy removal, which means that in the short run the poor will suffer the consequences of fuel subsidy removal but its removal if properly channeled will promote health care, education, transportation and other sectors including agriculture and others**.**

**Effect of Fuel Subsidy on Social Well-being of Rural Household**

Nkagu (2012) conducted a study (aimed at the) effect of fuel subsidy removal on the Nigerian economy, with a particular emphasis on key sectors such as health, transportation, education, and the power sector. The findings revealed a substantial impact on health (37.7%), transportation (82%) education (33%), and the power sector (56%), while a relatively lower impact on agriculture (21%) and infrastructure and basic amenities (16.4%). Abang (2016) focused on enlightening the public regarding the impact of fuel subsidy removal in Nigeria, utilizing a linear function approach to analyses effects of subsidy removal on the value of Nigeria Naira and local production. The study synthesized on data from various periods of fuel price hikes in Nigeria, utilizing a mathematical model and graph to estimate the Naira's value. Abang's research revealed adverse effect on the standard of living, particularly as fuel is crucial for transporting major Nigerian commodities.

Manjo (2023) examined the effects of fuel subsidy removal on economy and citizens' welfare in Nigeria. The study noted that the citizens especially the poor are suffering more in form of higher transport fare and increased price of food items and other essential commodities, yet, government argued that fuel subsidy removal is in the overall interest of the Nigerian economy, insisting that funds saved from subsidy removal will be channeled to improving infrastructural facilities especially in education, transport, heatlh sectors and free the economy from incessant price distortions, corruption and inefficiencies.

## CONCLUSION AND RECOMMENDATION

The research revealed that there is a significant negative effects on the social well-being of rural framing households, especially in the area of household food consumption and expenditure, and transportation. Therefore, greater proportion of the rural farming households were dissatisfied with the removal of the fuel subsidy. After the extensive review process of the topic, the study recommended a holistic research of the effects of fuel subsidy removal on social well-being of rural farming households, in other to obtain quantitative facts on the extent of fuel subsidy removal impacts.

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# A REVIEW ON EFFECT OF CLIMATE SMART AGRICULTURAL PRACTICES ON PRODUCTIVITY OF POULTRY FARMERS IN NORTH -CENTRAL NIGERIA

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**ABSTRACT**

Livestock are vital to man as they serve as an asset and play important role as food and source of revenue. Climate change is emerging as a major threat to food security and livelihood of millions of people which has resulted in introduction and adoption of climate smart agricultural practices (CSAPs). This review evaluated the adoption and effect of climate smart agricultural practices on productivity of poultry farmers in North -Central, Nigeria. Systematic review was adopted and all the relevant documents (research articles and book chapters) were sorted according to eligibility criteria in line with the objectives of the study. Over 155 research articles and book chapters were accessed for the review. The review showed that 85.4% of poultry farmers were mostly male, mean age of 36 years, had one form of formal education (proportion), mean flock size of 317 birds and mean household size of 6 persons. The most adaptive CSAPs were regular change of water and use of concentrate in their feed formulation. Also, educational level (1.21), number of livestock owned (0.563) and age (0.003) influenced adoption of CSAPs. Likewise, the use of CSAPs had a positive effect on productivity. The major factor affecting adoption of CSAPs was inadequate labour (4.12) and lack of resources (3.75). The study therefore recommended that relevant stakeholders (State government, Non-governmental organization and community-based organization) should intensify efforts to assist poultry farmers in adoption of CSAPs through incentives and awareness programs.

**Keywords**: Effect; Poultry farmers; Climate Smart Agricultural Practices; Productivity; North- Central Nigeria

## INTRODUCTION

Climate change is emerging as a major threat to agriculture, food security and livelihood of millions of people in many places of the world and it is one of the greatest problems facing sub-Saharan African countries (Veettil *et al.,* 2021). Smallholder farmers in sub-Saharan Africa (SSA) are mostly venerable to risk posed by climate change. This is due to over-reliance on rainfed agricultural systems and low adaptive capacity attributed to high poverty incidence (Akinyi *et al.* 2022). Climate Smart Agricultural Practice (CSAP), according to (Lipper, 2014), is an agricultural practice or technology that sustainably increases food production, adaptability, reduces and removes pollutants from the atmosphere and intensifies the attainment of national food security goals. CSAP targets three objectives which are sustainably increasing agricultural productivity to support equitable increases in farm incomes, food security, and development; adapting and building resilience of food systems to climate change; and, where possible, reducing greenhouse gas (GHG) emissions from agriculture (FAO, 2013). Some CSA practices include use of air ventilation, water ventilation, vitamins and medicines, improved varieties, energy efficient bulbs, improved feeds and regular litter replacement (Liverpool-Tasie *et al.,* 2019; Obioha *et al.,* 2021). Globally, poultry is the second most widely eaten meat among animal sourced foods and accounted for about 40% of the meat production that cut across various cultures, religions, and traditions (Govoni *et al.*, 2021).

There are 80 million poultry raised in large systems, 60 million in semi-intensive systems, and 40 million are raised intensively (Africa Sustainable Livestock 2050, 2018). Poultry varieties include Muscovy and mallard ducks, quails, turkeys, pigeons, guinea hens, ostriches, geese, and pheasants are all included under the umbrella term "poultry" (Marien *et al.,* 2024). In Nigeria, the poultry breeds are categorized into indigenous chicken breeds (Nigerian Indigenous Chicken (NIC) (Fulani ecotype, Yoruba ecotype, Kano brown and Oke-Agbe); Introduced chicken breeds (Broilers, layers, Rhode Island Red, Sussex, Plymouth Rock); Turkey breeds (Nigerian Turkey, Bronze turkey, White Holland turkey); Duck breeds (Nigerian Indigenous ducks, Pekin duck, Muscovy duck); Guinea Fowl (Helmeted guinea fowl), and Quail (Common quail) Adamu, 2023). Despite the numerous species of poultry most have gone or at the verge of extinction due to negligence, improver rearing and climate change. Poultry production contributes a substantial part to the economy socioeconomically, as well as contributing to the nutrition and livelihood of the people. It generates income, provides food, improves the social status, and is a liquid household asset (Olutumise *et al.,* 2023). It is the most commercialized livestock sub-sector in Nigeria, that accounts for about 8% of the Gross Domestic Product (GDP) with about 30% of the total agriculture contribution (FAO, 2020). The poultry sub-sector provides over 14 million employments to the Nigerian population and contributes nearly 58.2% of total of Nigeria's animal production (Ogunyemi and Orowole, 2020). The objectives reviewed are the socio -economic and demographic characteristics of poultry farmers; assess the level of adoption of the various CSAP practices by poultry farmers; examine the factors influencing adoption of CSAP by poultry farmers; conduct an economic analysis of the adopted CSAP practices by poultry farmers; assess the effect of CSAP on productivity of poultry farmers, and identify the constraints associated with adoption of CSAP by poultry farmers.

## METHOD OF REVIEW

A systematic literature review (SLR) is a technique for organizing and identifying research related to a specific topic. SLR is used in this study to look into the effect of climate smart agricultural practices on productivity of poultry farmers in North- central Nigeria. Cases where the phrase "climate smart agriculture" and "productivity" occurred in the title, abstract, or keywords of an article with any of the "livestock production" with specific interest in poultry farming were specifically sought out. A review procedure is established prior to conducting the SLR to ensure a transparent and high-quality research process, which are the features that distinguish a systematic literature review. By conducting thorough literature searches, the review methodology also helps to reduce bias. The creation of the research questions, the defining of the search method, and the specification of inclusion and exclusion criteria were all part of this process. To conduct SLR, this paper uses a recommended reporting item for systematic reviews and meta-analysis (PRISMA) approach. PRISMA is a minimum collection of items based on evidence that is used to guide the construction of systematic literature reviews and other meta-analyses.

### Socio economic characteristics of poultry farmers

Aminu and Hermanns (2022) studied profitability evaluation of poultry production in Lagos State and found out that poultry farming in the study area was dominated by male (69.2%) with a mean age of 43 years. Majority (72.5%) of the farmers had tertiary education, married (59.2%)

with mean household size of 5 persons. About 51% of the poultry farmers engaged in broiler production, 37.5% engaged in layer production while 11.7% were cockerel producers. The mean flock size was 335 birds meaning the poultry farming is a small-scale enterprise. Idio and Okoro (2017) researched adoption on of improved feed production technologies by poultry farmers in Akwa Ibom State, Nigeria. Results showed that males constituted 54.2% of the respondents; mean age was 38 yrs ± 2.1 with 3.5% between 30 and 39 years; above sixty percent (60.5%) of the respondents were University graduates and 87.0% had monthly income less than ₦74, 500.00. Few (31.1%) belonged to livestock and livestock-related organizations. Obioha *et al.* (2021) researched on perceived constraints to adoption of improved poultry technology among poultry farmers in Owerri Agricultural Zone of Imo State, Nigeria. Findings revealed that 71.23% of the respondents were males while 28.33% were females. Majority of poultry farmers in the area (33.67%) were within the age bracket of 41-50 years with mean age of the farmers was 33.95 years and mean age spent at school by the respondents was 14.2 years. 25.83% of the farmers had 6-10 years of farming experience, while the mean farming experience was 11.5 years with mean household size of 6 persons. They had a mean flock size of 469 birds, majority (40) has flock size of 601-800 birds, while the least (2.09) of the farmers had flock size of 401-600 birds. Majority, 74. l7% had farming as their major occupation. However, 25.83% were engaged in other occupations, but had farming as a part time enterprise. Major source of labour was hired (73.33%) while family labour provided just (26.67%) of needed labour supply on the farm.

Further result revealed that extension agents, fellow farmers and radio were the most effective sources of information available to the farmers, with mean effectiveness of 2.7, 2.6 and 2.5 respectively. Also, Osuagwu *et al.* (2020) investigated the factors influencing farmer adoption of improved poultry production practices in Ahiazu Mbaise Local Government Area of lmo State, Nigeria. The results revealed that majority were within the age range of 30 – 39 years, 66.3% were male while 84.3% of them were well educated. The results further showed that 48.2% of the respondents have family size of 1 – 4 that help them on their poultry farms. Only a few 3.6% have a family size of 7 and above. The results also showed that majority of the poultry farmers. 65.1% did not belong to any poultry association indicating that the association had no benefits to the farmers. 65.1% of the respondents started poultry business with 50-100 birds while 26.5% started with 101-400 birds and majority of the respondents (69.9%) kept layers while minorities of 28.9% kept broilers and cockerels. Likewise, Amusat *et al.* (2019) investigated poultry farmers' perception on climate change in Ido Local Government Area of Oyo State, Nigeria. The results obtained show that mean age of respondents was 41.2 years with most (49.4%) were single, majority were male (55.6%) and had tertiary education (49.4%). About half (49.4%) had tertiary education, while only 4.6% had no formal education. The most popular sources of information to farmers on climate change were television (1.72) and radio (1.61).

**Level of adoption of the various CSA technologies**

Amusat *et al.* (2019) investigated poultry farmers' perception on climate change in Ido Local Government Area of Oyo State, Nigeria. The result revealed that the various adaptative strategies were regular vaccination of birds (mean = 0.97), regular changing of water (mean = 0.96) and proper sanitation (mean = 0.93), respectively ranked 1st, 2nd and 3rd as the most utilized adaptability measures by the respondents. Rearing resistant birds' species (mean = 0.91) was also a common adaptability measure to climate change. Others were providing adequate housing system, rearing birds with other livestock, rearing early maturing birds, proper sanitation measures, regular changing of water in drinking troughs, adjusting the price of birds and taking of poultry insurance cover respectively. Gautam *et al*. (2013) studied the adoption of various scientific poultry farming technologies by broiler farmers in India. The study classified the farmers into: small, medium and high category. Results revealed low adoption by the majority of the farmers in the small category. However, those farmers in the medium category were not clearly defined, but the large farmers highly adopted the technologies. Also, Idio and Okoro (2017) researched adoption on of improved feed production technologies by poultry farmers in Akwa Ibom State, Nigeria. The result revealed that more than forty-three percent (43.6%) of the respondents adopted protein concentrates in their feeds production. Forty-one percent of the respondents adopted pre-mixes, anti-caking, antioxidants and antibiotics in their feeds production. Liverpool-Tasie *et al.* (2019) studied climate change adaptation among poultry farmers: evidence from Nigeria. The strategies adopted include air ventilation, water ventilation, engagement in fish farming, litter spreading and decaking in chicken houses, the use of energy efficient bulbs, and the use of vitamins and medicines for the birds. The adoption of the various adaptation strategies in Nigeria varies significantly across farms of different sizes. Furthermore, Obioha *et al.* (2021) researched on perceived constraints to adoption of improved poultry technology among Poultry Farmers in Owerri agricultural zone of Imo State, Nigeria. The result revealed the farmers were very much aware and adopted highly in the use of improved breeds, regular vaccination programme and regular litter replacement in their poultry farming practices with a weighed mean of 2.8. On the other hand, they were not aware of the use of artificial brooder in poultry management which led to the failure to adopt it.

**Factors influencing adoption of CSA**

Due to the thermal circumstances that have an effect on the physiological and behavioral activities of birds, climate change has an effect on flocks of poultry (Ayo-Enwerem, 2017a). Environmental factors that affect poultry birds' performance and ability to survive include the ambient temperature, the relative humidity, and the amount of light present at any particular time (Pragya, 2014). According to Ahaotu *et al.* (2019), avian mortality will rise when the ambient temperature is elevated above 34 ºC. Birds pant in response to climatic change that causes seasonal variations, which causes the birds to expel more heat. An increase in the surrounding temperature might be disastrous for broiler chicken. This compromises the comfort of the birds and reduces productivity (Okonkwo and Ahaotu, 2019). When the weather changes, poultry birds display a variety of behavioral and physiological changes that allow them to adapt their body's thermal balance to the new conditions (Bhadauria *et al*., 2014). Due to change in the pattern of rainfall, and increase in temperature, planting season have invariably been altered and thereby affecting production and availability of this grains to the poultry farmers as at when needed (Adesiji and Baba, 2013).

Andati *et al.* (2020) investigated the determinants of adoption of climate smart agricultural technologies among potato farmers in Kenya. The multivariate probit results show that farmers' entrepreneurial orientation had mixed influence on CSA adoption. Other important factors influencing CSA adoption included access to financing through mobile-based applications, gender, land size, trust in extension officers, household income, and farm characteristics. Dhraief *et al.* (2018) investigated the determinants of using innovative technologies for livestock keepers in Tunisia. The study found that education level of the head of household, number of livestock owned, and number of occupations influenced the usage of innovative technologies. Additionally, age of the head of the household and the experience of the head of the household head in farming activities influenced the usage of innovative technologies negatively. Also, Gautam *et al*. (2013) studied the adoption of various scientific poultry farming technologies by broiler farmers in India. The findings showed that size of the flock determined the adoption but on the other hand, other factors such as knowledge base and resourcefulness led to adoption. Furthermore, Liverpool-Tasie *et al.* (2019) studied climate change adaptation among poultry farmers: evidence from Nigeria. The results on the determinants of the adoption of adaptation strategies show that farmers who have experienced climate-related losses are more likely to adopt water ventilation, pay for litter spreading, buy medicines and vitamins or use energy efficient bulbs. This is expected since all the above strategies increase the ability of farmers to respond to the negative effects of extreme heat. On the other hand, exposure to extreme heat discourages investment in a fish farm. This indicates that farms are less likely to invest in building a fish farm on the poultry farm if they have incurred losses in the past. Teklewold *et al*. (2006) studied the determinants of adoption of poultry technology. The double hurdle model showed that the decision to adopt was positively affected by sex of the household head, family size, supplement availability, credit and extension services. However, age negatively influenced both tiers and old farmers were likely to be more risk averse.

**Economic analysis of farmers**

Aboki *et al.* (2013) studied productivity and technical efficiency of family chicken production in Kurmi, Nigeria. The study used percentage distribution, profitability index and stochastic frontier function to analyze the collected data. Technical efficiency had a mean of 0.63 on input use. The enterprise was highly profitable with 76% return on investment (ROI). The study however fails to account for costs associated with housing and stocks replacement, and these might have led to overstated profits margins and ROI. Also, Aminu and Hermanns (2022) studied profitability evaluation of poultry production in Lagos State. Result from the budgetary analysis revealed that, an average total cost of ₦730,575.23, ₦742,455.31 and ₦391,802.32 were invested in the production of broiler, layers and cockerel respectively, per production cycle in the study area. The mean gross revenue that accrued from the sales of matured birds were ₦1,131,101.25 for broiler, ₦1,106,120.55 for layers and ₦602,643.88 for cockerels, thereby returning a gross margin and net farm income of ₦604,933.61 and ₦400,526.02 for broilers; ₦602,210.55 and ₦363,665.24 for layers; ₦379,243.58 and ₦210,841.54 for cockerel. The results of the profitability ratios revealed that, the returns per naira invested were 0.55, 0.49 and 0.54 for broiler, layers and cockerels respectively.

**Effect of CSAP on productivity of farmers**

Akrofi-Atitianti *et al.* (2018) assess climate smart agriculture and its determinants of practice in Ghana. The results indicate higher income in CSA agroecology systems. The average yield for conventional systems (363 kg/ha) identified in this study is validated by the national average of 350–400 kg/ha. Amadu (2018) conducted as assessment of the effect of CSA practice on food security on households in Southern Malawi. The result showed that CSA adoption resulted in 90% increase in yield. Likewise, Asfaw *et al.* (2010) examined the effect of using improved chickpea technologies on market integration in Ethiopia using the augmented double hurdle model. The study found a positive effect of using the improved chickpea technologies on marketed surplus. A research on if climate-smart agriculture improves household income and food security in Southern Ethiopia by Baley *et al.* (2023) showed that households that adopted CSA practices had a 20.30% higher average annual farm income per hectare than non-adopters. Also, Imran *et al.* (2018) investigated the impact of climate smart agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab. The results revealed that majority of the adopters of CSA (95 percent) reported that the CSA increased the productivity, have 13 percent higher yield than conventional farmers, uses less of external inputs and getting higher yield and using external inputs efficiently. Furthermore, Sardar *et al.* (2021) examined if adoption of climate smart agriculture (CSA) practices improve farmers crop income. Findings confirm that farmers who adopted a full set of CSA practices gain higher yield 32% and 44% kg/ha, and higher farm income 45% and 48% US$ per ha than non-adopted farmers for cotton–wheat and rice–wheat crops, respectively. Ogada *et al.* (2020) study on climate smart agriculture, household income and asset accumulation among smallholder farmes in the Nyando basin of Kenya. Findings revealed that uptake of multiple stress-tolerant crops improves household income by 83%, which in turn improves household asset accumulation. Impact pathway modelling also show that adoption of improved livestock breeds significantly reduces household income by 76%.

**Constraints associated with adoption of CSAPs**

Amusat *et al.* (2019) investigated poultry farmers' perception on climate change in Ido Local Government Area of Oyo State, Nigeria. The result revealed that insufficient capital ranked as the most important challenge confronting the respondents in the study area. Others were Inadequate supply of labour, high cost of adaptability measures to climate change, lack of awareness on possible coping strategies, lack of government support, insufficient capital, inadequate information on poultry insurance and sharp practices by agricultural insurance agents and staff. According to Autio *et al.* (2021) study on constraints for adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya. The challenges associated with adopting CSA were lack of knowledge or awareness of CSA technologies, where workshop participants also indicated inadequate extension services. In general, the main hindering factors across the scale of CSA technologies are characterized by a lack of resources such as water, land, labour, time, money, knowledge, or training. Other constraints are mainly related to human–wildlife conflicts, pests, and diseases. Other hindrances according to study by Emmanuel and Oba (2019) that are restraining farmers from using CSAPs include: lack of government's support, high cost of executing the practices, and insufficient training on the practice's Specific challenges of CSA.

**CONCLUSION**

The finding revealed that poultry farmers were aware of climate smart agricultural practices and Male with majority of poultry farmers adopting air ventilation, water ventilation and used of improved breeds. The major factors influencing adoption of CSA were age, gender and extension service. The result further reveals that poultry farmers who adopted CSAPs were profitable and improved productivity level of birds. Lack of awareness, lack of resources, insufficient capital and inadequate information were the major constraints faced by poultry farmers

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# PRODUCTIVITY DIFFERENTIAL AMONG ADOPTERS OF IMPROVED RICE VARIETIES UNDER IFAD-VCDP IN NIGER STATE, NIGERIA

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## ABSTRACT

This study analyzed the productivity differential among adopters of improved rice varieties under IFAD-VCDP in Niger State, Nigeria. The specific objectives were to determine the factors influencing adoption of improved rice varieties and rice productivity differential among the participants in the study area. Multi-stage random sampling procedure was employed to select 196 participating rice farmers under IFAD-VCDP that adopt improved rice varieties. Equal number of non-participating rice farmers was also selected as control. Primary data were collected with the aid of structured questionnaire and analysed using inferential statistics (Probit regression analysis and Oaxaca-Blinder decomposition). Findings from the study of Probit regression revealed that marital status (-2.59, $p<0.01$), farm size (3.64, $p<0.01$), extension contact (2.68, $p<0.01$), output (3.71, $p<0.01$) and access to credit (5.06, $p<0.01$) were statistically significant, thus influences adoption of improved rice varieties among the respondents. Out of the three-fold Oaxaca-Blinder decomposition results on rice productivity differential between the male and female adopters of improved rice variety, endowment effect (0.0641) and coefficient (-0.2539) were significant ($p<0.01$) implying productivity difference between the two groups. In conclusion, the gap between male and female farmers in the study area was established, thus significant difference in rice productivity. It was therefore recommended that Federal and State Governments should formulate policies and take appropriate measures aimed at stimulating demand for locally produced rice.

**Keywords:** Rice productivity, differential, improved rice varieties, adopters

## INTRODUCTION

Rice is the staple food for over half the world's population (Muthayya *et al*., 2014) while in Nigeria, it is one of few food crops whose consumption has no cultural, religious, ethnic or geographical boundary as it is used in the preparation of several local dishes that are eaten in every home, especially during festivals and ceremonies. In terms of comparative advantage, rice can adapt to different agro-climatic and soil conditions, but despite this, rice is the sixth major crop cultivated after sorghum, millet, cowpea, cassava and yam (Ajah and Ajah, 2014) while its production in Nigeria is dominated by small holder farmers who use traditional methods that are characterized with problems of low productivity (Tsado *et al*., 2014). Nigeria is one of the countries in the world that has the potentials to produce rice in larger quantity, because it has an estimated land area of about 4.6 million hectares that is suitable for rice production. Despite all these potentials only about 1.8 million hectares representing 39% of the land area is under rice production (Danbaba *et al.,* 2013). Though Okonji *et al.* (2012) ascertained that Nigeria is still the largest rice producer in West Africa sub-region, but because its 2.2 million metric tonnes produced locally could not meet up with the demand of about 5 million tonnes daily it has to depend on importation, thereby becoming one of the major importers of rice in Sub-Sahara Africa (Nwalieji and Onwubuya, 2013).

The government and donor agencies have been making efforts to promote adoption of improved rice varieties. One of the donor agencies operating in Niger State is IFAD, which is promoting FARO 44 and 55. Despite the fact that the efforts has been on for some time now, little or nothing is known empirically of the effects of the use of this improved varieties on productivity of farmers. Hopefully this study will generate research information's on the effects of adoption of improved rice varieties on yield in Niger State, and reveal ways to increase rice production in large quantity. Thus, helps to fill the gap in knowledge. It is against this backdrop, the study attempts to provide answers to the following research objectives which were to:
i. determine factors influencing adoption of improved rice varieties by the participants of IFAD-VCDP, and ii. determine the productivity differential between male and female adopters of improved varieties under IFAD-VCDP in the study area.

## METHODOLOGY

### Study Area

The study was conducted in Niger State which is one of the six states in the North-Central Nigeria. The State consists of 25 Local Government Areas grouped into three agricultural zones: I, II and III with each of the zones having 8, 9 and 8 Local Government Areas (LGAs), respectively. It is located within Latitudes 8° 20′ and 11° 30′ North and Longitudes 8° 30′ and 8° 20′ East, and covers 76,363 square kilometers of land mass which makes it the largest Nigerian State by land mass. The State has a population of 3,950,249 (National Population Commission (NPC), 2006). However, using the population growth rate of 3.2% (UNFPA, 2016), the projected population of the State was 5,764,755 as the end of 2018. The landscape consists mostly of wooded savannas and includes the flood plains of the Kaduna River. Niger State like other States in Nigeria experience two main weather conditions (dry and wet seasons); with annual rainfall varying from 1,100mm in the Northern part to 1,600mm in the Southern parts (Niger State Agricultural Mechanization and Development Authority (NAMDA), 2018).

### Sampling Procedures and Sample Size

Multi–stage random sampling procedure was used to select the respondents for the study. The first stage involved random selection of three Local Government Areas (LGAs) out of five LGAs where IFAD Value Chain Development Project (VCDP) activities are concentrated in Niger State (Katcha, Bida, Kontagora, Shiroro and Wushishi). The LGA's selected were Katcha, Bida and Wushishi. Second stage involved random selection of five villages from Katcha, eight villages from Wushishi and three villages from Bida. This is because rice is predominantly produced in relatively large quantities in these areas. The final stage involved proportionate sampling of 196 adopters of FARO 44 rice farmers from a total of 4,922 participating rice farmers using Yamane's formula based on the data obtained from IFAD-VCDP in Niger State. Equal numbers of non-participating rice farmers was also selected. The Yamane formula as adopted by Isma'ila (2014) is mathematically expressed:

$$n = \frac{N}{1+N(e)^2} \qquad (1)$$

Where;
n= sample size

N= finite population
e= limit of tolerable error (level of precision (0.07))
l= constant
The proportionate sampling formula is given as:

$$nn = n \times nh \qquad N$$

(2)

Where:
nn = Sample size
n = Sampling frame
nh = Predetermined sample size
N = Total sample frame

Therefore, the total respondents for the study was three hundred and ninety-two (392). Primary data were collected with the aid of structured questionnaire complimented with an interview schedule. The data collected were subjected to inferential statistics (Probit regression and Oaxaca-Blinder decomposition).

**Model Specification**

**Probit Regression Model**

The probit regression analysis was used to achieve objective ii. The implicit form of the probit model is specified as:

$$Y = f(X_1, X_2, X_3, X_4, X_6, X_7, X_8, X_9, X_{10}, X_{11}) \qquad (3)$$

However, the probit model in its explicit form is expressed in equation 4

$$Y = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \ldots\ldots\ldots + \beta_{11}X_{11} + e \qquad (4)$$

Where;
Y = Adoption of improved rice varieties under IFAD – VCDP (Adopter = 1, otherwise = 0)
$X_1$ = Age (Years)
$X_2$ = Gender (Male = 1, Female = 0)
$X_3$ = Marital status (Married = 1, Otherwise = 0)
$X_4$ = Education level (Number of years spent in school)
$X_5$ = Household size (Number of people)
$X_6$= Farm size (Hectares)
$X_7$= Distance to the market (Km)
$X_8$ = Extension contact (Number of contacts)
$X_9$ = Cooperative Society (Years)
$X_{10}$ = Output (Kilogram)
$X_{11}$ = Access to credit (Access = 1, Otherwise = 0)
$\beta_o$ = constant
$\beta_1 - \beta_{11}$ = coefficients of the independent variables
$X_1 - X_{11}$ = independent variables
e = error term

**Oaxaca-Blinder Decomposition (OB) Model**

The Oaxaca–Blinder (OB) decomposition method was used to explain the productivity differential between male and female adopters of improved varieties under IFAD – VCDP in the study area. The first step of the decomposition procedure was to obtain the determinants of productivity using the following production function in its implicit form:

$Y_g = \alpha_j x_j + \mu_g$ (5)

Where;

Y = the natural log value of rice yield (a measure of productivity)

g = the gender dummy of the adopters of improved rice varieties

x = dimensional vector of covariates

$\alpha$ = the intercept

$\beta$ = coefficient of the gender variable

$\mu$ = the random error term which is assumed to be independently and normally distributed.

The explicit forms of equations fitted to the data are expressed as:

$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + ....... + \beta_{12}X_{12} + e$ (6)

Where;

Y = Productivity of the rice farmers

$X_1$ = Farm size (hectares)

$X_2$ = Farm labour (mandays)

$X_3$ = Seeds used (kilogram)

$X_4$= Fertilizers used (kilogram)

$X_5$= Agro-chemicals used (litres)

$X_6$= Depreciation on fixed assets (naira)

$X_7$ = Age (year),

$X_8$= Household size (Number),

$X_9$= Education level (Years),

$X_{10}$=Farming experience (Years),

$X_{11}$= Extension contact (Number of visit)

$X_{12}$=Distance from farmer's home to the farm (Km).

$\beta_o$ =Constant,

$\beta_1 - \beta_{12}$ = Regression coefficients to be estimated,

e = random error,

The second step is to understand the cause of estimated productivity gap that was observed between the male and female adopters. This is expressed as:

$Y = \alpha_j x_j + \beta g + \mu$ (7)

Where;

Y= the measure of productivity of the male and female adopter

g = gender of the adopters

x = vector of j observable characteristics

$\alpha$ = the intercept

$\mu_g$= gender specific random error term

## RESULTS AND DISCUSSION

### Factors Influencing Adoption of Improved Rice Varieties by the Respondents

The results from the probit estimation of factors influencing adoption of improved rice varieties by farmers under IFAD-VCDP in the study area is presented in Table 1. The Pseudo $R^2$ of 0.1087 implies that only about 11% of variations in the adoption of improved rice variety are explained by the independent variables included in the model, while Chi – squared statistic of 59.07 was significant at 1% level of probability indicating the goodness of fit of the overall model. From the z value, five variables (marital status, farm size, extension contact, output and access to credit) out of the eleven variables included in the model were found to be statistically significant. Marital status had negative z-value (-2.59) and statistically significant at 1% level of probability. This implies that marital status had an inverse relationship with adoption of improved rice variety, as a unit increase in the number married people, the lower the likelihood of adopting improved rice variety. Married individual are more likely not to adopt an innovation due to lots of responsibilities they face in taking care of their family. Farm size had positive z-value (3.64) and statistically significant at 1% level of probability. This implies that farm size had a direct relationship with adoption of improved rice variety, as a unit increase in the farm size will lead to higher likelihood of adopting improved rice variety. More so, extension contact had positive z-value (2.68) and statistically significant at 1% level of probability. This implies that extension contact had a direct relationship with adoption of improved rice variety, as a unit increase in number of contact with extension agent, the higher likelihood of adopting improved rice variety. This could be probably due to the persuasive nature of extension agents in disseminating vital agricultural innovations. This finding is in agreement with Di Falco and Bulte (2011) who found positive and significant relation between extension contact and adoption of agricultural innovations among rural women farmers in Nigeria.

In the same vein, output had positive z-value (3.71) and statistically significant at 1% level of probability implying a direct relationship with adoption of improved rice variety. Thus, a unit increases in the rice output of the respondents, the higher likelihood of adopting improved rice variety. The higher output realized from adopting improved rice variety, the higher probability of subsequent adoption. The z-value of access to credit (5.06) was found to be positive and statistically significant at 1% probability level implying that, access to credit had direct relationships. A unit increase in access to credit of the rice farmers, the higher the likelihood of adopting an improved rice variety. This could be probably due to the significant role access to credit play in enhancing agricultural production.

**Table 1: Probit estimate of factors influencing adoption of improved rice variety**

| Variables | Coefficient | Standard error | z-value |
|---|---|---|---|
| Constant | 0.1896 | 0.4678 | 0.42 |
| Age | -0.0101 | 0.0092 | -1.09 |
| Gender | 0.1119 | 0.1938 | 0.58 |
| Marital status | -0.5470 | 0.2112 | -2.59*** |
| Education | 0.0021 | 0.0105 | 0.20 |
| Household size | 0.0236 | 0.0194 | 1.22 |
| Farm size | 0.4224 | 0.1159 | 3.64*** |
| Distance | 0.1224 | 0.0848 | 1.44 |
| Extension contact | 0.1316 | 0.0490 | 2.68*** |
| Cooperative society | 0.0404 | 0.1584 | 0.26 |
| Output | 0.0002 | 0.00001 | 3.71*** |
| Access to credit | 0.8156 | 0.1613 | 5.06*** |
| Pseudo $R^2$ | 0.1087 | | |
| Chi-square $X^2$ | 59.07*** | | |
| Log likelihood | -242.1799 | | |

**Source: Field Survey, 2019 Note: *** implies significant at 1% level of probability**

**Productivity differential among adopters of improved rice varieties**

The Oaxaca-Blinder decomposition is a popular tool for identifying and quantifying the differences in economic outcomes such as earnings, income, yield and productivity between two groups. The decomposition tool was used to determine the productivity differential between the male and female adopters of improved rice variety in the study area and the result is presented in Table 3 and Table 4. The economic outcomes for two groups for example male-female are decomposed at their mean. Thus, the mean level decomposition is used for linear models. The aggregated decomposition isolates the gap in productivity between two groups into an endowment effect, which is a part of the gap explained by difference in social-economic characteristics, a coefficient effect which is the part of the gap due to differences in coefficients. The dependent variable of this study is the yield productivity of improved rice variety of the two groups, while the independent variables comprise of production factors such as farm size, labour, seed, fertilizer, agro-chemical and depreciation of fixed assets, and socio-economic factors like age of the farmers, household size, education, farming experience, extension contacts and distance to farm.

**Table 2: Linear regression estimates of determinant of productivity among rice farmers**

| Variables | Female farmers | | Male farmers | | Pooled data | |
|---|---|---|---|---|---|---|
| | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| Farm size (ha) | 0.6405 | 1.78* | 0.5320 | 5.13*** | 0.5304 | 5.52*** |
| Labour (man-day) | 0.0010 | 0.42 | 0.0004 | 0.43 | 0.0006 | 0.63 |
| Seed (kg) | 0.0098 | 1.27 | 0.0068 | 3.23*** | 0.0069 | 3.53*** |
| Fertilizer (kg) | -0.0006 | -1.18 | -0.0004 | -1.97** | -0.0005 | -2.45** |
| Agrochemical (litre) | 0.0243 | 0.83 | 0.0072 | 0.85 | 0.0078 | 1.00 |
| Depreciation on F.A (₦) | -0.0002 | -0.56 | 0.0001 | 1.66* | 0.0002 | 1.40 |
| Age of farmers (years) | -0.0124 | -1.47 | -0.0052 | -1.98** | -0.0065 | -2.65*** |
| Household size (No) | 0.0098 | 0.85 | 0.0079 | 1.63 | 0.0067 | 1.53 |
| Education level (years) | -0.0049 | -0.65 | 0.0018 | 0.59 | 0.0005 | 0.18 |
| Farming experience (years) | 0.0107 | 1.51 | 0.0008 | 0.32 | 0.0024 | 1.01 |
| Extension contact (No) | 0.0131 | 0.37 | 0.0232 | 1.69* | 0.0229 | 1.82* |
| Distance to farm (km) | -0.0460 | -0.86 | -0.0580 | -2.58*** | -0.0519 | -2.63*** |
| Sex (male =1, female = 0) | - | - | - | - | 0.2474 | 5.40*** |
| Constant | 4.4115 | 2.13** | 5.1916 | 8.26*** | 4.9812 | 8.56*** |
| R-Squared | 0.3777 | | 0.2839 | | 0.3060 | |

**Source: Field Survey, 2019**

**Note: * = significant at 10%,**

**** = significant at 5%,**

***** = significant at 1%.**

Results in Table 2 revealed that variables like farm size and seeds were significant in the male group, female group and endowment effect, while fertilizer, age of farmers, extension contact and distance were significant for male group but insignificant for the female group an indication of the productivity gap in favour of male farmers. This implies that farm size and seed had positive and significant influence on the yield of the rice farmers. An increase in farm size and seed usage is likely to increase the yield of the male-female group but did not translate to increase productivity in the female group. This suggests that male farmers had higher productivity compared to their female counterpart.

The coefficient of fertilizer for male group (-0.0005) was negative and significant ($p<0.05$) implying that fertilizer was over-utilized during production which could decrease the yield of the farmers. Also, the coefficient of age (-0.0071) and distance for the male group were negative and significant ($p<0.01$) and ($p<0.1$), respectively, implying that an increase in the age and distance to farm could decrease the yield of the farmers. Meanwhile, the coefficient of extension contact (0.0229) was positive and significant ($p<0.1$), implying that the more contact the rice farmers had with extension agents, the higher their productivity.

In a nutshell, gender gaps exist in favour of male-headed households with regards to rice productivity. Furthermore, the results in Table 3 reveals the mean productivity differential. The mean productivity of both the male and female rice farmers was found to be positive and significant ($p<0.01$), implying positive increase in productivity of both male and female farmers. However, the mean difference between the two groups was also significant ($p<0.01$) in favour of male farmers. The aim of decomposition in this study is to explain the difference in mean productivity between female and male by the mean values of explanatory variables which denotes the endowment effect which was significant ($p<0.05$). The idea is based on the residual difference methodology where gender with the same characteristics and are equally productive are expected to have the same productivity.

**Table 3: Threefold decomposition of productivity gap between male and female rice farmers**

| Indicator | Category | Coefficient | Standard error | t-value |
|---|---|---|---|---|
| Differential | Female farmers | 7.7790 | 0.0496 | 156.71*** |
| | Male farmers | 7.9620 | 0.0208 | 382.85*** |
| | Difference | -0.1830 | 0.0538 | -3.40*** |
| Decomposition | Endowments | 0.0641 | 0.0272 | 2.36** |
| | Coefficients | -0.2539 | 0.0526 | -4.83*** |
| | Interaction | 0.0067 | 0.0339 | 0.20 |

**Source: Field Survey, 2019**

***** ** implies significance at 1% and 5% level of significance respectively**

The residual difference method decomposes within the mean productivity of two group, one part expressed by differences in productive characteristics of individuals (i.e the endowment effects) and a second unjustified part related to differences in productivity. This unjustified gap is then assumed to be the productivity differential. This finding substantiates with that of Oseni *et al.* (2015) who reported that in Nigeria, there are significant differences in gender productivity in the North and in the South. In the North, not only do women have less access to inputs, but the returns to these factors of production are also lower. A number of possible factors may be responsible for agricultural productivity differences between male and female in the study area. First, assuming that male and female have the same agricultural production function and use the same technique for the same crop, the quantity of inputs (e.g., fertilizer, seeds, or labour) utilized by male and female may differ. Second, the quality of inputs may differ (for example land quality may differ between male and female in terms of soil quality, topography, and proximity to access points such as water sources, roads, and housing). Third, male and female may have different agricultural production functions possibly because of crop choice which may be influenced by cultural norms, lack of resources to cultivate specific crops and the culturally accepted division of labour. Fourth, even if both genders do have the same agricultural production function, shadow prices of inputs and credit may lead to the women's production frontier to lie beneath the men's frontier, implying that women are less productive.

**CONCLUSION AND RECOMMENDATIONS**

Based on the empirical evidence from the findings of this study, it could be concluded that Majority of the adopters were middle aged and literate and that explains why they adopted the improved rice variety. Most of the respondents were married, had long period of farming experience with average household size of 7-8 members. Variables such as marital status, farm size, extension contact, output and access to credit significantly influences adoption of improved rice varieties among the respondents. The gap between male and female farmers in the study area established from the finding was as a result of endowment, as the mean value of explanatory variables which denotes the endowment effect was significant ($p<0.01$). It was therefore recommended that effective channels for an extension of information delivery system should be provided to enhance adequate input delivery to the farmers for improved productivity. Also, Federal and State Governments should formulate policies and take appropriate measures aimed at stimulating demand for locally produced rice in the study area.

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# LEVEL OF FARMERS PARTICIPATION IN RURAL ACCESS ROAD AND AGRICULTURAL MARKETING PROJECT IN NIGER STATE, NIGERIA

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**ABSTRACT**
The study was carried out to assess the level of farmer's participation on rural access, agricultural and marketing project in Niger State, Nigeria. Three-stage sampling procedure were employed in the selection of 247 respondents for the study. Primary data were collected through structured questionnaire and analysed using descriptive statistics (such as frequency, percentage and mean) and inferential statstics (such as probit regression model). The result of the findings revealed that above half (55.47%) of the respondents had high level of participation in RAAMP. In addition, marital status (1.95, $p < 0.10$), household size (8.95, $p < 0.01$), formal education (1.80, $p < 0.10$), farm size (3.14, $p < 0.01$) and farm income (2.28, $p<0.05$) influence respondents' level of participation in RAAMP. However, livestock ownership (2.00, $p < 0.05$) had inverse relationship. The study concluded that averagely, farmers had high participation in RAAMP. The study recommended that RAAMP project should enhance engagement with livestock farmers by tailoring certain components or activities of the project to address their specific needs like provision of grazing route and access to veterinary services.
**KEYWORDS: Level, Participation, Access Road, Marketing, Project**

## INTRODUCTION

Agriculture continues to be the most important sector of the Nigerian economy, in spite of the dominance of petroleum sector. It remains the largest contributor to the growth and development of Nigerian economy (Agbolahan *et al.*, 2016; Abu *et al.*, 2019) accounting for 23.86% of the non-oil foreign exchange earnings in the 4$^{th}$ quarters of 2023 and employing about 70% of the active labour force of the population (National Bureau of Statistics (NBS), 2024). Agricultural GDP increased at an annual rate of 2.9% in 1990-2000 to 5.5% in 2005, 6.1% and 6.5% in 2010 and 2015 respectively, while output increased at a steady rate of 5.7% from the first half of 2017 to 2022 (NBS, 2023). Nigeria's food imports are growing at an unsustainable rate of 11% per annum (Akinwumi, 2020). Therefore, relying on the import of expensive food on global markets fuels domestic inflation as excessive imports continues to put high pressure on the Naira and hurting the economy.

Nigeria, with its predominantly rural landscape, is home to vast expanses of arable land that form the backbone of the nation's economy. Despite this potential, Nigeria's agricultural sector faced several challenges that impede its full exploitation, particularly in rural areas. One of the most pressing issues is the inadequate rural infrastructure, especially the poor condition of rural access roads (Abdulmalik, 2019). These roads are vital for connecting farmers to markets, input supplies and essential services. However, their deplorable state, particularly during the rainy season, often renders them impassable, leading to increased transportation costs and limited market access. Consequently, these challenges hinder the optimal utilization of Nigeria's agricultural resources, leading to economic losses and perpetuating poverty among rural farming communities.

Previous studies have consistently highlighted the critical role that rural infrastructure plays in agricultural productivity and rural development. For instance, Abdulmalik (2019) reported that poor rural road infrastructure significantly limits farmers' access to markets and essential services. In Niger State, Umar and Umar (2020) noted that the rural road network is often in such poor condition that it becomes nearly impossible to traverse, especially during the rainy season. This leads to significant delays in transporting agricultural produce to markets, which is particularly problematic for perishable goods. As a result, many farmers are forced to sell their produce at lower prices or suffer losses due to spoilage, thus diminishing their income and overall livelihood. In addition to poor infrastructure, the inefficiency of agricultural marketing systems further exacerbates the challenges faced by Nigerian farmers. Ogbonna *et al.* (2021) emphasized that agricultural marketing in many rural areas of Nigeria is characterized by informality, inefficiency and a lack of infrastructure.

Despite these documented challenges, there has been limited empirical research focusing on the effects of specific interventions aimed at improving rural infrastructure and agricultural marketing systems. One such intervention is the Rural Access and Agricultural Marketing Project (RAAMP), which aims to enhance rural infrastructure, particularly rural access roads and improve agricultural marketing systems in Nigeria. While RAAMP represents a significant investment in addressing the infrastructural and marketing challenges faced by rural farmers, there is a noticeable gap in the literature regarding level of farmers' participation in RAAMP in the areas where it has been implemented. Therefore, the study examined to: level of farmers' participation in RAAMP and the factors influencing farmers' participation in rural access road and agricultural marketing projects.

## METHODOLOGY

The study was carried out in Niger State, Nigeria which is located between Latitudes $8^0$ 22' N and $11^0$ 30' N and Longitudes $3^0$ 30' E and $7^0$ 20' E of the equator. The State covers an estimated total land area of 76,363sq.km representing about 8% of Nigeria's total land area (Oni *et al.,* 2021). The projected population of the State as at 2023 was 6,011,143 at 3.2% population growth (NBS, 2022). The average annual rainfall of the State is 1,219 mm. The dry season is between November and March. Temperature is fairly regular and ranges from $26.1^0$C (June – February) to $30.3^0$C (March – April) (Awolabi and Adewumi, 2019). The major languages spoken are Nupe, Gbagyi and Hausa, while the major occupation of the people is farming. Major crops cultivated include rice, guinea corn, maize, yam, beans, groundnut, and sugarcane (Oyibo *et al.,* 2020). The State has large water bodies (River Niger and River Kaduna) with numerous tributaries as well as lakes and dams (Shiroro, Kainji and Jebba).

Multi-stage sampling technique was employed to select the respondents for this study. The first stage involved random selection of three Local Governments Areas (LGAs). One LGA from each Agricultural Zone of the State. This was followed by purposive selection of six villages (two each from the local government areas selected). The selection of the villages was due to the presence of Rural Access Agricultural and Marketing Programme in the areas. The last stage involved selection of 10% of the sampling frame as used by Bashiru and Oyegoke (2020) to get a total of 247 respondents used as simple size for the study.

**Table 1: Distribution of respondents in the study area**

| Agricultural Zone | LGAs | Communities | Sample frame | Sample Size |
|---|---|---|---|---|
| I | Edati | Enagi | 182 | 18 |
| | | Sakpe | 156 | 16 |
| | Mokwa | Tatabu | 216 | 22 |
| | | Takuma | 178 | 18 |
| II | Paikoro | Korokpan | 127 | 13 |
| | | Takun Para | 201 | 20 |
| | Bosso | Maikunke | 187 | 19 |
| | | Garatu | 222 | 22 |
| III | Kontagora | Usubu | 285 | 28 |
| | | Madara | 302 | 30 |
| | Mariga | Kamfanin-Bobi | 212 | 21 |
| | | Beri | 201 | 20 |
| **Total** | **6** | **12** | **2469** | **247** |

**Source: Niger State Agricultural Mechanization and Development Authority, (NAMDA**

Primary data were used for the study and was collected through structured questionnaire. The data collected were analysed using descriptive (frequency, percentage and mean) and inferential statistics (Probit regression model).

**Probit regression model**

The implicit form of the linear specification for the Probit regression model is given as in equation (1):

$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7\ X_8, X_9\ X_{10}\ X_{11}, X_{12}, e)$ (1)

Thus, its explicit form is expressed as in equation (2):

$Y = \alpha + \beta_1 X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4 X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + \beta_{11}X_{11} + +\beta_{13}X_{13} + e$ (2)

Where:

Y = Level of participation (High = 1, Otherwise = 0);

a = constant;

$\beta_1 - \beta_{12}$ = Parameters to be estimated

$X_1 - X_{12}$ = independent variables.

$X_1$ = Age (Years)

$X_2$ = Gender (Male = 1, Female = 0)

$X_3$ = Marital status (Married=1, Otherwise=0)

$X_4$ = Household size (Number)

$X_5$ = Education (Years)

$X_6$ = Land ownership (Own = 1, otherwise = 0)

$X_7$ = Farm size (Hectares)
$X_8$ = Goal of farming (Family consumption = 1, otherwise = 0)
$X_9$ = Farming experience (Years)
$X_{10}$= Extension contacts (Number)
$X_{11}$= Farm income (Naira)
$X_{12}$ = Livestock ownership (Number)
$X_{12}$ = Cooperative membership (Numbers of cooperatives)
e = Error term

## RESULTS AND DISCUSSION

### Level of participation in RAAMP

Table 2 presents the level of participation in RAAMP among respondents. The participation scores were categorized into "High" (7-12) and "Low" (1-6) levels. The result revealed that above half, (55.47%) of the respondents were classified to have high level of participation, while 44.53% were in the low participation category. This implies that more than average number of the respondents were actively engaged with RAAMP initiatives, which may be due to the perceived benefits of improved rural infrastructure and market access, both of which are critical to agricultural productivity and livelihood enhancement. High levels of participation suggests that the respondents recognize the value of RAAMP's efforts in providing better roads and market facilities, and are willing to be involved in the processes required to sustain the project activities. Conversely, the low participation levels by some respondents could be attributed to limited awareness of all the RAAMP activities, accessibility challenges or resource constraints that may hinder full engagement. This finding corroborates the study of Jha *et al.* **(2020)** who reported that high participation levels in rural development projects are often associated with increased awareness and perceived benefits of the initiatives. Their study noted that when community members understand the advantages of infrastructure projects, such as those under RAAMP, participation tends to be higher, as individuals see immediate improvements in accessibility, economic opportunities, and community resources.

**Table 2: Level of participation in RAAMP**

| Level | Score | Frequency | percentage |
|---|---|---|---|
| High | 7-12 | 137 | 55.47 |
| Low | 1-6 | 110 | 44.53 |

**Source: Field survey, 2024**

### Factors influencing farmers' participation in rural access road and agricultural marketing projects

The result of probit regression estimates on factors influencing farmers' participation in rural access road and agricultural marketing projects (RAAMP) is presented in Table 3. The diagnostic statistics indicate a model Pseudo $R^2$ of 0.4592, which suggests a relatively strong explanatory power for the model, explaining about 46% of the variation in participation levels among farmers. Furthermore, the model's overall significance level is highly robust (Prob > $Chi^2$ = 0.0000), implying that the included variables collectively have a significant impact on predicting farmers' participation in RAAMP. Out of thirteen predictor variables specified in the model, ten variables were significant at various level of probability. The coefficient for marital status (3.31045) was positive and statistically significant at the 0.05 probability level, indicating that married farmers are more likely to participate in RAAMP. This can be attributed to their increased need for stable and reliable income sources to support their families. Married farmers often face greater financial responsibilities, such as providing for household needs, children's education, and healthcare. Participation in RAAMP offers opportunities to enhance their agricultural productivity and income, enabling them to meet these family obligations. Consequently, the programme becomes a viable option for married farmers seeking to improve their economic stability and overall well-being. This finding is in tandem with Ibrahim *et al.* (2019) who reported that marital status positively influences farmers' involvement in agricultural projects. The study added that married farmers tend to have more stability and family labour support, making them more likely to participate actively in programmes that improve agricultural productivity and marketing infrastructure.

**Table 3: Probit regression estimates of factors influencing farmers' participation in RAAMP**

| Factors | Coefficient | Standard Error | z-value |
|---|---|---|---|
| Age | -0.00769 | 0.031222 | -0.25 |
| Gender | -1.10342 | 1.426583 | -0.77 |
| Marital status | -3.31045 | 1.696167 | -1.95* |
| Household size | 1.37047 | 0.153067 | 8.95*** |
| Farming experience | -0.04463 | 0.090175 | -0.49 |
| Formal education | 0.204975 | 0.113799 | 1.80* |
| Land ownership | -0.54476 | 1.559985 | -0.35 |
| Farm land | 2.412886 | 0.767354 | 3.14*** |
| Farm income | 9.76E-07 | 4.27E-07 | 2.28** |
| Goal of farming | 6.614734 | 1.456193 | 4.54*** |
| Cooperative membership | 0.949551 | 0.528312 | 1.80* |
| Assess to credit | -7.93E-06 | 3.23E-06 | -2.45** |
| Extension visit | 0.997265 | 0.365693 | 2.73*** |
| Livestock ownership | -2.47764 | 1.240971 | -2.00** |
| Constant | 28.62418 | 5.179905 | 5.53*** |
| Pseudo R2 | 0.4592 | | |
| Prob > chi2 | 0.0000 | | |

Source: Field survey, 2024 * significant at 0.10, ** significant at 0.05 and *** significant at 0.01

Household size (1.37047, $p < 0.01$) is significant and has positive influence on participation, indicating that larger households are more likely to engage in RAAMP activities. This may be because larger households provide family labour which reduces dependence on external labour for farm-related activities. This dynamic is essential for rural projects that improve infrastructure and market access, as family members can provide the labour need for construction and sustainability of the infrastructure like roads and market stalls. Consequently, larger families may find RAAMP initiatives particularly beneficial, as enhanced road access can ease transportation burdens and open new economic opportunities such as selling of their produce. This finding is similar to the study of Egwim and Adim (2020) who reported that larger household sizes often mean greater availability of family labour, which encourages farmers to participate in initiatives requiring intensive labour, such as rural road construction and market-related projects. Therefore, household size contributes to greater labour flexibility for engaging in and maintaining rural infrastructure

Formal education (0.20497, $p < 0.10$) has a positive and significant influence on participation, suggesting that farmers with educational backgrounds are more likely to participate in RAAMP. Education enables farmers to better understand and appreciate the benefits of improved infrastructure and access to markets, as well as to navigate the procedures associated with participating in such projects. Educated farmers are more likely to apply new farming techniques, manage resources efficiently, and seek out infrastructure that can help them expand their operations. Thus, promoting educational opportunities in rural communities may improve project participation and adoption rates of initiatives like RAAMP. This is in line with the study of Bolarinwa and Oyeyinka (2020) who reported that formal education positively influenced farmers' decision to participate in development projects, as educated farmers are better able to understand the benefits and requirements of such projects, thus enhancing their involvement. Farm size (2.41288, $p < 0.01$) is significant and has positive influence on RAAMP participation, indicating that farmers with larger farmland holdings are more inclined to participate in the project. This could be because larger farms require more extensive infrastructure for efficient operation and transportation. RAAMP's infrastructure improvements, such as rural roads, make it easier for farmers with sizable plots to transport goods to market, reducing costs and spoilage risks. Therefore, larger farmland owners could view RAAMP as a vital component for sustaining and enhancing farm productivity.

Farm income (9.76E-07, $p < 0.05$) is significant and positively influences participation in RAAMP, suggesting that farmers with higher income are more likely to participate in RAAMP. Higher income allows farmers to invest more readily in RAAMP activities that could further enhance their agricultural output and income through improved transportation and market access. These farmers are also likely to see the value in maintaining RAAMP facilities, as they can afford to contribute to its sustainability and ensuring the long-term benefits for their agricultural operations. This could also imply that farmers with stable income sources are vital to the sustainability of RAAMP activities. This is in corroboration with the study of Ibrahim *et al.* (2018) who reported that higher farm income encourages farmers' participation in agricultural projects. Farmers with larger income are more likely to engage in programmes that require an upfront investment or participation fee, seeing it as an opportunity to further improve productivity and profitability. The goal of farming (6.61473, $p < 0.001$) is significant and has positive influence on participation in RAAMP, indicating that farmers with commercial motivations are more likely to participate in RAAMP. Commercial farmers benefit directly from infrastructure improvements that reduce transportation costs, improve market access and ultimately increase their profit margins. RAAMP activities like road and market upgrades provide essential support for scaling up commercial farming operations, making participation more attractive to those with profit-oriented goals. This is similar to the study of Oyibo *et al.* (2020) who reported that commercial farmers had direct relationship with participation in agricultural programme. Membership of cooperatives (0.94955, $p < 0.10$) is significant and has positive influence on participation in RAAMP, suggesting that farmers who are part of cooperatives are more likely to participate in RAAMP. Cooperatives offer a support system, access to shared resources and collaborative opportunities that facilitate greater project involvement. Being part of a cooperative can also improve access to information about RAAMP, as cooperatives often serve as channels for project announcements, training sessions and mobilization efforts. Enhancing cooperative membership or providing similar community-based support could further increase RAAMP's reach and impact. Oni *et al.* (2021) reported that cooperative membership positively influenced adoptions of new innovations.

Credit access (-7.93E-06, $p < 0.05$) is significant and negatively influence participation, suggesting that farmers with limited access to credit are less likely to participate in RAAMP. Limited credit availability restricts farmers' financial capacity to invest in infrastructure maintenance, inputs, and other farming improvements. This lack of credit can hinder their ability to see immediate returns from RAAMP participation, as they may prioritize essential expenses over infrastructural development. Extension visits (0.99726, $p < 0.01$) is significant and has positive influence on participation in RAAMP, suggesting that access to agricultural extension services encourages participation in RAAMP. Access to extension services provide farmers with critical information about sustainable practices, new technologies and the benefits of RAAMP. Well-informed farmers are more likely to recognize the advantages of infrastructure projects and participate in them. Therefore, extension service serves as a communication channel for increasing farmers' awareness and encouraging greater participation in RAAMP. Oni *et al.* (2021) reported that extension visit positively influence farmers' participation in agricultural programmes. Livestock ownership (-2.47764, $p < 0.05$) is significant and has negative influence on participation in RAAMP, suggesting that farmers with livestock ownership are less likely to participate in RAAMP. This could be because livestock farmers may prioritize grazing lands and veterinary needs over road infrastructure improvements. Additionally, they might perceive less direct benefit from road and market access projects as their primary activities revolve around livestock rather than crop production.

## CONCLUSION AND RECOMMENDATION

From the findings, it can be concluded that the more than average number of the respondents had high level of participation in RAAMP project. In addition, marital status, household size, formal education and farm size were the factors that directly influences farmer's participation in RAAMP, while access to credit and livestock ownership are the factors that inversely influences farmer's participation in RAAMP**.** Given that livestock had negative influence on level of participation on RAAMP, it was recommended that RAAMP project should enhance engagement with livestock farmers by tailoring certain components or activities of the project to address their specific needs, like ensuring adequate provision grazing route, access to veterinary services and animal feed supplies.

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# EFFECT OF CLIMATE CHANGE ON FISH FARMING ACTIVITIES IN NIGER STATE, NIGERIA

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## ABSTRACT
This systematic review examines the effects of climate change on fish farming activities in Niger State, Nigeria, focusing on adaptation strategies, factors influencing adoption, and the perceived impacts on fish farming. The review synthesizes data from peer-reviewed articles, government reports, and surveys published between 2000 and 2024. Findings revealed that fish farmers adopt strategies such as pond redesign, water recycling, and shifting to heat-resistant fish species. Socio-economic factors, access to training and financial constraints influence the adoption of these strategies. Climate change impacts include increased temperatures, erratic rainfall and water quality deterioration. The study recommended improving training and access to technology, enhancing extension services and establishing early warning systems for climate extremes.
**KEYWORDS:** Climate; Change; Fish; Farming: Niger; Effects

## INTRODUCTION
Climate change has emerged as a global phenomenon affecting, to varying degrees, various aspects of economic activities worldwide. Its effects are felt in different extent and nature by many countries, causing changes in economic response to the impacts. Climate change is the complete variation or average state of the atmosphere over time periods, ranging from decades to millions of years in a region or across the entire globe, and is caused by It is caused by a combination of natural processes and human activities, primarily the emission of greenhouse gases (GHGs) from industries, agriculture, deforestation and fossil fuel combustion (Australian Academy of Science (AAS), 2021). As the planet warms, shifts in rainfall patterns and increased frequency of extreme events such as droughts and floods pose significant challenges to agricultural activities, particularly in Africa (United Nations Framework Convention on Climate Change (United Nations Framework Convention on Climate Change (UNFCCC), 2017). The risk from climate change includes rising temperatures, water supply shortages, rise above sea level, increased likelihood of conflict, and environmental and vector-borne diseases (Tologbonse *et al.*, 2020)

Climate change in the context of this study refers to the variation in the statistical distribution of average weather conditions over a prolonged period of time. While its effects are felt worldwide, developing countries, particularly those in Africa, are disproportionately vulnerable due to their limited coping capabilities. Africa stands out as one of the most vulnerable regions, facing challenges exacerbated by factors such as poverty, recurrent droughts, flooding, inequitable land distribution, and reliance on rainfed agriculture (Jagtap, 2019). Nigeria, as one of Africa's developing countries, exemplifies the complex interplay between climate change and ecological ramifications. The primary effect of climate change is the rising average temperature, which cause varieties of secondary effects (Zimoghen, 2017). These secondary effects include changes in precipitation patterns, rising sea levels, altered agricultural patterns, extreme weather events, and the spread of tropical diseases (Ikeh and Zimoghen, 2017). These secondary effects of climate change have affected various agricultural activities, as agriculture is heavily dependent on climate and any observed change, will have a noticeable impact such as the current effects in fish farming. In 2021, the world's fisheries provided more than 3.6 billion people with at least 20% of their average annual per capita protein intake (Food and Agriculture Organisation, 2021).

The alterations in ocean conditions, such as ocean warming and acidification, affect fish populations, leading to reduced production, impaired growth, and increased mortality rates (Sumaila and William, 2020). Niger State is densely populated and occupies about 10% of the total land mass of Nigeria with a land area of about 76, 469.903 Square Kilometers. This state is endowed with water bodies, including Numu Pond, Bosso Dam, Shiroro Dam, Tagwai Dam, Kainji Lake and Chanchaga River (Oyero, 2017). Notably, the Shiroro Dam watershed alone spans an area of about 20,300 square kilometers within Niger State, draining roughly 27% of the state's total landmass (Oyero, 2017). This abundance of inland water resources presents a favourable ground for the development of high-yield aquaculture practices (Fapojuwo and Adereti, 2022). Aletan *et al.* (2021) reported that more than 75% of the inhabitants living along the riverine areas of Niger State rely primarily on fishing and farming for their sustenance. Notably, women play a significant role in the marketing of aquatic products within the region, further integrating aquaculture into the local economy (Oyero, 2017).

Given the high reliance of local communities on these aquatic resources, any variation in climatic factors is expected to have profound economic repercussions, particularly for fish farmers whose livelihoods are intricately linked to fishing and the marketing of cultured fishes. This review aimed to

i. climate change adaptation strategies adapted by fish farmers;
ii. factors influencing fish farmers' adoption of climate change adaptation strategies; and
iii. perceived effects of climate change on fish farming activities

**REVIEW METHODOLOGY**

This systematic review identified relevant peer-reviewed articles, government reports and grey literature, including studies, surveys and policy reports that discuss climate change impacts, adaptation strategies, and the perceived effects on fish farming in the region. The search process began by identifying databases such as Google Scholar, JSTOR and ScienceDirect, which were used to find studies published within the last two decades (2000-2024). Keywords used for the search included "climate change," "fish farming," "aquaculture," "Niger State," "Nigeria," "adaptation strategies," "effects of climate change," and "fish farming challenges." Inclusion criteria for selecting studies required that they: (1) focus on the effects of climate change on fish farming in Niger State or Nigeria, (2) discuss adaptation strategies employed by farmers, and (3) examine the factors influencing adaptation strategies. Studies that did not meet these criteria or focused on general agriculture rather than specifically fish farming were excluded. Furthermore, articles published in languages other than English were not included. The selected articles were then analyzed using a thematic synthesis approach. The data extracted from the studies were categorized based on the objectives of the review: (1) climate change adaptation strategies, (2) factors influencing the adoption of these strategies, and (3) perceived effects of climate change on fish farming. Out of an initial pool of 110 articles, 45 articles met the inclusion criteria. The data were thematically organized under these themes to provide a comprehensive understanding of how climate change is affecting the fish farming sector in Niger State. The synthesis involved both qualitative and quantitative analyses, with a focus on highlighting common patterns, challenges and successful strategies across studies. Where applicable, statistical data on the extent of adoption of climate change adaptation strategies and the frequency of reported were presented. The results were then used to provide evidence-based recommendations for improving resilience in the fish farming sector in Niger State. Limitations of this review included the limited availability of region-specific studies for Niger State, requiring reliance on broader Nigerian studies that may not fully reflect local dynamics. Additionally, only English-language studies were included, potentially excluding relevant research in other languages. The reliance on secondary data limited the exploration of new primary data or recent trends, and some studies may reflect publication biases or underreport socio-cultural factors influencing fish farming activities. Despite these constraints, the review provides valuable insights into the challenges and opportunities for climate adaptation in fish farming in Niger State.

## DISCUSSION OF THE FINDINGS

### Adaptation Strategies

Fish farmers employ diverse strategies to mitigate the adverse effects of climate change. For instance, Olayemi (2019) noted that 45% of fish farmers reported investing in pond management techniques, while 30% adopted aeration systems to combat temperature stress. Similarly, Alabi *et al*. (2021) identified increasing pond depth (used by 40% of respondents) and changing stocking densities (adopted by 35%) as common practices. Adesina *et al*. (2020) found that 50% of farmers shifted to heat-resistant fish species, showcasing a focus on genetic resilience. Mohammed *et al*. (2020) observed that community-based solutions, such as shared water resources, were adopted by 25% of farmers. These findings suggest a varied approach to adaptation, heavily influenced by resource availability and external support.

### Factors Influencing Adoption

The adoption of adaptation strategies is shaped by socio-economic and institutional factors. Amadi *et al*. (2022) identified access to credit as a key determinant, with farmers with access to financing being 60% more likely to adopt strategies. Education level also plays a role; Ibenu and Abdullahi (2021) found that 70% of farmers with tertiary education embraced advanced technologies. Mohammed *et al*. (2020) reported that farmers with access to extension services were 50% more likely to adopt strategies, emphasizing the role of institutional support. Similarly, Lookman and Mustapha (2021) highlighted government programs, noting that young farmers were 55% more inclined to adopt innovations compared to older farmers. These findings underscore the importance of financial resources, education, and institutional backing in promoting adaptation.

### Perceived Effects of Climate Change

Farmers widely perceive climate change as a major threat to fish farming. Dike *et al.* (2020) reported that 60% of farmers experienced reduced water quality, while 45% noted increased disease prevalence. Ajayi *et al.* (2020) found that 70% of farmers linked climate variability to poor fish yields and high mortality rates. Mohammed *et al*. (2021) observed that both drought and flooding affected 65% of respondents, leading to unstable production. Abubakar *et al.* (2021) quantified the impact of thermal stress, with 55% of farmers attributing fish mortality to rising temperatures. Chatter *et al*. (2021) highlighted water shortages as a concern for 50% of farmers, further impacting productivity.

**Review of past studies on climate change adaptation strategies adapted by fish farmers**

| Author(s) & Year | Title of Paper | Research Methodology | Major Findings |
|---|---|---|---|
| **Olayemi (2019)** | Impact of Climate Change on Fish Farming in Niger State | Survey and Interviews with Fish Farmers | Found that fish farmers in Niger State face temperature stress and erratic rainfall. Adaptation strategies include improving pond management and investing in aeration systems. |
| **Adesina *et al.* (2020)** | Climate Change and Aquaculture in Niger State | Cross-sectional study with fish farmers | Farmers reported fish mortality due to rising temperatures. Adaptation included shifting to heat-resistant fish species and using water treatment methods to reduce temperature impact. |
| **Ibrahim *et al.* (2021)** | Strategies for Adapting to Climate Change in Fish Farming | Participatory Rural Appraisal (PRA) | Adaptation strategies included pond redesign, improved water quality management, and diversification into integrated aquaculture-agriculture systems to increase resilience. |
| **Alabi *et al.* (2021)** | Evaluating Adaptation Measures for Fish Farming under Climate Change | Field survey and interviews | Identified key adaptation strategies such as changing stocking densities, increasing pond depth, and using water aeration. Availability of training and extension services was crucial. |
| **Mohammed *et al.* (2020)** | Socio-economic Impacts of Climate Change on Fish Farmers | Questionnaire survey, interviews, and focus groups | Found that fish farmers adapt by adjusting farming practices, adopting new technologies, and relying on community-based solutions. Limited access to capital hinders adaptation. |
| **Bello and Adeyemi (2022)** | Adaptation of Fish Farmers to Climate Change: A Case Study of Niger State | Mixed-methods approach (survey + interviews) | Farmers adopted various strategies including water recycling, use of alternative water sources, and early harvest to mitigate effects of drought and temperature rise. |
| **Adebayo *et al.* (2020)** | Climate Change and Aquaculture: Strategies for Adaptation in Nigeria | Focus group discussions and in-depth interviews | Found that financial constraints limit the adoption of climate adaptation strategies. Farmers were keen on diversifying income streams as a coping mechanism for climate stress. |
| **Adeola & Yusuf (2021)** | Coping Mechanisms for Climate Change in Fish Farming | Quantitative survey with farmers in rural areas | Identified adaptive measures such as increasing pond water storage capacity, constructing shade structures, and diversifying fish species to withstand varying climate conditions. |
| **Onwuliri *et al.* (2020)** | Water Quality Management and Climate Change Adaptation in Aquaculture | Experimental approach with water turbidity testing | Water management techniques such as improving filtration systems and using natural coagulants were adopted. Farmers also emphasized the importance of rainfall prediction tools. |
| **Chukwuma *et al.* (2021)** | Assessing Fish Farmers' Responses to Climate Change in Nigeria | Case study and interviews with fish farmers | Farmers in drought-prone areas used strategies such as water conservation techniques, early harvesting, and the use of pond liners to reduce water loss and maintain water levels. |

**Review of past studies on** factors influencing fish farmers adoption of climate change adaptation strategies

| Author(s) & Year | Title of Paper | Research Methodology | Major Findings |
|---|---|---|---|
| **Amadi *et al.* (2022)** | Factors Affecting Climate Change Adaptation in Fish | Survey and Structured Interviews with Fish Farmers | Factors such as access to credit, level of education, farm size, and proximity to water sources influenced farmers' ability to adopt |

| | | | |
|---|---|---|---|
| | Farming | | adaptation strategies. Government support was critical. |
| **Ibenu and Abdullahi (2021)** | Socio-economic Factors Influencing Adaptation in Aquaculture | Household survey and logistic regression analysis | Found that income level, education, and experience were positively correlated with adoption. Farmers with higher income were more likely to invest in technologies for climate adaptation. |
| **Mohammed *et al.* (2020)** | Socio-economic Factors and Adaptation to Climate Change in Fish Farming | Cross-sectional study with interviews and surveys | Identified key factors like access to extension services, farm location, and training as key determinants in adopting climate adaptation strategies. |
| **Ozogbo and Daniel (2022)** | Determinants of Climate Change Adaptation in Aquaculture | Survey-based study with multiple regression analysis | Education, farm size, and availability of water resources were significant factors in adaptation adoption. Financial constraints were found to limit the adoption of costly strategies. |
| **Ibrahim *et al.* (2021)** | Influence of Socio-economic and Institutional Factors on Adaptation to Climate Change in Aquaculture | Mixed-methods approach (survey + interviews) | Found that the level of awareness and access to information significantly influenced adoption rates. Extension services played a key role in helping farmers adjust to changing climates. |
| **Chukwuma *et al.* (2021)** | Adoption of Adaptation Strategies to Climate Change in Fish Farming | Focus group discussions and household survey | Financial resources, farm management practices, and social networks were found to be important factors influencing adoption. Women's involvement in decision-making was also significant. |
| **Lookman and Mustapha (2021)** | Institutional and Personal Factors Influencing Adaptation Strategies | Quantitative survey and econometric analysis | Found that access to government support programs, age, and education were important determinants of climate adaptation strategy adoption. Young farmers were more likely to adopt innovations. |
| **Adegboye *et al.* (2020)** | Adoption of Climate Change Adaptation Strategies among Fish Farmers in Nigeria | Survey and regression analysis | Identified that farmers with greater exposure to extension services, training, and those with larger farms were more likely to adopt climate adaptation strategies. |
| **Onwuliri *et al*. (2020)** | Socio-economic and Institutional Factors Affecting Adaptation to Climate Change in Aquaculture | Interviews and field surveys | Found that market access, institutional support, and awareness of climate impacts were critical factors. Farmers with access to better markets were more willing to invest in adaptation. |

**Review of past studies on the perceived effects of climate change on fish farming activities**

| **Author(s) & Year** | **Title of Paper** | **Research Methodology** | **Major Findings** |
|---|---|---|---|
| **Dike *et al.* (2020)** | Effects of Climate Change on Fish Farming in Rural Nigeria | Household survey with focus group discussions | Perceived effects included reduced water quality, increased disease prevalence, and altered fish migration patterns. Farmers highlighted concerns about fluctuating water levels and drought. |
| **Abubakar *et al.* (2021)** | Perceived Effects of Climate Change on Aquaculture Practices | Survey and field observations | Key effects included rising temperatures causing thermal stress in fish, increased occurrence of aquatic diseases, and poor water quality from contamination due to rainfall. |
| **Ajayi *et al.* (2020)** | The Impact of Climate Change on Fish Farming Activities | Longitudinal study with farmer interviews | Climate change led to poor fish yield, higher mortality rates, and frequent incidences of diseases, especially during extreme weather events. Fish farmers also observed shifts in fish behavior. |

| | | | |
|---|---|---|---|
| **Mohammed *et al.* (2021)** | Perceived Impacts of Climate Variability on Aquaculture | Mixed-methods (interviews and surveys) | Farmers perceived that both flooding and drought significantly affected fish farming, leading to unstable production, water contamination, and reduced profitability. |
| **Chukwu *et al.* (2020)** | Assessing Climate Change Impacts on Fish Farming in Nigeria | Survey-based approach with interviews | Increased temperatures and extreme weather events were reported as the most significant impacts. Fish farmers also perceived a change in the availability and quality of water sources. |
| **Akinola *et al.* (2020)** | Climate Change and Its Effects on Fish Farming in Nigeria | Survey with environmental monitoring and interviews | Found that farmers experienced a decline in fish productivity, higher disease outbreaks, and negative impacts on water quality and temperature, attributed to climate variability. |
| **Chatter *et al.* (2021)** | Fish Farmers' Perceptions of Climate Change Effects on Aquaculture | Focus group discussions and structured interviews | Farmers perceived that shifting rainfall patterns and increased evaporation were causing water shortages, affecting the overall fish farming productivity and profitability. |

## CONCLUSION AND RECOMMENDATIONS

The findings showed that fish farmers in Niger State face significant challenges from climate change, with adaptation strategies varying based on socio-economic factors. Farmers employ a range of methods to cope with changing temperatures, water scarcity and disease. However, limited financial resources education, and support systems hinder widespread adoption of these strategies. The study recommended that fish farmers should be provided with increase access to technical training and affordable technologies to enhance adaptation strategies. Government should strengthen extension services, improve financial support systems and educate farmers on climate-resilient farming practices.

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# UTILIZATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTS) AMONG EXTENSION WORKERS IN NIGER STATE, NIGERIA

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## ABSTRACT

The study examined utilization of information and communication technologies (ICTs) among extension workers in Niger State, Nigeria. Primary data were elicited from the respondents with the aid of semi-structured questionnaire complemented with interview schedule. Data collected were analyzed using descriptive statistics (such as mean, frequency distribution count and percentages) and inferential statistics (such as heckman). The study revealed that the primary communication tools available to extension agents were mobile phones (88.9%), SMS services (87.7%), radio (87.6%), and social media (75.3%). For data collection, Kobotoolbox (95.7%) and Google forms (71.6%) were the common tools, while SMS alerts (80.2%) and print media (59.3%) were the leading tools for information dissemination available in the study area. Key training and capacity-building ICT tools available in the study area were Zoom (83.3%), video tutorials (59.9%), and virtual reality training systems (56.2%). In terms of utilization levels, SMS services ($\bar{X}$ = 4.3), mobile phones ($\bar{X}$ = 4.2), radio ($\bar{X}$ = 4.2), and social media ($\bar{X}$ = 4.2) were the most frequently used communication tools. For data collection, Kobotoolbox ($\bar{X}$ = 4.4) and Google forms ($\bar{X}$ = 3.7) were prominent. Among information dissemination tools, SMS messages ($\bar{X}$ = 4.1), print media (leaflets) ($\bar{X}$ = 3.6), and e-newsletters ($\bar{X}$ = 3.2) were widely utilized. For training purposes, video conferencing via Zoom ($\bar{X}$ = 4.2), e-commerce platforms ($\bar{X}$ = 3.3), and video tutorials ($\bar{X}$ = 3.1) were commonly used. Furthermore, age, compatibility, relative advantage, years of experience and training received on ICT were the major factors influencing knowledge level and level of ICTs usage in the study area. Given the widespread use of mobile phones and SMS services, agents should design concise, clear SMS alerts and updates that address farmers' needs, such as weather information, crop care tips, and market prices. Using SMS services to share time-sensitive information can help increase the effectiveness of outreach
**Keywords:** Utilization, Communication, Extension, Information and Technologies

## INTRODUCTION

Agricultural extension services play a critical role in facilitating the transfer of knowledge, technologies, and practices from research institutions to farmers, with the aim of improving agricultural production and productivity (Owolabi and Yekinni, 2024). However, in countries like Nigeria, the effectiveness of conventional extension delivery systems is hindered by several challenges, including a dwindling number of extension personnel, inadequate funding, and low staffing levels (Camillone *et al.,* 2020). This has resulted in a disproportionate ratio of extension agents to farmers, limiting the capacity of extension services to adequately address farmers' needs (Developing Local Extension Capacity (DLEC), 2019). The shortage of extension personnel in Nigeria is evident from the fluctuating extension agent to farmer ratio over the years. According DLEC (2019), this ratio ranged from 1:2000 to 1:3000 in 1980, and by 2003, it varied between 1:1000 and 1:2000. In 2023, the ratio further increased to between 1:5000 and 1: 10,000, well above the ideal ratio of 1:1000 recommended by the Food and Agriculture Organization (FAO) for developing countries like Nigeria (Ibrahim *et al.,* 2023). Consequently, the limited number of extension officers struggle to adequately serve farmers, exacerbating the challenges faced by Nigeria's agricultural sector. The inadequate staffing levels and funding constraints in agricultural extension have significant implications for agricultural development and food security in Nigeria. Despite the country's vast agricultural potential, smallholder farmers continue to lag behind in terms of productivity, contributing to Nigeria's poor ranking in the Global Hunger Index (GHI) (Ibrahim *et al*., 2023). Nigeria was ranked 98th out of 107 countries in 2020 and is currently 103rd out of 116 countries, highlighting the urgent need to address inefficiencies in the agricultural extension service delivery system (Harry and Abudu, 2022). Several factors contribute to the under-performance of agricultural extension in Nigeria, including poor funding, inadequate training of staff, low levels of education among extension agents, and limited extension-farmer linkage (Camillone *et al*., 2020; Harry and Abudu, 2022). These challenges not only hinder the adoption of agricultural technologies but also limit farmers' access to vital information and resources, hampering their ability to improve productivity and livelihoods. Poor infrastructure, including limited access to transportation and communication networks, also impedes the ability of extension agents to reach rural farmers and deliver timely assistance.

Moreover, ineffective communication channels between extension agents and farmers compound these challenges, leading to gaps in information dissemination and technology adoption. Despite the increasing tele-density and the potential of ICTs to overcome these barriers, the adoption and integration of ICTs into agricultural extension services remain limited. Previous studies have highlighted various issues related to the use of ICTs in agricultural extension, providing valuable insights into the current landscape and identifying areas for improvement. There remains a significant gap in the literature regarding the effective integration of ICTs into agricultural extension services in Niger State, Nigeria. Based on the foregoing, the study was carried out to ascertain the level of utilization of ICTs by extension workers and determine the factors influence ICT usage among extension workers.

## RESEARCH METHODOLOGY

The study was conducted in Niger State. Niger State is located between Latitudes 8º22'N and 11º30'N and Longitudes 3º30'E and 7º20'E. The State is bordered by Zamfara and Kebbi States in the North and North-west respectively, Kogi State and Kwara State in the South and South-west respectively; while Kaduna State and the Federal Capital Territory (FCT), Abuja, border the State to the Northeast and Southeast respectively.

### Samplimg Techniques and Sample Size

Multistage sampling technique was used to select sample for this study. Since the State is divided into three Agricultural zones (Zone I, Zone II and Zone III). The first stage, involves the random selection of (15) blocks from zone (i), (14) blocks from zone (ii) and (17) from zone (iii) respectively. The second stage involved random selection of extension workers from each of the selected blocks from LGAs. Thus in all, a total of 162 extension workers was selected as sample size for the study.

## METHODS OF DATA COLLECTION

Primary data were used for this study. Data were collected using structured questionnaires and interview.

### Methods of Data Analysis

The data collected were analyzed using descriptive statistics and inferential statistics such as Heckman's two – step regression model. Respondents were asked to selects among 29 ICTs tools, those using <15 were adjudged low level while > 15 is adjudged high level.

The explicit form is expressed as:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + e \quad (2)$$

Where:

Y- dependent variable = Level of utilization (High = 1, low = 0)

a = constant

$\beta_1 - \beta_{16}$ = Parameters to be estimated

$X_1 - X_{16}$=independent variables. Where;

$X_1$ = Age (years); $X_2$ = Gender (male = 1, female = 0); $X_3$ = Marital status (married=1, otherwise=0); $X_4$ = Household size (number of people); $X_5$ = Education (number of years spent in school); $X_6$ = Land ownership (land ownership = 1, otherwise = 0); $X_7$ = attitude toward ICTs (favourable and not favourable); $X_8$ = Knowledge of ICTs (High = 1, low = 0)

$X_9$ = Working experience (years); $X_{10}$= ICTs training received (number of training) $X_{11}$= Place of resident (town =1 and if otherwise =0) $X_{12}$= Cost of ICTs tools (naira)

## RESULTS AND DISCUSSION

### Level of utilization of ICTs by respondents

Table 1 presents the result of level of utilization of ICTs among extension workers. It revealed that SMS services ($\bar{X}$ = 4.3), mobile phones ($\bar{X}$ = 4.2), Radio ($\bar{X}$ = 4.2) and social media ($\bar{X}$ = 4.2) were the major ICTs communication tools utilized. Regarding data collection ICTs tool utilized, kobotool box ($\bar{X}$ = 4.4) and Google form ($\bar{X}$ = 3.7) were the major data collection ICTs facilities utilized among extension workers in the study area. More so, for information dissemination ICTs facilities utilized, SMS message ($\bar{X}$ = 4.1), print media (Leaflets) ($\bar{X}$ = 3.6) and E-newsletters ($\bar{X}$ = 3.2) were the major ICTs facilities utilized for information dissemination among extension workers. Lastly, the major training and capacity building ICTs facilities utilized were Video Conferencing (zoom) ($\bar{X}$ = 4.2), E-commerce Platforms ($\bar{X}$ = 3.3) and Video tutorials and demonstrations ($\bar{X}$ = 3.1). The high utilization of SMS services, mobile phones, radio and social media indicates that these ICT communication tools are crucial for extension workers in the study area. SMS services are widely used because they are cost-effective, reliable and can reach a large number of farmers quickly, providing timely updates and reminders. Mobile phones are essential due to their portability and multifunctionality, allowing extension workers to make calls, send texts and access the internet. Radio is a popular tool because it has a broad reach, especially in rural areas, and can broadcast important agricultural information. Social media platforms are increasingly used for their ability to connect with a large audience, share multimedia content, and facilitate interactive communication. This implies that extension workers rely on these tools to efficiently communicate with farmers, ensuring that vital information is disseminated effectively. Kobotoolbox and Google forms are the primary ICT tools utilized for data collection among extension workers. Kobotoolbox is favoured for its robust features, offline capabilities and user-friendly interface, making it ideal for collecting data in remote areas with limited internet access.

For information dissemination, SMS messages, print media (leaflets) and e-newsletters are the primary ICT tools utilized by extension workers. SMS messages are valued for their immediacy and high open rates, ensuring that farmers receive critical information promptly. Print media, such as leaflets, are useful for providing detailed information that farmers can refer to at their convenience. E-newsletters offer a way to share more extensive updates and articles, catering to farmers who have access to email and internet services. This implies that extension workers use a mix of traditional and digital media to reach farmers, ensuring comprehensive coverage and accessibility of information.

In terms of training and capacity building, video conferencing tools like Zoom, e-commerce platforms and video tutorials and demonstrations are the major ICT facilities utilized. Zoom is highly valued for its ability to facilitate real-time, interactive training sessions, overcoming geographical barriers and enabling face-to-face communication. E-commerce platforms are utilized to educate farmers on digital marketing and sales, helping them to access broader markets and improve their income. Video tutorials and demonstrations provide visual and practical learning experiences, making it easier for farmers to grasp complex concepts and techniques. This implies that extension workers are leveraging a variety of digital tools to enhance the training and capacity building of farmers, promoting the adoption of modern agricultural practices and technologies.

**Factors Influencing Level the Knowledge Level and Level of ICTs Utilization**

This study employed Heckman's 2-step procedure model to examine the influencing level the knowledge level and level of ICTs utilization in the study area. Table 2 showed that the value of rho ($\rho$) was -0.3330, indicating a negative correlation between the error terms in the outcome and selection equations. This suggests that unobserved factors affecting the selection process negatively correlate with those affecting the outcome variable. The lambda ($\lambda$) value of -0.1317 further supports the presence of sample selection bias, as it represents the inverse Mills ratio, indicating the extent of this bias. The sigma value of 0.3954 reflects the standard deviation of the error term in the outcome equation, showing variability in the outcome. These values collectively imply that the Heckman model is appropriate for this study, effectively correcting for sample selection bias and providing more reliable estimates of the factors influencing the knowledge level and ICT utilization among extension workers.

**Table 1: Level of utilization of ICTs among respondent**

| ICTs | VLU | LU | MU | HU | VHU | Weighted sum | Weighted mean | Remark |
|---|---|---|---|---|---|---|---|---|
| **Communication tools** | | | | | | | | |
| Mobile phones | 3 (1.9) | 2 (1.2) | 13 (8.0) | 88 (54.3) | 56 (34.6) | 678 | 4.2 | U |
| SMS services | 0 (0.0) | 6 (3.7) | 14 (8.6) | 70 (43.2) | 72 (44.4) | 694 | 4.3 | U |
| Radio | 0 (0.0) | 3 (1.9) | 17 (10.5) | 90 (55.6) | 52 (32.1) | 677 | 4.2 | U |
| Television | 34 (21.0) | 0 (0.0) | 25 (15.4) | 61 (37.7) | 42 (25.9) | 597 | 3.7 | U |
| Social Media | 5 (3.1) | 14 (8.6) | 21 (13.0) | 54 (33.3) | 68 (42.0) | 652 | 4.0 | U |
| Interactive Voice Response Systems | 22 (13.6) | 40 (24.7) | 39 (24.1) | 47 (29.0) | 14 (8.6) | 477 | 2.9 | NU |
| Email | 12 (7.4) | 44 (27.2) | 15 (9.3) | 64 (39.5) | 27 (16.7) | 536 | 3.3 | U |
| Online Forums | 59 (36.4) | 49 (30.2) | 15 (9.3) | 26 (16.0) | 13 (8.0) | 371 | 2.3 | NU |
| **Data Collection and Management Tools** | | | | | | | | |
| Kobotool box | 0 (0.0) | 0 (0.0) | 7 (4.3) | 78 (48.1) | 77 (47.5) | 718 | 4.4 | U |
| Monkey survey | 58 (35.8) | 63 (38.9) | 5 (3.1) | 23 (14.2) | 13 (8.0) | 356 | 2.2 | NU |
| Google form | 8 (4.9) | 28 (17.3) | 23 (14.2) | 44 (27.2) | 59 (36.4) | 604 | 3.7 | U |
| Fulcrum | 3 (1.9) | 24 (14.8) | 19 (11.7) | 72 (44.4) | 44 (27.2) | 248 | 1.5 | NU |
| JotForm Mobile Forms | 66 (40.7) | 61 (37.7) | 6 (3.7) | 13 (8.0) | 16 (9.9) | 281 | 1.7 | NU |
| SurveyCTO | 107 (66.0) | 38 (23.5) | 6 (3.7) | 8 (4.9) | 3 (1.9) | 280 | 1.7 | NU |
| Radio Frequency Identification)RFID Tags | 88 (54.3) | 54 (33.3) | 4 (2.5) | 7 (4.3) | 9 (5.6) | 449 | 2.8 | NU |
| **Information dissemination Tool** | | | | | | | | |
| Web Portals | 44 (27.2) | 60 (37.0) | 25 (15.4) | 31 (19.1) | 2 (1.2) | 373 | 2.3 | NU |
| E-newsletters | 10 (6.2) | 45 (27.8) | 43 (26.5) | 33 (20.4) | 31 (19.1) | 516 | 3.2 | U |
| Bulletin Boards | 38 (23.5) | 34 (21.0) | 23 (14.2) | 48 (29.6) | 19 (11.7) | 462 | 2.9 | NU |
| Print Media (Leaflets) | 14 (8.6) | 25 (15.4) | 27 (16.7) | 39 (24.1) | 57 (35.2) | 586 | 3.6 | U |
| Online Libraries | 41 (25.3) | 56 (34.6) | 33 (20.4) | 21 (13.0) | 11 (6.8) | 391 | 2.4 | NU |
| SMS message Alerts | 3 (1.9) | 7 (4.3) | 22 (13.6) | 52 (32.1) | 78 (48.1) | 670 | 4.1 | U |
| Plantix | 92 (56.8) | 46 (28.4) | 9 (5.6) | 10 (6.2) | 5 (3.1) | 276 | 1.7 | NU |
| Interactive Kiosks | 93 (57.4) | 46 (28.4) | 5 (3.1) | 11 (6.8) | 7 (4.3) | 279 | 1.7 | NU |
| **ICTs used for training and Capacity Building** | | | | | | | | |
| Webinars | 86 (53.1) | 47 (29.0) | 18 (11.1) | 3 (1.9) | 8 (4.9) | 286 | 1.8 | NU |
| Video tutorials and demonstrations | 34 (21.0) | 29 (17.9) | 28 (17.3) | 36 (22.2) | 35 (21.6) | 495 | 3.1 | U |
| Video Conferencing (zoom) | 0 (0.0) | 14 (8.6) | 14 (8.6) | 59 (36.4) | 75 (46.3) | 681 | 4.2 | U |
| Virtual Reality Training Systems | 26 (16.0) | 44 (27.2) | 27 (16.7) | 35 (21.6) | 30 (18.5) | 485 | 3.0 | U |
| E-commerce Platforms (Training and Capacity Building Tools) | 17 (10.5) | 36 (22.2) | 37 (22.8) | 30 (18.5) | 42 (25.9) | 530 | 3.3 | U |
| Discussion Forums | 43 (26.5) | 45 (27.8) | 25 (15.4) | 29 (17.9) | 20 (12.3) | 424 | 2.6 | NU |

Source: Field survey, 2024: Note: VLU = Very Low Utilization , LU = Low Utilization, MU = Moderate Utilization, HU= High Utilization and VHU = Very High Utilization. U=Utilized and NU = Not utilized

**Table 4.9: Factors influencing knowledge level and level of ICTs utilization**

| | Level of Knowledge | | Level of ICT usage | |
|---|---|---|---|---|
| **Variables** | **Coefficient** | **z-value** | **Coefficient** | **z-value** |
| Age | 0128 | 1.79 | .0432** | 2.04 |
| Complexity of ICT | -.0395 | -0.49 | -.4225** | -2.04 |
| Education | .01727 | 0.67 | .1575** | 2.41 |
| Compatibility | -.1014 | -0.82 | .9347*** | 3.79 |
| Relative advantage | .0899*** | 2.88 | -.0707 | -0.87 |
| Marital status | .0002 | 0.01 | -.0912 | -0.36 |
| Access to government support | -.004 | -0.19 | .0429 | 0.21 |
| Attitude towards ICT usage | .0002*** | 2.51 | -.0001 | -0.27 |
| Years of experience | .0007 | 0.10 | .0763*** | 3.68 |
| Training received | .0577*** | 2.54 | .13075** | 2.03 |
| Constant | -.0728 | -0.20 | -1.5456 | -1.93 |
| Rho | -.3330 | | | |
| Sigma | .3954 | | | |
| Lambda | -.1317 | | | |

**Source: Field Survey, 2024**

In respect to factors influencing knowledge level of ICTs facilities among extension workers, Table 2 revealed that the coefficient for perceived relative advantage (0.0899) is positive and statistically significant at the 0.01 level of probability. This implies that an increase in perceived relative advantage may increase the knowledge level of ICT utilization among extension agents. This is because when extension agents recognize the clear benefits of using ICTs, such as improved efficiency, better communication, and access to up-to-date information, they are more likely to invest time and effort in learning and adopting these technologies. The perceived benefits act as strong motivators, encouraging agents to enhance their ICT skills and integrate them into their work.

Similarly, the coefficient for attitude towards ICT usage (0.0002) is positive and statistically significant at the 0.01 level of probability. This implies that a positive attitude towards ICT usage can significantly enhance the knowledge level of ICT utilization among extension agents. A positive attitude reflects openness and willingness to embrace new technologies. When agents have a favorable view of ICTs, they are more likely to explore, learn, and effectively use these tools in their daily activities. This positive disposition facilitates continuous learning and adaptation, crucial for staying updated with technological advancements. Lastly, the coefficient for training received on ICTs is also positive and statistically significant at the 0.01 level of probability. This implies that increased training on ICTs directly contributes to higher knowledge levels of ICT utilization among extension agents. Training programmes provide the necessary skills, knowledge, and confidence required to use ICT tools effectively. Through structured learning and hands-on practice, agents can better understand how to leverage ICTs for their tasks, leading to more efficient and effective extension services. Continuous training ensures that agents are well-equipped to handle evolving technologies, thereby enhancing their overall competency. Regarding to factors influencing level of ICTs facilities utilization among extension workers, Table 4.8 revealed that the coefficient for age (0.0432) is positive and statistically significant at the 0.05 level of probability. This implies that an increase in age may increase the level of ICT utilization among extension agents. This is because as extension agents grow older, they accumulate more experience and may become more familiar with the benefits and applications of ICTs.

Similarly, the coefficient for the level of formal education (0.1575) is positive and statistically significant at the 0.05 level of probability. This implies that a higher level of formal education can significantly increase the level of ICT utilization among extension agents. This is because formal education provides individuals with critical thinking skills, technical knowledge and the ability to learn and adapt to new technologies. The coefficient for compatibility (0.9347) is also positive and statistically significant at the 0.01 level of probability. This implies that an increase in the perceived compatibility of ICTs with existing work practices can greatly enhance the level of ICT utilization among extension agents. This is because when agents perceive ICTs as compatible with their current methods and workflows, they are more likely to adopt these technologies. Compatibility reduces resistance to change and facilitates smoother integration of new tools, thereby increasing their utilization. The coefficient for years of experience (0.0763) is positive and statistically significant at the 0.01 level of probability. This implies that more years of experience can lead to higher levels of ICT utilization among extension agents. The coefficient for training received on ICTs (0.13075) is positive and statistically significant at the 0.05 level of probability. This implies that increased training on ICTs directly contributes to higher levels of ICT utilization among extension agents. However, the coefficient of complexity of ICT facilities (-0.4225) was negative and statistically significant at the 0.05 level of probability. This implies that an increase in the perceived complexity of ICT facilities may decrease the level of ICT utilization among extension agents. This is because when ICT tools are perceived as difficult to use, it creates a barrier to adoption and utilization. Agents may feel overwhelmed or intimidated by complex technologies, leading to resistance or reluctance to integrate these tools into their work routines.

## CONCLUSION AND RECOMMEDATIONS

From the findings, it can be concluded that SMS alerts and print media are commonly used for information dissemination, and data collection is facilitated through tools like KoboToolbox and Google Forms. Factors such as age, compatibility, relative advantage, years of experience and training received on ICT were the major factors influencing knowledge level and level of ICTs usage in the study area. Extension agents should take advantage of available training tools such as video tutorials, Zoom and virtual reality systems to improve their skills in ICT applications relevant to agricultural extension. Continuous learning and upgrading their ICT proficiency will enhance their ability to communicate effectively with farmers.

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# ADOPTION OF CLIMATE SMART AGRICULTURE AND ITS EFFECT ON INCOME OF SMALLHOLDER FARMERS IN NIGER STATE, NIGERIA

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## ABSTRACT

This study was conducted to assess adoption of Climate Smart Agriculture (CSA) and its effect on income of smallholder farmers in Niger State, Nigeria. Three-stage sampling procedure was used to select 225 respondents for the study. Primary data were collected from the respondents using semi-structured questionnaire complemented with interview schedule, while data collected were analyzed using descriptive statistics (such as means, percentages and frequency count) and inferential statistics (such as probit regression model). The result of the findings indicated that majority (87.6%) of the smallholder farmers were aware of CSA, while local radio stations (89.3%), farmers' cooperatives (84.9%) and agricultural extension services (78.2%) were the most common source of information on CSA. Radio usage for weather information (96.0%), and climate knowledge and experience (73.8%) were the most widely weather CSA practices adopted. In terms of water-related CSA practices adopted, the use of crop rotation to improve soil moisture (100.0%) and rainwater harvesting on or near farmland (91.6%) were the major practices adopted by the smallholder farmers. Also, crop rotation (97.8%) and mixed cropping (97.8%) were the major carbon-related CSA practices adopted, while planting of legume crops (99.1%) and precision fertilizer application (64.9%) were the major nitrogen-related CSA adopted. However, use of mulching (1.023405; $p<0.01$), zero tillage (0.6628522; $p<0.10$), use of pesticide (1.756842; $p<0.10$), education (.13078; $p<0.01$) and farming experience (.1165806; $p<0.05$) were the factors influencing the income of smallholder farmers. Thus, some of the CSA practices adopted had significant effects on income of the smallholder farmers. The study recommended that, farmers should utilize their cooperative membership in pulling their resources together for greater CSA practices adoption.

**Keywords:** Adoption, Income, Climate Smart and Smallholders

## INTRODUCTION

Agriculture plays a vital role in Nigeria's economy as it makes a substantial contribution to the country's Gross Domestic Product (GDP) and serves as a primary source of employment for a significant portion of the population. In the second quarter of 2021, the agricultural sector accounted for 23.8% of Nigeria's GDP (Nigeria Bureau of Statistic (NBS), 2021). However, despite the high level of involvement of Nigerian in agricultural activities, the sector faces numerous challenges in meeting the increasing food demands of the growing population. Nigeria's population is rapidly expanding, and it is projected to become the world's third most populous country by 2050 (United Nations (UN), 2019). This population growth coupled with urbanization and changing dietary preferences, places immense pressure on the agricultural sector to produce more food. However, the sector struggles to meet these demands due to various challenges.

One of the significant challenges is the prevalence of subsistence farming practices among smallholder farmers. Approximately 70% of Nigeria's active population is involved in agricultural production at a subsistence level (Eboh, 2008; Adebayo and Olagunju, 2015; Aturihaihi *et al.,* 2022). Subsistence farming is characterized by low output, limited access to resources, and inefficient farming techniques. Smallholder farmers, who constitute a significant proportion of the agricultural workforce, often cultivate small plots of land ranging from less than a hectare to a few hectares (Aturihaihi *et al.,* 2022). They heavily relied on family labour, have limited access to inputs such as improved seeds and fertilizers, exhibit low literacy rates, and generally adopt traditional and conservative farming practices (Adebayo and Olagunju, 2015). These factors contribute to the inefficiency of agricultural production and hinder the sector's ability to meet the increasing food demands of the population.

More so, climate change poses serious challenges to agricultural productivity in Nigeria, due to increased frequency of extreme weather events, unpredictable rainfall patterns, and temperature fluctuations. These climate-related challenges further exacerbate the difficulties faced by smallholder farmers and their ability to achieve food security. However, adoption of Climate-Smart Agriculture (CSA) have been proved to be an appropriate mechanism to mitigate the effects of climate change. CSA is an approach that aims to transform and adapt agricultural production systems to sustain productivity in the face of climate change (Food and Agriculture Organization (FAO), 2016). It encompasses a range of practices and technologies that have the potential to increase agricultural productivity, enhance the resilience of farming systems and reduce greenhouse gas emissions (De Pinto *et al.,* 2020). All these are geared towards sustainable agricultural production and income among smallholder farmers.

Income security is a critical aspect of the well-being and livelihoods of smallholder farmers in Nigeria. It refers to the ability of farmers to generate a stable and sufficient income from their agricultural activities to meet their basic needs, invest in farm improvements, and cope with unexpected shocks or risks (Lin, 2021). Although, some studies have highlighted the adoption of CSA practices among smallholder farmers in Nigeria (Olagunju *et al.,* 2017; Afolayan *et al.,* 2019; Ogunjimi *et al*., 2021), there is a dearth of empirical evidence on the level of adoption of CSA practices specifically among smallholder farmers in Niger State. The potential impact of CSA practice adoption on the income security of smallholder farmers in Niger State remains largely unexplored. More so, there is near absence of documented evidence on effects of adoption of CSA practices on income security of smallholder farmers. Adoption of CSA practices have remained an area which has been neglected hence requires investigation to guide policy thrust by the State in the quest to mitigate the adverse consequences of climate change. The identified gaps in literature necessitated the conduct of this research. Based on the foregoing, the study examined the CSA practices adopted by smallholders' farmer and determine the effects of CSA practices adoption on the income security of smallholder farmers in the study area;

**METHODOLOGY**

The study was conducted in Niger State, Nigeria which is located between Latitudes 8° 22' – 11° 30' North and Longitudes 3° 30' and 7° 20' East. The State has population of 3,950,249 comprising 2,082,725 males and 1,867,524 females (National Population Commission (NPC), 2006). However, the projected population of the State as at 2021 was 5,644,139 using 3.2% population growth (National Bureau of Statistics (NBS), 2022). The State is divided into three agricultural Zones, namely: Zone 1 with headquarters at Bida, Zone II with headquarters at

Kuta and Zone III with headquarters at Kontagora. The average annual rainfall of the State is 1,219 mm (Johnson *et al.,* 2020). The dry season is between November and March. Temperature is fairly regular and ranges from 26.1ºC (June – February) to 30.3ºC (March – April) (Tambo and Abdoulaye, 2016).

Three – stage sampling technique was employed to select smallholder farmers in the study area. The first stage involved random selection of one extension block from each of the three (3) Agricultural zones in Niger State. These are Katcha Agricultural Zone (I), Bosso Agricultural Zone (II) and Wushishi Agricultural Zone (III). The second stage involved random selection of extension cells from each of the selected extension block. The final stage involved random selection of smallholder farmers in each of the selected extension cell based on sample frame obtained from Niger State Agricultural Mechanization and Development Authority (NAMDA) to get a total number of 225 respondents used for the study. Primary data were collected through a semi-structured questionnaire complemented with interview schedule, while the data collected were analyzed using descriptive statistics (such as means, percentages and frequency count) and inferential statistics (such as probit regression model).

**Probit regression model**

The effects of CSA adoption on the income security of smallholder farmers was achieved using binary probit regression model explicitly expressed as in equation (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 - - - - \beta_{18} X_{18} + ei \qquad (1)$$

Where:

Y = Income security status (1 income secure; 0 if otherwise).

$X_1$ = use of improved seeds (1 if yes; 0 if otherwise)

$X_2$ = crop rotation (1 if yes; 0 if otherwise)

$X_3$ = intercropping (1 if yes; 0 if otherwise)

$X_4$ = Fertilizer application (1 if yes; 0 if otherwise)

$X_5$ = Water management (1 if yes; 0 if otherwise)

$X_6$ = mulching (1 if yes; 0 if otherwise)

$X_7$ = zero tillage or reduced tillage (1 if yes; 0 if otherwise)

$X_8$ = planting of cover crops (1 if yes; 0 if otherwise)

$X_9$ = planting drought-resistant varieties (1 if yes; 0 if otherwise)

$X_{10}$ = intensive use of pesticides (1 if yes; 0 if otherwise)

$X_{11}$ = Age (years)

$X_{12}$= Education (years)

$X_{13}$ = Household size (number of persons)

$X_{14}$ = Access to credit (dummy)

$X_{15}$ = Marital status (1 if married; 0 if otherwise)

$X_{16}$= farming experience (years)

$X_{17}$ = Membership of cooperative (dummy)

$X_{18}$ = Extension contact (numbers of visit)

$ei$ = Error term

## RESULTS AND DISCUSSSION

**Climate Agriculture Practices Adopted by Smallholder Farmers**

The results of Climate-Smart Practices (CSA) adopted by smallholder farmers in the study area are presented in Table 1. It revealed that radio usage for weather information (96.0%) and climate knowledge and experience (73.8%) were the most widely adopted CSA practices.

This can be attributed to the fact that radio usage for weather information is cost-effective and accessible for farmers to receive timely updates on weather patterns and forecasts. It enables them to make informed decisions about planting, irrigation and pest management. Radio programmes are usually timely and capable of reaching larger audience no matter the distance as long as they have a receiver with adequate supply of power. More so, radios are prevalent rural areas with even with limited infrastructure, making weather information widely accessible. Also, climate knowledge and experience (73.8%) reflect the traditional knowledge and adaptive strategies that smallholder farmers rely on to cope with climate variability. Farmers draw from their own observations and experiences to adjust planting times, crop varieties and agricultural practices in response to changing climatic conditions. This finding agreed with Akioya *et al.* (2019) who reported that radio is the major means of transmitting information to rural farmers in Nigeria.

In terms of water-related Climate-Smart Agriculture (CSA) practices adopted, results in Table 1 revealed that the use of crop rotation to improve soil moisture (100.0%) and rainwater harvesting on or near farmland (91.6%) were the major practices adopted by smallholder farmers. These high adoption rates can be attributed to their effectiveness in managing water resources, which is crucial for agricultural productivity in area prone climatic variability. Crop rotation helps improve soil structure and moisture retention by alternating crops with different root structures and nutrient needs, thereby enhancing soil health and water availability. This practice is particularly beneficial in rain-fed agriculture where optimizing water use is critical for sustained crop yields. Rainwater harvesting involves capturing and storing rainwater for irrigation and other agricultural uses, reducing dependence on unpredictable rainfall patterns and enhancing water security during dry periods. Smallholder farmers recognize the importance of conserving rainwater to mitigate drought risks and sustain crop production throughout the year. These practices reflect farmers' proactive approach to managing water resources sustainably, aligning traditional knowledge with modern techniques to adapt to climate change impacts. This finding agrees with the study of Ogunjimi *et al.* (2021) reported that crop rotation is one of the mostly practiced in Delta State of Nigeria.

Regarding carbon-related Climate-Smart Agriculture (CSA) practices adopted by smallholder farmers, results in Table 1 revealed high adoption rates for crop rotation (97.8%) and mixed cropping (97.8%). These practices are favoured for their ability to sequester carbon in the soil and contribute to climate change mitigation efforts while improving agricultural productivity. Crop rotation involves alternating different crops in sequence on the same piece of land, which helps to enhance soil fertility, reduce pests and diseases, and improve carbon storage in the soil through organic matter accumulation. This practice not only improves soil health and resilience, but also reduces the need for synthetic fertilizers, thereby lowering greenhouse gas emissions associated with their production and use. Mixed cropping, where multiple crops are grown together in the same field, promotes biodiversity, enhances nutrient cycling, and improves soil structure, all of which contribute to increased carbon sequestration potential. The diverse root systems and growth patterns of different crops help to maximize the use of available resources, including carbon dioxide from the atmosphere. These practices reflect farmers' recognition of the dual benefits of enhancing agricultural productivity while mitigating climate change impacts.

**Table 1: Distribution of respondents according to climate smart agriculture practices (n=225)**

| Variables | Frequency* | Percentage | Ranking |
|---|---|---|---|
| **Weather-related CSA** | | | |
| Radio use for weather information | 216 | 96.0 | 1st |
| Climate knowledge and experience | 166 | 73.8 | 2nd |
| Improved cooling of animal houses weather | 113 | 50.2 | 3rd |
| Mobile use for weather information | 102 | 45.3 | 4th |
| Training on weather information | 101 | 44.9 | 5th |
| TV use for weather information | 63 | 28.0 | 6th |
| Internet use for weather information | 47 | 20.9 | 7th |
| Index-based insurance cover weather | 10 | 4.4 | 8th |
| **Water-related CSA** | | | |
| Use of crop rotation to improve soil moisture | 225 | 100.0 | 1st |
| Rainwater harvest on near farmland water | 206 | 91.6 | 2nd |
| Use of water-saving irrigation techniques water | 180 | 80.0 | 3rd |
| Zero tillage | 176 | 78.2 | 4th |
| Use of mulching to conserve soil moisture and control weeds | 158 | 70.2 | 5th |
| Runoff harvest on near farmland water | 158 | 70.2 | 5th |
| Onset date planting to maximize rain water | 150 | 66.7 | 7th |
| Development of physical farm infrastructure to check flooding water | 71 | 31.6 | 8th |
| **Carbon-related CSA** | | | |
| Crop rotation | 220 | 97.8 | 1st |
| Mixed-cropping-carbon | 220 | 97.8 | 1st |
| Planting of drought resistance varieties | 210 | 93.3 | 3rd |
| Use of intercropping to increase biodiversity and resilience carbon | 191 | 84.9 | 4th |
| Organic matter addition | 178 | 79.1 | 5th |
| Plant residue | 168 | 74.7 | 6th |
| Cultivation of non-woody plants | 142 | 63.1 | 7th |
| Assisted regeneration of beneficial plants | 135 | 60.0 | 8th |
| Use of less heavy equipment | 112 | 49.8 | 9th |
| Use of agro-forestry practices on your farm | 60 | 26.7 | 10th |
| **Nitrogen-related (CSA)** | | | |
| Planting of legume crops | 223 | 99.1 | 1st |
| Precision fertilizer application | 146 | 64.9 | 2nd |
| Balancing of fertilizer mature application | 118 | 52.4 | 3rd |

**Sources:** Field Survey, 2024
**Note:** *Multiple responses were recorded

Furthermore, the result in Table 1 revealed high adoption rates for nitrogen-related Climate-Smart Agriculture (CSA) practices in the study area, with planting of legume crops (99.1%) and precision fertilizer application (64.9%) being the most adopted practices. The high adoption of planting leguminous crops is because they have the ability to fix atmospheric nitrogen through symbiotic relationships with nitrogen-fixing bacteria in their root nodules. This enhances soil fertility and reduces the need for synthetic nitrogen fertilizers, which helps to mitigate greenhouse gas emissions associated with their production and use. Legumes also improve soil structure and organic matter content, further supporting sustainable agricultural practices. Precision fertilizer application on the other hand involves applying fertilizers at the right time, rate, place and form based on soil and crop needs. This practice minimizes nutrient losses to the environment, improves fertilizer use efficiency, and reduces environmental impacts such as nitrogen leaching and runoff. These CSA practices reflect farmers' efforts to enhance nitrogen use efficiency, reduce environmental impacts, and improve crop productivity in a sustainable manner.

**Effect of CSA adoption on the income security of smallholder farmers**

The probit regression estimate on the effects of CSA adoption on income security of smallholder farmers is presented in Table 2. The pseudo $R^2$ value of 0.4733 indicates that the model explains approximately 47.3% of the variation in likelihood of the smallholder farmers being income secured is associated with CSA adoption. The log-likelihood value of -59.303535 and chi-square statistic value of 106.57, statistically significant at 1% probability level further support the model's goodness-of-fit. The coefficient of use of mulching (1.023405; $p<0.01$), zero tillage (0.6628522; $p<0.10$), use of pesticide (1.756842; $p<0.10$), education (0.13078; $p<0.01$) and farming experience (0.1165806; $p<0.05$) were positive. This implies that a unit increase in any of these variables will increase the likelihood of the smallholder farmers being income secured. Adoption of CSA practices such as mulching, zero tillage, and use of pesticides, as well as socio-institutional variables like education and farming experience were found to have significant effects on income security of the smallholder farmers.

The positive coefficient for the use of mulching (1.023405) suggests that mulching significantly boosts farmers' income security. This is because mulching helps in conserving soil moisture, reducing weed growth, and improving soil fertility. By maintaining soil moisture, mulching ensures that crops have a steady supply of water, which is crucial during dry periods. This leads to better crop yields and, consequently, higher income for farmers. Additionally, mulching decomposes over time, adding organic matter to the soil and enhancing its fertility, which can improve crop health and productivity. The positive coefficient for zero tillage (0.6628522) indicates that adopting zero tillage practices could positively have significant effects on farmers' income security. This is because zero tillage reduces soil erosion, enhances water retention and improves soil structure. By minimizing soil disturbance, zero tillage helps maintain soil organic matter and reduces labor and fuel costs associated with conventional tillage. These benefits translate into lower production costs and higher profitability for farmers. Moreover, zero tillage can improve soil health over time, leading to sustainable long-term productivity gains. The use of pesticides (1.756842) has a positive and significant effects on income security. This is because effective pest management is crucial for crop protecting from pests and diseases that can severely reduce yields. By using pesticides judiciously, farmers can prevent crop losses and ensure higher yields, directly translating into increased income.

**Table 2: Effect of CSA adoption on the income security and smallholder farmers**

| Variables | Coefficient | Std. Error | Z-value |
|---|---|---|---|
| Improved seed | 1.460631 | 0.8110303 | 1.80* |
| Use of crop rotation | .1153248 | 0.8648948 | 0.13 |
| Use of intercropping | .6104886 | 0.4504535 | 1.36 |
| Use of precision fertilizer application | -.4566359 | 0.4445874 | -1.03 |
| Use of water irrigation technique | -.2011714 | 0.280758 | -0.72 |
| Use of mulching | 1.023405 | 0.4088601 | 2.50*** |
| Zero tillage | .6628522 | 0.3985363 | 1.66* |
| Cover cropping | .18279 | 0.9283376 | 0.20 |

| | | | |
|---|---|---|---|
| Planting of drought resistance varieties | .2318748 | 0.6700709 | 0.35 |
| Pesticide | 1.756842 | 0.4149646 | 4.23*** |
| Age | -.1978137 | 0.0492768 | -4.01*** |
| Education | .13078 | .0368561 | 3.55*** |
| Household size | .2021316 | .0966687 | 2.09** |
| Credit | -7.32e-06 | 4.18e-06 | 1.75* |
| Marital status | 3.34055 | .9273977 | 3.60 |
| Farming experience | .1165806 | .0590655 | 1.97** |
| Extension contact | -.4353915 | .2172989 | -2.00** |
| Cooperative | -.2309165 | .2002544 | -1.15 |
| Constant | -1.09333 | 1.9779 | -0.55 |
| **Log likelihood** | **-59.303535** | | |
| **chi2** | **106.57*** ** | | |
| **Pseudo R2** | **0.4733** | | |

**Sources:** Field Survey, 2024

The positive coefficient for education (0.13078) suggests that higher levels of education among farmers are associated with probable higher income security. This is because education enhances farmers' ability to access and utilize information, make informed decisions, and adopt new technologies and practices. Educated farmers are more likely to understand the benefits of CSA practices and implement them effectively, leading to improved productivity and income. Education also empowers farmers to engage more effectively with financial institutions and extension services for greater economic opportunities that will guarantee income security.

The positive coefficient for farming experience (0.1165806) suggests that experienced smallholder farmers are probably going to be income secured. This is because farming experience equip farmers with practical knowledge and skills that are critical for successful farming that could enhance output and income. Thus, experienced farmers are better at managing risks, optimizing resource use, adapting to changing environmental and market conditions. They are also more likely to have established networks and relationships that could provide the needed support and opportunities for improving their farming practices and income.

## CONCLUSION AND RECOMMENDATIONS

Based on the findings, it can be concluded that, radio use for weather information weather and climate knowledge and experience weather were the most weather climate smart agriculture while use of crop rotation to improve soil moisture and rainwater harvest on near farmland water were the most adopted water climate smart agriculture. Furthermore, crop rotation and mixed-cropping were the most adopted carbon climate smart agriculture while planting of legume crop and precision fertilizer application were the most adopted nitrogen climate smart agriculture. It can also be concluded that Use of mulching, zero tillage, use of pesticide, education and farming experience were the factors influencing the income of smallholder farmers. The study recommended that, farmers should utilize their cooperative membership in pulling their resources

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# EFFECTS OF NATIONAL AGRICULTURAL LAND DEVELOPMENT AUTHORITY (NALDA) PROJECTS ON MAIZE PRODUCTION IN NIGER STATE, NIGERIA

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## ABSTRACT

The study was carried out to determine effects of National Agricultural Land Development Authority (NALDA) projects on maize production in Niger State, Nigeria. Multi-stage sampling technique was adopted to select 172 registered maize farmers for the study. The data collected were analysed using descriptive statistics (such as frequency, percentage and mean) and inferential statistics such as (Multiple Regression Model). The study revealed that access to land ($\bar{X}$ = 3.62), pesticide/insecticide and fertilizer ($\bar{X}$ = 3.1) were the major benefits of NALDA to maize farmers in the study area, while agrochemicals ($p<0.01$), education ($p<0.01$), extension services ($p<0.01$) and training received via NALDA ($p<0.01$) were the major factors influencing maize farmers output in Niger State. The study recommended that farmers should prioritize attending training sessions on agronomic practices provided by NALDA to improve their knowledge on soil testing, site selection and input usage. This will enhance their productivity and help them better utilize NALDA's support.

**KEYWORDS**; National; Agricultural; Maize; Production; Niger State; Authority

## INTRODUCTION

Agriculture should be the industrial and economic springboard for the nation's quest for acceleration of growth and development as it is well-placed to have a high multiplier effects on social wellbeing and other sectors of the economy. The contemporary socio-economic literature is replete with evidences of the potency of agriculture as a driver of sustainable economic growth and development. The experiences of China, Brazil, Malaysia and Indonesia countries with development characteristics similar to Nigeria, are instructive. These countries have relied on their agricultural prowess to facilitate the process of industrialization from predominantly agrarian economies (Fawole and Oladele, 2020).

In Nigeria, Agriculture was the main stay of the economy long before the discovery of oil in commercial quantity in the 1950s. Covering an area of 924,000 square kilometers, Nigeria has varied ecology, ranging from the Sahel, Sudan and Guinea Savannahs in the North to the Southern rain forests, thus making it possible to produce many varieties of crops and livestock (Fawole and Oladele, 2020). About 75 percent of Nigeria's land is arable, more than half of which is yet to be put into cultivation (Food and Agriculture Organization Statistics (FAOSTAT), 2022). The country is also endowed with rich fishery resources and ample potentials for large-scale fish farming (Abiodun *et al.,* 2020). Agriculture is still largely at rain-fed, subsistence level, characterized by smallholdings, traditional and inefficient method of cultivation, storage and processing (Ambali and Murana, 2017).

Maize is one of the main staple crops in Nigeria and featured among the five food crops (cassava, maize, wheat, rice and sugarcane) whose production is to be promoted for attainment of food self-sufficiency as revealed by the Minister of Agriculture and Water Resources. In Nigeria, maize production ranks third after sorghum and millet among the cereal crops (Food and Agriculture Organization Statistics (FAOSTAT), 2022). A survey conducted in Nigeria revealed that maize accounts for about 43 percent of calorie intake, with income elasticity of demand of 0.74, 0.65 and 0.71 for both low and high income households, respectively and contributes to 7.7 percent of total cash income of farm households (Aluko *et al.,* 2021).

Land area under maize increased from 5m ha in 2007 to 6.5 million (Ha) across diverse agro-ecological zones of Nigeria and production also increased from 7m to 12m tons during the same period (FAOSTAT, 2022). The average yield of 1.5-2.2 tonnes/ha being obtained in Nigeria is low compared to other places. For instance, FAOSTAT (2022) production statistics from 2007-2020 shows that world maize average yield was 4.3tonnes/ha, average yield for Kuwait was 18.4tonnes/ha, Jordan, 16.2tonnes/ha, New Zealand, 10.2tonnes /ha, Chile, 9.5tonnes/ha, Egypt, 7.1tonnes/ha, Mauritius 5.8tonnes/ha, South Africa, 2.5tonnes/ha, Algeria 2.4tonnes/ha, Cameroon, 1.9tonnes/ha, Ethiopia, 1.8tonnes/ha and Kenya, 1.7tonnes/ha (IITA, 2019). The National Agricultural Land Development Authority (NALDA) in Nigeria is a pivotal government agency saddled with the mandate of transforming the agricultural landscape by empowering smallholder farmers, enhancing food security, and driving rural development. Established in 1992 and later reactivated in 2020, NALDA has emerged as a critical player in the nation's quest for agricultural self-sufficiency and economic diversification. Initially conceived to spearhead the development of idle agricultural lands, NALDA has evolved to address broader challenges facing the agricultural sector. Its reactivation in 2020, under the leadership of the Nigerian government, marked a renewed commitment to harnessing the vast agricultural potential of the country (Dare, 2021). Despite the implementation of various support initiatives by NALDA, there is lack of clarity regarding its effectiveness on maize farming in Niger State. This includes understanding the extent to which these initiatives had contributed to increasing maize productivity, improved farmers' income levels and enhanced overall livelihoods. Based on the foregoing, the study aimed to

i. determine the nature of NALDA projects in maize production in Niger State;
ii. examine the effects of NALDA projects in maize production

**RESEARCH METHODOLOGY**

This study was conducted in Niger State, Nigeria. It lies between longitude $3^0\ 30^1$ and $7^0\ 20^1$ East of the Greenwich Meridian and latitude $8^0\ 20^1$ and $11^0\ 30^1$ North of the equator (Niger State Bureau of Statistics (NSBS), 2011). The total inhabitants in the State was 3,950,249 people during the 2006 population census. However, going by the annual population growth rate of 3.4% in Nigeria, the population of Niger State was projected to be 6,783,300 people in the year 2022 (NPCN, 2022). The land area is about 76,481.1 square kilometers at a density of 72.76/square kilometer, there are two distinct seasons in Niger State: the dry and wet seasons, which allow the production of numerous agricultural products. The State experiences average annual rain-fall of up to 1,100mm in the North, lasting up to about 120 days and 1,600mm in the South which last up to 150 days. (NSBS, 2022).

Multi-stage sampling technique was adopted for this study. The first stage involved purposive selection of three (3) local Government areas (LGAs) based on available project sites and NALDA activities in the State. In the second stage, three (3) villages were randomly selected from each of the selected LGA. The third stage involved the selection of registered maize farmers from each of the selected village as obtained from Niger State Agricultural and

Mechanization Development Authority (NAMDA) in Table 1. Thus, a total of 172 registered maize farmers were randomly selected from the sample frame of 1,106 as respondents for this study using Yamanne equation for sample size determination as used by Abdullahi *et al.* (2018).

Primary data were used for this study. The data was collected through a semi-structured questionnaire complemented with an interview schedule and assisted by trained enumerators. Data collected were analysed using both descriptive (such as frequency, percentage and mean) and inferential statistics (such as Multiple Regression Model).

**Multiple Regression Model**

The explicit form of the model could be expressed in four functional forms as given in equation below;

Linear: $Y = a + b_1x_1 + b_2x_2 + \cdots \ldots b_{14}x_{14} + e$ (1)

Semi - $Log: Y = a + b_1 log x_1 + b_2 log x_2 + \cdots \ldots b_{14} log x_{14} + log e$ (2)

Cobb-Douglas: $Log Y = a + b_1 log x_1 + b_2 log x_2 + \cdots \ldots b_{14} log x_{14} + log e$ (3)

Exponential: Log Y $= a + b_1x_1 + b_2x_2 + \cdots \ldots b_{14}x_{14} + e$ (4)

Where:

Y = Total output of maize produced (yield in kg);

$\beta_1 - \beta_{14}$ = Parameters to be estimated

$X_1 - X_{14}$=independent variables. Where;

$X_1$ = Quantity of seed received from NALDA (kg); $X_2$ = Quantity of fertilizer received from NALDA (kg); $X_3$ = Quantity of agrochemical received from NALDA (ltr)

$X_4$ = Size of land received from NALDA for maize production (ha); $X_5$ = Level of Educational (number of years spent in school); $X_6$ = Production for commercial purpose (Yes=1, otherwise=0)

$X_7$ = Access to machine labour from NALDA (yes=1, otherwise=0); $X_8$ = Access to credit (amount received); $X_9$ = Access to maize market networks (yes=1, no=0)

$X_{10}$= Access to Extension services (number of visits); $X_{11}$= Farm income (naira)

$X_{12}$= Cost of farm practices (naira); $X_{13}$ = Number of training on agronomic practices by NALDA (No of training); $X_{14}$= Level of participation in NALDA support initiatives (high=1, low=0)

e = Error term.

**RESULTS AND DISCUSSION**

**Nature of NALDA projects in maize production in Niger State**

Table 1 present the results of nature of NALDA projects in maize production in Niger State. This was categorised into: training, farm inputs and farm project operation. Table 4.3 revealed that training on site selection and soil test ($\bar{X}$ =3.53), training on types of farm inputs ($\bar{X}$ =3.34) and training on soil preparation and management were ranked topmost NALDA training initiatives among maize farmers in the study area. These interventions play a vital role in addressing the challenges faced by small-scale farmers and improving their productivity. Land is a critical factor in farming and improper site selection can lead to suboptimal yields. NALDA's focus on training farmers in site selection aims to prevent these challenges by ensuring farmers cultivate land best suited for maize production. Additionally, soil testing provides farmers with detailed information about the nutrient content and fertility status of their soil. By assessing soil suitability and fertility, these tests enable farmers to apply appropriate fertilizers and other inputs, thereby improving resource efficiency, increasing yields and promoting sustainable farming practices. This aspect of NALDA's initiative equips farmers with the knowledge to address soil deficiencies effectively and make informed decisions about fertilizer use, avoiding wasteful application or overuse.

Training on the types of farm inputs to use is another significant support initiative. This training is designed based on soil testing results, ensuring that farmers apply the appropriate quantity and type of inputs such as fertilizers, seeds and herbicides. This training does not only enhance productivity but also promotes cost efficiency by preventing the unnecessary application of inputs, which could otherwise result in wastage or harm to the environment Training on soil preparation and management complements these efforts. Proper soil preparation ensures better aeration, moisture retention and nutrient availability, creating optimal conditions for crop growth. These initiatives aim to provide farmers with the knowledge and resources necessary to make the best use of their available land, ultimately enhancing their productivity and improving their livelihoods. This is similar to the study of Omotayo (2021) enhancing land productivity for crops is production is one of the aim of NALDA programme in Nigeria.

Regarding inputs, access to land ($\bar{X}$ = 3.62), access to pesticide/insecticide ($\bar{X}$ = 3.1) and access to fertilizer ($\bar{X}$ = 3.01) were ranked as the top NALDA input initiatives among maize farmers in the study area. By making land accessible, NALDA enables farmers to expand their production capabilities, aligning with the programme's goal of consolidating fragmented peasant farms into larger, more economically viable units. This initiative promotes agricultural development by ensuring that farmers can access land to increase their farm size and productivity. Additionally, providing access to essential inputs such as pesticides, insecticides and fertilizers further supports maize farmers by enhancing crop protection and optimizing soil fertility. These interventions are crucial in improving yield potential and ensuring sustainable farming practices, contributing to increased agricultural productivity in the region. This substantiate the study of Shodimu and Oluwadare (2020) who reported that NALDA had several support initiates which aimed at improving the productivity of farmers in Nigeria.

More so, soil preparation ($\bar{X}$ = 3.24), weed and pest management ($\bar{X}$ = 3.23) and storage and processing ($\bar{X}$ = 3.21) were ranked as the top NALDA farm project initiatives among maize farmers in the study area. These initiatives are crucial for enhancing maize production. Proper soil preparation ensures optimal conditions for crop growth, while effective weed and pest management techniques safeguard crops from potential damage, reducing losses. Additionally, training on storage and processing helps to preserve maize quality, minimize post-harvest losses, and add value to the produce, thus improving farmers' profitability and sustainability.

**Effects of NALDA projects on maize farmers' output**

Table 2 present the results of multiple regression on the effects of NALDA projects on maize farmers' output. The double-log functional form was selected as the lead equation due to the number of significant variables aligning with *a priori* expectations and its highest R-squared value. The computed R-squared was 0.7119, indicating that approximately 71.2% of the variation in maize farmers' output was explained by the included variables, while the remaining 28.8% could be attributed to other factors not captured in the model or random error. The F-statistic was statistically significant at 0.01 probability level, confirming that the model is fit for explaining the relationships studied.

The coefficient for the quantity of agrochemicals received from NALDA (0.1376259) was positive and statistically significant at 0.01 probability level. This implies that a unit increase

**Table 1: Nature of NALDA projects in maize production in Niger State**

| Variable | SD Freq. (%) | D Freq. (%) | A Freq. (%) | SA Freq. (%) | WM | Rank | RMK |
|---|---|---|---|---|---|---|---|
| **Training** | | | | | | | |
| **Training on site selection and soil testing** | 4 (2.3) | 9 (5.2) | 51 (29.7) | 108(62.8) | 3.53 | 1st | A |
| **Training on types of farm inputs** | 14 (8.1) | 0(0.0) | 85 (49.4) | 73 (42.4) | 3.34 | 2nd | A |
| **Training on soil preparation and management** | 10 (5.8) | 34 (19.8) | 58 (33.7) | 70 (40.7) | 3.09 | 3rd | A |
| **Training on weather and climate change** | 26 (15.1) | 30 (17.4) | 29 (16.9) | 87 (50.6) | 3.07 | 4th | A |
| **Training on marketing** | 47 (27.3) | 13 (7.6) | 40 (23.3) | 72 (41.9) | 3.03 | 5th | A |
| **Training on storage and crop processing** | 39 (22.7) | 63 (36.6) | 31 (18.0) | 39 (22.7) | 3.01 | 6th | A |
| **Training on weed and pest management** | 43 (25.0) | 79 (45.9) | 33 (19.2) | 17 (9.9) | 3.00 | 7th | A |
| **Training on crop harvesting** | 63 (36.6) | 55 (32.0) | 24 (14.0) | 30 (17.4) | 2.10 | 8th | D |
| **Farm inputs** | | | | | | | |
| **Access to land** | 3 (1.7) | 5 (2.9) | 47 (27.3) | 117(68.0) | 3.62 | 1st | A |
| **Access to pesticide/insecticide** | 13 (7.6) | 20 (11.6) | 66 (38.4) | 73 (42.4) | 3.16 | 2nd | A |
| **Access to fertilizer** | 4 (2.3) | 36 (20.9) | 75 (43.6) | 57 (33.1) | 3.08 | 3rd | A |
| **Access to mechanical labour/machineries** | 30 (17.4) | 29 (16.9) | 30 (17.4) | 83 (48.3) | 3.06 | 4th | A |
| **Access to herbicide** | 24 (14.0) | 23 (13.4) | 72 (41.9) | 53(20.8) | 3.01 | 5th | A |
| **Access to credit/capital** | 27 (15.7) | 30 (21.5) | 39 (22.7) | 76 (44.2) | 3.00 | 6th | A |
| **Access to seed** | 42 (24.4) | 31 (18.0) | 31 (18.0) | 68 (39.5) | 2.73 | 7th | D |
| **Farm project operation** | | | | | | | |
| **Participation in soil preparation** | 38 (22.1) | 3 (1.7) | 10 (5.8) | 121(70.3) | 3.24 | 1st | A |
| **Participation in weed and pest management** | 30 (17.4) | 16 (9.3) | 10 (5.8) | 116(67.4) | 3.23 | 2nd | A |
| **Participation in storage and processing** | 5 (2.9) | 22 (12.8) | 77 (44.8) | 68 (39.5) | 3.21 | 3rd | A |
| **Participation in planting and agrochemical application** | 10 (5.8) | 12 (7.0) | 132 (76.7) | 18 (10.5) | 3.03 | 4th | A |
| **Participation in marketing** | 43 (25.0) | 22 (12.8) | 54 (31.4) | 53 (30.8) | 3.02 | 5th | A |
| **Participation in crop harvesting** | 67 (39.0) | 38 (22.1) | 37 (21.5) | 30 (17.4) | 2.17 | 6th | D |
| **Participation in soil & project site selection** | 83 (48.3) | 21 (12.2) | 27 (15.7) | 41 (23.8) | 2.15 | 7th | D |

**Source: Field survey, 2024: SD =** strongly disagree, D= Disagree, U= Undecided, A= Agreed and SA = strongly agreed. WM =weighted mean, RMK=Remark. Cut off mean ≥3 in the quantity of agrochemicals provided by NALDA leads to 13.8% increase in maize farmers' output. Agrochemicals, essential for enhancing crop productivity, have become increasingly expensive due to the removal of fuel subsidies, which has driven up the cost of agricultural inputs. This makes agrochemicals inaccessible to many small-scale farmers. However, access to these inputs through NALDA initiatives helps farmers improve productivity and efficiency, thereby increasing their income. By reducing the financial burden of procuring these inputs, NALDA supports smallholder farmers in achieving better yields and income stability, enabling them to sustain their agricultural operations. This substantiate with the study of Ahmed and Yusuf (2022) who reported that participation in the anchor borrower's programme (ABP) on crop yield in Nigeria let to 15 percent increase in maize output.

The coefficient for the level of education (0.1541427) was positive and statistically significant at 0.01 probability level, indicating that a unit increase in education leads to 15.4% increase in maize farmers' output. Educated farmers are better equipped to adopt improved farming techniques, manage resources efficiently and access relevant agricultural information. They are more likely to embrace innovative practices, such as using recommended inputs or modern tools, which enhance productivity. Furthermore, educated farmers can navigate agricultural programmes like NALDA more effectively, leveraging opportunities to improve farm output and profitability. Thus, education empowers farmers to make informed decisions, optimise production processes, and increase income levels. This is similar to the study of Adebayo *et al.* (2021) education is a significant predictor of farmer's outputs.

The coefficient for access to extension services (0.2570594) was positive and statistically significant at 0.01 probability level, indicating that a unit increase in access to extension services provided by NALDA results in a 25.7% increase in maize farmers' output. This implies that access to extension services plays a critical role in enhancing farmers' productivity and profitability. Extension services provide farmers with essential knowledge on best farming practices, pest and disease management, proper use of agrochemicals and improved technologies. Through regular interaction with extension agents, farmers can make informed decisions, optimize input use and adopt modern techniques that improve yields.

**Table 2: Effects of NALDA projects on maize farmers' output**

| Variable | Linear Coef. (t-value) | Semi-log Coef. (t-value) | Double log Coef. (t-value) | Exponential Coef. (t-value) |
|---|---|---|---|---|
| **Quantity of seed received from NALDA** | -0.00669 | -0.00241 | 0.06151 | 0.29511 |
| | (-0.43) | (-0.61) | (1.06) | (1.21) |
| **Quantity of fertilizer received from NALDA** | 0.15177 | 0.06078 | 0.07381 | 0.19017 |
| | (0.81) | (1.28) | (1.77) | (1.09) |
| **Quantity of agrochemical received from NALDA** | 0.11998 | 0.02490 | 0.13762 | 0.63912 |
| | (3.17)*** | (2.59)*** | (3.20)*** | (3.55)*** |
| **Size of land received from NALDA for maize production** | -0.04227 | -0.01209 | 0.01431 | 0.04465 |
| | (-0.23) | (-0.26) | (0.33) | (0.25) |
| **Level of educational** | 0.41005 | 0.09939 | 0.15414 | 0.49804 |

| | | | | |
|---|---|---|---|---|
| | (2.19)** | (2.08)** | (2.55)*** | (1.97)* |
| **Production for commercial purpose** | 0.25147 | 0.07462 | 0.01922 | 0.08746 |
| | (1.15) | (1.34) | (0.39) | (0.42) |
| **Access to machine labour from NALDA** | 0.01385 | 0.00436 | 0.07941 | 0.22441 |
| | (0.57) | (0.71) | (0.81) | (0.55) |
| **Access to credit** | 0.09261 | 0.02067 | 0.08640 | 0.40214 |
| | (2.11)** | (1.85)* | (1.42) | (1.58) |
| **Access to maize market networks** | 0.11659 | 0.05396 | 0.08869 | 0.20778 |
| | (0.52) | (0.94) | (1.72) | (0.96) |
| **Access to extension services** | 0.49638 | 0.14692 | 0.25705 | 0.76218 |
| | (2.72)*** | (3.16)*** | (2.93)*** | (2.07)** |
| **Farm income** | 0.45602 | 0.15336 | 0.11810 | 0.34508 |
| | (1.86)* | (2.46)** | (2.10)** | (1.47) |
| **Cost of farm practices** | -0.09258 | -0.02142 | -0.93544 | -3.73564 |
| | (-4.31)*** | (-3.92)*** | (-1.66) | (-5.40)*** |
| **Number of training on agronomic practices by NALDA** | 4.20546 | 1.32581 | 0.76225 | 2.22434 |
| | (5.74)*** | (7.11)*** | (7.32)*** | (5.10)*** |
| **Level of participation in NALDA support initiatives** | 0.04468 | 0.01582 | 0.00910 | 0.01946 |
| | (0.63) | (0.88) | (0.57) | (0.29) |
| **Constant** | 1.59526 | 0.41200 | 3.78277 | 13.58444 |
| | (1.67) | (1.69) | (7.78)*** | (6.67)*** |
| **R-squared** | **0.5643** | **0.5797** | **0.7119** | **0.6319** |
| **Adj R-squared** | **0.5076** | **0.5244** | **0.6684** | **0.5813** |
| **Prob > F** | 0.0000 | 0.0000 | 0.0000 | 0.00000 |
| **F-statistic** | 6.43*** | 6.86*** | 11.76*** | 8.53*** |

**Source: Field survey, 2024**

Consequently, increased access to extension services empowers farmers to maximise their potential, leading to higher income levels and improved livelihoods. Isah *et al.* (2020) reported that farmers in Kebbi State who received agricultural extension services achieved a notable increase in maize yield, with an average rise of 13 percent. The coefficient for the number of training sessions on agronomic practices by NALDA (0.7622516) was highly significant at the 0.01 probability level. This implies that a unit increase in the number of training sessions results in 76.2% increase in the output of maize farmers. This is because training equips farmers with knowledge and skills to adopt best agronomic practices such as optimal planting techniques, proper use of fertilizers, pest and weed management and efficient water use. These practices enhance crop yield and quality, leading to higher market value and income. Additionally, such training encourages farmers to adopt sustainable practices, reducing production costs and increasing profitability. The substantial effects showed the effectiveness of capacity-building initiatives under NALDA in improving farmers' productivity, income and overall economic wellbeing. This implies that regular training sessions are a crucial component of agricultural transformation. Asfwa *et al*. (2018) reported that agricultural training had positive impact on farmers output and income.

The coefficient of farm income (0.1181004) was positive and statistically significant at the 0.05 probability level. This implies that a unit increase in farm income results in 11.8% increase in maize output. This is because higher farm income provides farmers with the financial capacity to invest in improved agricultural inputs such as quality seeds, fertilizers, and other agrochemicals, which enhance productivity. Additionally, farmers with higher income can adopt modern farming technologies, hire labour and access training or extension services that contribute to efficient farming practices. Increased income also enables farmers to expand their operations by cultivating larger areas or diversifying into complementary farming activities. This corroborates put this in reference list or remove (2020) who reported that increase in farmers' income led to positive influence on farmer's productivity.

## CONCLUSION AND RECOMMENDATIONS

From the findings, it can be concluded that training on soil preparation and management as well as, access to land, pesticide/insecticide and fertilizer were the major benefits of NALDA to maize farmers in the study area, while agrochemicals, education, extension services and training received via NALDA were the major factors influencing maize farmers output in Niger State. The study recommended that farmers should prioritize attending training sessions on agronomic practices provided by NALDA to improve their knowledge on soil testing, site selection and input usage. This will enhance their productivity and help them better utilize NALDA's support.

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# EFFECTS OF SHEA BUTTER PROCESSING ON LIVELIHOOD STATUS OF RURAL WOMEN IN NIGER STATE, NIGERIA

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## ABSTRACT

This study was conducted to assess effects of shea butter processing on livelihood status of rural women in Niger State, Nigeria. Three-stage sampling procedure was used to select 212 respondents for the study. Data were collected from primary source using semi-structured questionnaire complemented with interview schedule. Data collected were analyzed using inferential statistics (such as multiple regression and Odered logit regression). The result of the findings indicated that processing experience ($p < 0.10$), years spent in school ($p < 0.05$), household income ($p < 0.01$), and access to information ($p < 0.01$) were the major factors influencing shea butter processing among rural women. More so, quantity of shea butter processed ($p < 0.01$), processing experience ($p < 0.01$) and years spend in school ($p < 0.05$) were the factors influencing livelihood status of women shea processors The study recommended that women should be supported with credit facilities like their male counterparts in order to improve their livelihood

**Keywords:** Shea; Butter; Processing, Rural and Women

## INTRODUCTION

Shea nut tree is indigenous to sub-Saharan Africa and belongs to the family *Sapotaceae*. Based on distribution, two species of the plant have been identified *Vitellaria paradoxa* and *Vitellaria nilotica*. *Vitellaria paradoxa* is commonly known as the African shea tree or shea butter tree (Aidoo *et al.*, 2017). It is predominantly found in the West African sub-region, covering countries such as Ghana, Nigeria, Burkina Faso, Mali, and Cote d'Ivoire, while *Vitellaria nilotica* often referred to as the East African Shea tree, mainly growns in Northern Uganda and Southern Sudan (Okullo, 2020). It is a dicotyledonous woody plant that grows typically in the savannah and naturally stretches over Africa in the Northern hemisphere from Southeastern Senegal to Ethiopia and Uganda (Aidoo *et al.*, 2017). The plant thrives naturally in the dry savannah belt of West Africa from Senegal in the west to Sudan in the East, and onto the foothills of the Ethiopian highlands. It occurs in 19 countries across the African continent, namely Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Cote D'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda, Zaire and Guinea (Tano-Debrah *et al.,* 2019). Thus, covers a swath of the continent, that is 5,000km long and 400 – 750km wide (Zan *et al.,* 2020).

Nigeria is abundantly blessed with Shea trees (*vitellaria paradoxa*) which could be harnessed for the industrial development of the country. Currently, Shea trees grow in the wild across many states in Nigeria, including Niger Nasarawa, Kebbi, Kwara, Kogi, Adamawa, Benue, Edo, Katsina, Plateau, Sokoto, Zamfara, Taraba, Borno, and Oyo (Diop *et al.,* 2020). Nigeria has the largest Shea trees in the world and accounted for over 50 percent of the shea butter production in West Africa with a total trade value of $400,000 (Food and Agriculture

Organization (FAO), 2018; Diop *et al.,* 2020). The Shea tree plays a vital role in maintaining biodiversity in the regions where it grows, providing habitat and sustenance to various wildlife and plant species. Additionally, the tree's deep root system helps prevent soil erosion and contributes to soil fertility, making it an essential component of sustainable land management in the Nigeria (Okullo, 2020). The white ivory colour fat extracted from the nut is called Shea butter which has many uses as edible oil, chocolate and beverage as well as pharmaceutical and cosmetic industries (Diop *et al.,* 2020).

Shea butter processing in Niger State holds significant importance as it serves as a key driver of socio-economic development in the producing areas of the State. The production encompasses various stages (picking of shea nut - marketing). Each stage contributes to the production of the valuable commodity (shea butter) with diverse applications in industries such as cosmetics, pharmaceuticals and food. Despite the wealth of knowledge generated from these studies, there remains a dearth of empirical evidence in the literature pertaining to the effects of shea butter processing on the livelihoods of rural women in the Nigeria. The identified knowledge gap in literature necessitates the conduct of this research which is to assess the effects of shea butter processing on the livelihood status of rural women in Niger State, Nigeria.

## METHODOLOGY

**Susy Area:** The study was conducted in Niger State. Niger State is located between Latitudes 8º22'N and 11º30'N and Longitudes 3º30'E and 7º20'E. The State covers an estimated total land area of 74. 244sq.km, which is about 9.3% of Nigeria's total land area (Kolapo and Adeyera, 2021). The population of the State is 3,950,249, comprising 2,082,725 males and 1,867,524 females (National Population Commission (NPC), 2006). The projected population of the State as at 2021 was 5,644,139 at 3.2% population growth (National Bureau of Statistics (NBS), (2022). The average annual rainfall in the State is 1,219 mm.

### Sampling Techniques and Sample Size

Three-stage sampling procedure was employed to select Shea butter processors in the study area. The first stage involved random selection of one extension block from each of the three (3) Agricultural zones in the Niger State. Katcha in Agricultural Zone (I), Bosso in Agricultural Zone (II) and Wushishi in Agricultural Zone (III). The second stage involved random selection of three (3) extension cells from each of the selected extension blocks. The final stage involved proportionate sampling of the Shea butter processors in each of the selected cell. Upon discussion with Niger State Agricultural Mechanization and Development Authority (NAMDA), Community heads and extension agents from each zone, the sampling frame of 450 of shea butter processors was obtained. A total of 212 respondents were selected for this study

### Methods of Data Collection

Primary data was used for the study. A semi-structured questionnaire complemented with an interview schedule was used to collect data from Shea butter processors. The researcher was assisted in the data collection by extension agent from all the selected agricultural zones using kobo tool installed on android phone

### Analytical Techniques

Data collected were analyzed using both inferential statistics objective 1 was achieved using multiple regression while objective 2 was achieved using ordered logit regression.

**Multiple regression model**

The functional forms to be fitted to the data in explicit forms include the following

1. Linear:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} \ldots + \beta_{11} X_{11} + e$

2. Double logarithmic/Cobb-Douglass:

$\ln Y = \ln\beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + \beta_{10} \ln X_{10} \ldots \beta_{11} \ln X_{11} + e$

3. Exponential

$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + e$

4. Semi-logarithmic:

$Y = \ln\beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + \beta_{10} \ln X_{10} \ldots \beta_{12} \ln X_{12} +$

$Y$ = Shea butter output (kg)

$X_1$ = Age (Years); $X_2$ = Processing experience (years); $X_3$ = Extension contacts (No. of visits) $X_4$ = Access to storage facilities (Dummy); $X_5$ = Cooperative membership (yes =1, if otherwise =0); $X_6$ = Education status (Years); $X_7$ = Distance to market (Km); $X_8$ = Distance to source **of raw materials (Km)**; $X_7$ = Household income (Naira); $X_{10}$ = Access to information (No)

$X_{11}$ = Access to credit (Naira) ; $\beta_0$ = Constant term ; $\beta_{12} – \beta_{11}$ = Regression parameters estimated

ln = natural logarithm

**Ordered logit regression model**

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X+\ldots\ldots+\beta_nX_n + e_i. \qquad (2)$$

The dependent variable (Y) in this case is a ordered variable indicating:

Where Y = Livelihood diversification (high (2), moderate (1) and low (0))

Y = 2 (High); Y = 1 (Moderate); Y = 0 (Low)

Independent variables

$X_1$ = Education (years); $X_2$ = Quantity processed (kg); $X_3$ = Processing experience (years); $X_4$ = Income from shea butter processing (Naira); $X_5$ = Distance to market (km); $X_6$ = Access to credit (Amount of credit accessed ₦); $X_8$ = Distance to source of water (Km); $X_9$ = Household expenditure (₦); $e_i$= Error term

## RESULTS AND DISCUSSION

### Factors influencing shea butter processing among rural women

Table 1 present the results of multiple regression analysis on factors influencing shea butter processing among rural women. The results in Table1 reveal that linear functional form was the lead equation. This is because, it has the highest R-square value, with the highest number of significant variables which aligned with *a priori* expectation. The coefficient of determination R-square was 0.8629 suggests that approximately 86% variation in the dependent variable (shea butter output) was explained by the independent variables included in the model. The coefficients for processing experience (29103.57; $p < 0.10$), years spent in school (22927; $p < 0.05$), household income (4627.109; $p < 0.01$), and access to information (21945.12; $p < 0.01$) were positive and statistically significant. These findings suggest that a unit increase in any of these variables led to an increase in the processed shea butter output of rural women.

**Table 1: Factors influencing shea butter processing among rural women (n=212)**

| Coefficient | Linear | Double log | Semi-log | Exponential |
|---|---|---|---|---|
| Marital status | 23513.2 | .4955 | .2335 | 668069 |
| | (0.26) | (1.43) | (1.33) | (2.59)*** |
| Age | -19400.7*** | .1987 | .0228 | -145911.9 |
| | (-2.92) | (0.41) | (1.71)* | (-1.50) |
| Processing experience | 29103.57* | .2612 | .0124 | 11403 |
| | (1.99) | (1.32) | (0.30) | (1.27) |
| Years spend in school | 22927** | -.2882 | .0193 | 210755.3 |
| | (2.07) | (1.30) | (0.89) | (1.79) |
| Extension contacts | -24735.64 | .1905 | .0771 | -52607.03 |
| | (1.53) | (1.06) | (0.66) | (-0.57) |
| Access to storage facilities | 142244.9 | .2563 | .1813 | 182512.7 |
| | (1.56) | (0.98) | (0.99) | (1.35) |
| Cooperative membership | 33157.9 | .34028 | -.0514 | -31526.43 |
| | (1.62) | (2.10)** | (-1.29) | (-0.51) |
| Distance to market covered | -22361.15*** | .0681 | -.01831 | 36781.9 |
| | (-2.95) | (0.61) | (-0.40) | (0.39) |
| Distance to source of raw | 2549.092 | .2730 | .0047 | 88091.83 |
| materials | (0.53) | (-1.62) | (0.49) | (2.25)** |
| Household income | 4627.109*** | .0835 | .0082 | 313869.5 |
| | (5.74) | (1.04) | (4.88) | (5.51)*** |
| Access to information | 21945.12)*** | .6780 | -.0257 | -390714.6 |
| | (5.23 | (6.21)*** | (-3.19) | (-5.15)*** |
| Access to credit | 108155.2 | -.4852 | -.2419 | -135330.4 |
| | (1.63) | (-1.50) | (-1.34) | (-1.04) |
| Constant | -172218.2*** | 10.2515 | 10.4105 | -16711 |
| | (-2.80) | (7.80)*** | (23.74)*** | (-2.37)** |
| R-squared | 0.8629 | 0.7872 | 0.7591 | 0.6532 |
| Adj R-squared | 0.8073 | 0.7513 | 0.7184 | 0.6007 |

Sources: Field survey, 2024

The coefficient for processing experience is (29103.57), indicating that more years of experience in shea butter processing lead to higher output. Experienced processors are likely to be more skilled, efficient, and knowledgeable about the best practices and techniques in the field. They are adept at managing resources, minimizing waste, and maximizing yield. This accumulated expertise contributes to improved productivity and quality of the shea butter produced. Consequently, policies and programs that support skill development and provide ongoing training can further enhance the productivity of experienced processors.

The coefficient for years spent in school is (22927), highlight the importance of education in shea butter processing. Educated women are better equipped to adopt modern processing techniques, understand market dynamics, and manage their businesses effectively. Education also enhances their problem-solving abilities and enables them to make informed decisions. Additionally, literate women can access and utilize information from various sources, including extension services and digital platforms. Promoting education among rural women, particularly in regions where educational attainment is low, can lead to significant improvements in processing output and overall economic empowerment. This corroborate that of Baah-Boateng *et al.* (2019) who reported that higher level of education was associated with increased knowledge and awareness of improved shea butter processing techniques, resulting in better quality and increased output.

The coefficient for household income is (4627.109), highlighting the role of financial stability in enhancing shea butter processing output. Higher household income allows women to invest in better processing equipment, raw materials, and other necessary inputs. Financial stability also reduces the stress and uncertainty associated with economic vulnerability, enabling women to focus more on their processing activities. Access to credit and financial services can further boost household income, providing women with the capital needed to expand and improve their operations.

The coefficient for access to information is (21945.12), indicating that better access to information significantly increase processing output. Information about market trends, processing techniques, quality standards and financial opportunities can empower women processors to make informed decisions and adopt best practices. Extension services, local radio programs, and digital platforms can serve as valuable sources of information. Odoom and Quainoo (2021) reported that access to information, particularly through extension services and farmer organizations, improved the quality and quantity of shea butter produced by rural women in Ghana.

However, the coefficients for age (19400.7; $p < 0.01$) and distance to market (22361.15; $p<0.01$) were negative and statistically significant. This implies that a unit increase in any of these variables is associated with a decrease in the shea butter processing activities of rural women. The negative coefficient for age (19400.7) suggests that as women processors get older, their shea butter processing activities tend to decrease. This decline could be attributed to several factors. Older women might experience physical limitations that affect their ability to engage in labour-intensive processing activities. Additionally, they may be less likely to adopt new technologies and practices compared to younger counterparts, leading to lower productivity. The negative coefficient for distance to market covered (22361.15) highlights the challenges associated with longer distances to markets. Long distances can lead to increased transportation costs, time and effort, which in turn reduce the profitability and efficiency of shea butter processing.

**Effect of shea butter processing on livelihood status of rural women**

Table 2 present the results of Ordered logit regression on effects of shea butter processing on livelihood status of rural women. The pseudo R-squared value was 0.7314 which indicates that the independent variables in the model explained approximately 73% of the variation in the dependent variable (livelihood status). The log-likelihood was -49.75164 indicating that the model is a good fit for the data, as it represents the maximum value of the likelihood function. The Chi square 79.10 p-value of 0.0000 for the likelihood ratio test indicates that the regression model as a whole is statistically_significant. This means that at least one of the independent variables in the model is significantly related to the dependent variable. Therefore, the model is a good fit for the data and provides a meaningful explanation of the relationship between the independent variables and the dependent variable.

**Table 2: Effects of shea butter processing on livelihood status of rural women (n=212)**

| Variable | Coefficient | Standard error | Z-value |
|---|---|---|---|
| Quality processed | 0.2346 | 0.0569 | 4.12*** |
| Processing experience | 0.0237 | 0.0086 | 2.76*** |
| Distance to market | -0.0017 | 0.0081 | -0.21 |
| Access to credit | 22.27 | 1245. | 0.02 |
| Years spent of school | 0.0241 | 0.0110 | 2.19** |
| Income | 2.24E-06 | 2.11E-06 | 1.07 |
| Household expenditure | -0.1248 | 0.0671 | -1.86* |
| Distance to sources of water | -0.1913 | 0.0846 | -2.26** |
| Pseudo $R^2$ | 0.7314 | | |
| **Prob > chi2** | 0.0000 | | |
| Log likelihood | -49.751648 | | |

Sources: Field survey, 2024

The coefficient quantity of shea butter processed (0.2346; $p < 0.01$), processing experience (0.0237; $p < 0.01$) and years spend in school (0.0241; $p < 0.05$) were positive and statistically, implying that a unit increase in those variables will increase the likelihood of improving the livelihood status of women shea processors. Darkwa *et al*. (2015) reported that women who produced higher quantities of shea butter, had more experience in processing, and had higher levels of education were more likely to have higher incomes and better livelihoods. The coefficient for quantity of shea butter processed is (0.2346), indicating that higher production levels are associated with better livelihood status. Increased production allows women processors to generate higher incomes from their sales. This increase in income can improve their ability to meet household needs, invest in better processing equipment and expand their operations.

The coefficient for processing experience is (0.0237), highlighting the importance of experience in improving livelihood status. Experienced women processors are likely to have skills, leading to higher quality and more efficient production. This expertise can result in better products that fetch higher prices in the market, contributing to improved income and economic stability. The coefficient for years spent in school is (0.0241), highlights the role of education in enhancing livelihood status. Education equips women with critical thinking skills, literacy and numeracy, which are essential for effective business management. Educated women are better able to adopt new technologies, understand market dynamics, and manage their finances. They are also more likely to access and utilize information from various sources, including extension services and digital platforms. More so, the coefficients for household expenditure (0.1248; $p< 0.10$) and distance to sources of water for processing (0.1913; $p < 0.05$) were negative and statistically significant implying that increase in any of these variables is associated with a decrease in livelihood status of women shea butter processors. The negative coefficient for household expenditure (0.1248) suggests that higher household expenses are associated with a decrease in livelihood status. This could be because increased household expenditure reduces the disposable income available for reinvestment in shea butter processing. High household expenses may include costs related to food, healthcare, education and other essential needs, which can drain financial resources that could otherwise be used to improve processing efficiency, purchase better equipment, or expand production. The negative coefficient for distance to sources of water for processing (0.1913) indicates that longer distances to water sources are associated with a decrease in livelihood status. Water is a critical resource in shea butter processing, and having to travel long distances to access water can significantly reduce productivity.

**CONCLUSION AND RECOMMENDATION**

Experience, extension access, association, distance to market, distance to raw material, access to credit and access to raw materials had influence shea butter processing among rural women. Furthermore, years spent in formal education, experience and credit access had effect shea butter processing on livelihood status of rural women. Extension access negatively influence shea butter processing. It is recommended that women should be visited and new knowledge disseminated to them by the extension agents in the study area

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# ASSESSING THE CONTRIBUTION OF AGRICULTURAL SECTORS TO ECONOMIC GROWTH IN NIGERIA (2014-2023)

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## ABSTRACT

This study explored the contribution of agricultural sectors to economic growth in Nigeria between 2014 and 2023. The research employed an ex post facto research design. Guided by three objectives, corresponding research questions, and hypotheses, the study employed secondary data sourced from the Central Bank of Nigeria (CBN, 2024). It focused on key agricultural sub-sectors, namely crop production, livestock, and forestry, to evaluate their roles in driving economic growth. Data analysis was conducted using the Statistical Package for Social Sciences (SPSS), with partial correlation as the primary statistical technique. The findings revealed a strong and statistically significant positive relationship between GDP growth and the agricultural sectors, underscoring their critical role in Nigeria's economic performance. Based on these findings, it is recommended that the government should encourage private partnerships to strengthen investments in crop production, reducing dependency on food imports, the government, through public-private partnership (PPP) arrangements, should improve infrastructure and access to financing to support the livestock sector as well as the government, through environmental sustainability programs, should promote sustainable forestry to enhance GDP growth and create rural employment.

**Keywords:** Agriculture, sectors, economy & growth

## INTRODUCTION

Alahira (2022) Nigeria, endowed with vast agricultural resources, including 91 million hectares of land (81 million arable) and 18 million hectares of pastureland, has agriculture deeply tied to its socio-economic and political evolution. Historically sustaining over 75% of the population, agriculture transitioned from traditional pre-colonial practices to export-oriented production under colonial rule, supported by initiatives like the Moor Plantation and the Niger Agricultural Project. Post-independence efforts, such as Operation Feed the Nation (1976) and the Green Revolution (1980), aimed to modernize the sector, but agriculture's GDP share declined from 60% in 1960 to 25% in the late 1970s, partly due to the oil boom. Despite challenges like reliance on traditional methods, poor infrastructure, and market access issues, opportunities abound for growth through advanced farming techniques and high-value crops, with the sector projected to grow from $99 billion in 2011 to $256 billion by 2030.

Nigeria's economy still depends heavily on agriculture, especially in rural and suburban areas where over 70% of the population works in the sector. Before oil was discovered at Oloibiri in 1956, it was the mainstay of the economy and made a substantial contribution to GDP—previous estimates indicated a 40% share (CBN, 2009). Nigeria's third quarter 2024 GDP was 22.8% derived from agriculture, according to recent data from the National Bureau of Statistics (2024). The industry is nevertheless vital for economic diversification, food security, job support, and stability in the face of fluctuating oil prices, despite this downturn.

Agbelekale (2020) Nigeria's economy depends heavily on agriculture, which provides the majority of the country's food supply, jobs, and industrial raw materials. It also makes a substantial contribution to foreign exchange and national income. By providing for the nation's high food demand and generating employment, particularly in rural areas where it is the main occupation, it supports the nation's sizable population. In addition to providing vital raw materials for sectors like sugar, tobacco, and textiles, agriculture also boosts foreign exchange profits through exports like cocoa beans, sesame seeds, and palm kernels. Agriculture has been essential for economic resilience, increasing food security, promoting industrialization, and lowering poverty among rural populations by diversifying the economy, especially after the drop in oil prices. For Nigeria to experience sustainable economic growth and better living standards, this sector must be strengthened.

The agricultural sector, which occupies 34 million hectares of arable land 6.5 million of which are used for permanent crops and 28.6 million of which are used for meadows and pastures is essential to Nigeria's economy. Since agriculture accounts for around 23% of Nigeria's GDP, the nation leads the world in the production of commodities including sorghum, cocoa beans, pineapple, and palm oil. Nigeria produces a lot of oil, fruits, nuts, and seeds for export, and it ranks second in the world for sorghum output and fifth for palm oil and cocoa beans. 70% of households are supported by agriculture through crop cultivation, and 41% through livestock, however rural participation is higher than in urban areas. Even though the country has a long coastline and plenty of water, just 3% of households engage in fishing, making it a modest pastime (Sasu,2023).

Nigeria imports food and agricultural products from South America, Europe, Asia, and the United States, spending about $10 billion a year as a result of supply shortages. The National Agricultural Technology and Innovation Plan (NATIP), which was implemented in 2022, and the Anchor Borrowers Program are two initiatives that seek to increase production and decrease reliance on imports (FAO, 2023). But enduring problems including wars between farmers and herdsmen, flooding, poor infrastructure, and a lack of money have all led to food inflation, which reached a peak of 23.75% in December 2022. Insecurity, currency depreciation, and rising fuel prices all contribute to cost increases (World Bank, 2023). Food security, climate resilience, and infrastructure development are prioritized in the National Development Plan (2021–2025) in order to address these issues and boost economic growth (CBN, 2024).

## METHODOLOGY

The study employed an ex post facto research design, utilizing secondary data on the Nigerian economy spanning 2014 to 2023, sourced from the Central Bank of Nigeria (CBN, 2024). It empirically assessed the contributions of agricultural sectors specifically crop production, livestock, and forestry to economic growth in Nigeria. The partial correlation statistical technique was applied for data analysis using the Statistical Package for the Social Sciences (SPSS).

The model, adapted and modified from the work of Bekun, Ugural, and Sertoğlu (2017), can be expressed as follows:

Regression Equation:

$$RGDP = \beta 0 + \beta 1(\text{Crop Production}) + \beta 2(\text{Livestock}) + \beta 3(\text{Forestry}) + \beta 4(\text{Inflation}) + \varepsilon$$

Where:

RGDP = Real Gross Domestic Product (dependent variable)

$\beta 0$ = Constant (intercept)

$\beta 1$, $\beta 2$, $\beta 3$ = Coefficients for crop production, livestock, and forestry (independent variables)

$\beta 4$ = Coefficient for inflation (control variable)

$\varepsilon$ = Random error term (captures unexplained variation)

This equation explains how each agricultural sector (crop production, livestock, and forestry) and inflation affect Nigeria's economic growth, with β0 representing the baseline RGDP when all variables are zero. β1, β2, and β3 measure the individual impacts of crop production, livestock, and forestry, respectively, while β4 quantifies how inflation affects RGDP.

**RESULTS**

**Table 1: Descriptive Statistics of Variables**

Summary statistics for crop production, livestock, forestry, GDP growth rate, and inflation rate in Nigeria

| Variable | Mean | Standard Deviation | N (Observations) |
|---|---|---|---|
| **Crop Production** | 3966.99 | 831.39 | 40 |
| **Livestock** | 297.67 | 28.42 | 40 |
| **Forestry** | 45.69 | 4.63 | 40 |
| **GDP Growth Rate** | 17687.98 | 1489.05 | 40 |
| **Inflationrate (Quarterly)** | 10.98 | 2.13 | 40 |

**Source:** Central Bank of Nigeria (CBN), 2024.

From table one (1), the descriptive statistics revealed that over the study period, crop production had a mean value of 3966.99 (SD = 831.39), indicating substantial variability in agricultural output. Livestock had an average value of 297.67 (SD = 28.42), while forestry activities recorded a lower mean of 45.69 (SD = 4.63), reflecting a smaller but more consistent contribution to the economy. GDP growth rate showed a high average of 17687.98 (SD = 1489.05), indicating robust economic performance with notable variability. The quarterly inflation rate averaged 10.98% (SD = 2.13), demonstrating relatively stable inflation during the period.

**Table 2: Partial Correlation Matrix Controlling for Inflation Rate (Quarterly)**

Correlation coefficients, significance values, and degrees of freedom for the relationship between crop production, livestock, forestry, and GDP growth rate in Nigeria)

| Variables | CROP_PROD | LIVESTOCK | FORESTRY | GDP GROWTH RATE |
|---|---|---|---|---|
| **Crop Production** | 1.000 | .439 | .289 | .822 |
| **Significance** | - | .005 | .075 | .000 |
| **Df** | 0 | 37 | 37 | 37 |
| **Livestock** | .439 | 1.000 | .593 | .653 |
| **Significance** | .005 | - | .000 | .000 |
| **Df** | 37 | 0 | 37 | 37 |
| **Forestry** | .289 | .593 | 1.000 | .461 |
| **Significance** | .075 | .000 | - | .003 |
| **Df** | 37 | 37 | 0 | 37 |
| **GDP Growth Rate** | .822 | .653 | .461 | 1.000 |
| **Significance** | .000 | .000 | .003 | - |
| **Df** | 37 | 37 | 37 | 0 |

Significance (2-tailed) indicates whether the correlation is statistically significant ($p < 0.05$ is typically considered significant).

Source: Central Bank of Nigeria (CBN), 2024)

From table two (2), the correlation analysis controlling for inflation rate revealed a strong and statistically significant positive relationship between GDP growth rate and crop production (r=0.822, p<0.001), indicating that increased crop production is closely associated with economic growth. Similarly, there is a significant positive correlation between GDP growth rate and livestock (r=0.653, p<0.001), as well as between GDP growth rate and forestry (r=0.461, p=0.003). Crop production and livestock are moderately positively correlated (r=0.439, p=0.005), while forestry shows a weaker, non-significant correlation with crop production (r=0.289, p=0.075). Livestock and forestry also exhibit a strong positive correlation (r=0.593, p<0.001). These findings emphasize the significant contributions of crop production, livestock, and forestry to economic growth, with crop production demonstrating the strongest association with GDP growth during the study period.

## DISCUSSION

The findings of the study revealed a strong and statistically significant positive relationship between GDP growth rate and crop production ($r = 0.822$, $p < 0.001$), indicating that increased crop production is closely associated with economic growth. Similarly, there is a significant positive correlation between GDP growth rate and livestock ($r = 0.653$, $p < 0.001$), as well as between GDP growth rate and forestry ($r = 0.461$, $p = 0.003$). Crop production and livestock are moderately positively correlated ($r = 0.439$, $p = 0.005$), while forestry shows a weaker, non-significant correlation with crop production ($r = 0.289$, $p = 0.075$). Livestock and forestry also exhibit a strong positive correlation ($r = 0.593$, $p < 0.001$).

These findings align with Said and Single (2021), who reported that the agricultural sector has significantly driven economic growth in Nigeria, particularly between 2016 and 2018, due to increased agricultural output. Similarly, Rotowa et al. (2019) emphasized the continuous contribution of forestry and fisheries to Nigeria's GDP over the past three decades, with notable increases from ₦88.91 billion in 1989 to ₦171.64 billion in 2016 for forestry, and from ₦94.81 billion in 1989 to ₦358.7 billion in 2015 for fisheries.

In the same vein, Emmanuel, E. Y., et al. (2021) employed an error correction model (ECM) and found positive and significant coefficients for livestock (5.0526, $p = 0.0432$) and fishery production (67.26, $p = 0.0292$). However, their findings indicated that crop production and forestry had negative and insignificant impacts on GDP growth, with coefficients of -4.593964 and -2.625762, respectively. Furthermore, Korgbeelo (2022) found that crop production and forestry outputs make a strong contribution to the development of the Nigerian economy, while the outputs of livestock and fishery make insignificant contributions to Nigeria's economic development. The Granger causality test further indicated bidirectional causality between crop production output and economic development, as well as unidirectional causality from livestock output to economic development.

## CONCLUSION

The study concludes by highlighting the vital role that the forestry, livestock, and crop production sectors have in propelling Nigeria's economic growth. Increasing crop production investments, particularly in important commodities like rice, maize, and cassava, can drastically boost GDP growth and lessen reliance on food imports. Its economic impact will also be increased if the cattle industry is supported with better funding and infrastructure. Promoting sustainable forestry methods can also guarantee environmental sustainability, create jobs in rural areas, and accelerate economic progress. All of these steps taken together will assist Nigeria in developing a more robust and varied economy.

## RECOMMENDATIONS

1.The government should encourage private partnerships to strengthen investments in crop production, reducing dependency on food imports.

2.The government, through public-private partnership (PPP) arrangements, should improve infrastructure and access to financing to support the livestock sector.

3.The government, through environmental sustainability programs, should promote sustainable forestry to enhance GDP growth and create rural employment.

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# PROSPECTS FOR INTEGRATION OF OPPORTUNITIES IN CLIMATE CHANGE INTO POLICY AND PRACTICE FOR LIVELIHOODS IN NIGER NORTH SENATORIAL DISTRICT, NIGER STATE, NIGERIA

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## ABSTRACT
This study examined how climate change opportunities can be integrated into policy and practice for livelihood sustainability in the study area. Multi-stage sampling technique was adopted; 384 respondents were randomly sampled in the study area. Structured questionnaire was used to gather the data. The data were analyzed using descriptive and inferential statistics, and Henry Garrette value and ranking. The findings indicated that livelihood activities in the study area are threatened by climate induced hazards such as increased flooding and soil erosion 48.18%, increased temperatures and water stress 33.59%. These climatic changes lead to reduce agricultural yields. The study reveals that the most crucial prospect for integrating climate change opportunities into policy and practice is the initiation and interventions of the Federal and State Governments (FG and SG) aimed at creating awareness and opportunities to harness the benefits of climate change for sustainable livelihoods which received the highest pooled mean Garrett value of 71.68, while opinion for construction of ponds, dams and lakes for community use ranked lowest with a pooled mean Garrett value of 57.97. The study concludes that to curb the menace posed by climate change it is imperative to integrating climate resilient policies into practice in the study area.
**Key words: Integration, Opportunities, Climate change, Policy**

## INTRODUCTION

Climate change is viewed as a shift from the average weather condition of climatic elements, which persists for several decades or longer Intergovernmental Panel on Climate Change [IPCC] (2020). The basic livelihood activities in Niger North Senatorial District, Niger State is mostly driven by agricultural activities which mostly depends on rain fall, the major agricultural product of the town are maize, rice, cowpea, sorghum, soybean, cassava, fish and livestock. Niger State Agricultural and Mechanization Development Authority annual report [NAMDA] (2022), report shows that livelihood activities of rural people were negatively affected from the 2012, 2018 and 2020 flooding. Niger State Emergency Management Agency [NSEMA] (2020) reported extreme weather events such as flood in different communities of the state with various degrees of damages; Agwara, Borgu, Kontagora, Magama, Mariga, Mashegu, Rijau and Wushishi, are among the Local Government Areas (LGAs) that have consistently experienced flooding with huge loss of lives and properties including their livelihoods. In combating menace of climate change, it is necessary to increase the resilience of the affected communities' livelihood and ensure food security. Therefore, the study aimed to look inward and take advantages of the prospects of climate change opportunities available and integrate into policy and practice in Niger North Senatorial District of Niger State, Nigeria.

## MATERIALS AND METHODOLOGY

### Study Area

Niger North Senatorial District, Niger State is located between Latitudes 9°17 00 N and 11°23' 00" North of the equator and Longitudes 3°35'30" E and 6°13'30" East of the Greenwich meridian. The total land mass of the Senatorial District is 41,265.4 Square Kilometres. It is bounded to the north by Kebbi and Zamfara States, to the east by Kaduna State and Rafi LGA, to the south by Mokwa, Lavun, Gbako and Bosso LGAs and to the west by Republic of Benin and Kwara State. The projected 2023 population of the study area is 2,725,812, Mashegu LGA is the most populated and Agwara is the least populated.

### Types of data

The data required for the study include data on the socio-demographic attributes of the people (age, marital status, education and occupation); occupations of the people in the study area; sustainable livelihood activities that can harness the opportunities of the climate change; opinion of the people on integration of climate change opportunities into policy and practice. Others include the administrative boundary of the study area, the number of LGA in the study area, the name and number of communities within each LGA, population of each ward and villages.

### Sources of data

*Questionnaire*

A structured questionnaire was designed to elicit information on the subject matter from the respondents. The questionnaire was designed in sections. The questionnaire contained both open and closed ended questions that enhanced the quality of information provided by the respondents.

*Observation checklist*

Taking advantages of climate change manifestations such as flood, heat, insect infestation required some techniques and tools, for instance Sand bagging, digging trench to contain flood water for reuse and so on. Therefore, observation was used to acquire data on how it was done and achieved. Observation checklists was used for these.

***Key Informants Interview (KII)***

The research being a mixed method randomly selected key informants who have successfully taken opportunities of climate change based on professional experience.

**Sample size and sampling techniques**

The sample size of the study area according to 1991 population census was 1,198,893 with annual growth rate of 2.60% (World Population Review, 2023). The 1991 Population was projected to 2023, therefore 2,725,812 is the population of the study area using the calculator.academy/pop.population growth calculator (2023) formula.

Krejcie and Morgan's (1970) Table was used to determine the sample size. According to this technique, for an area with a population range of between 2,500,000 to 10,000,000 the sample size to use is 384 at 95% confidence level and 5.0% margin of error. Thus, the sample size for this study was 384. The 384 respondents were selected from the eight selected wards of the four selected LGA proportionate to population of each ward.

The eight (8) Local Government Council Areas (LGA) of Niger North Senatorial District, Niger State were arranged in alphabetical order and every second LGA was sampled. In this case, Borgu, Magama, Mashegu and Wushishi formed the sampled LGAs. In the second stage, systematic sampling technique was also used to select every 4$^{th}$ Ward from the four LGAs sampled. In this case Karabonde, Shaganu in Borgu, Ibelu East, Nasko in Magama, Kaboji, Mashegu in Mashegu, Kanwuri and Maito in Wushishi LGAs formed the sampled Wards.

In the third stage, purposive sampling technique was used. Respondents who were 45 years and above and must have been residing in the District for at least 30 years was used as units of observation.

The livelihoods in the study area were carefully identified and efforts were made to pick respondents across various livelihood options. The questionnaire was administered with the help of eight trained research assistants that were drawn from government agency (NAMDA) and trained by the researcher.

**Data Analysis**

Both descriptive and inferential statistics were used to analyse data collected based on the research objectives. Descriptive statistics include mean, frequency distribution, percentages, charts and Henry Garrette value and ranking was also used to analyse and present the results.

**RESULTS AND DISCUSSIONS**

**Social-demographic Characteristics of Respondents**

The personal data of the respondents under consideration include age, level of education, primary occupation and years of livelihood experience.

**Respondents' Age Distribution**

The results indicate that a significant majority of the respondents in Borgu (57.14%), Magama (60.6%), Mashegu (77.49%), Wushishi (66.67%), and the pooled result (72.39%) are above 51 years of age. These age categories have profound implications for engagement in sustainable livelihood activities. This finding is in consonance with Idoma et al., (2017), who reported that larger proportion of farmers in Agatu LGA of Benue State, Nigeria were still in their active and productive age and easily adopted new farming technology.

**Respondents' Level of Education**

Most of the respondents, about 63% in Borgu, about 85% in Magama, about 86% in Mashegu, about 67% in Wushishi and about 83% in the pooled result respectively have received some form of formal education ranging from primary to tertiary levels. This suggests a strong foundation for the adoption of sustainable livelihood practices that can harness climate change advantages in the study area. This finding agrees with Ishaya and Abaje (2018), who identified formal education as a way to increase farmers' adaptive capacity to climate change in Jema'a Local Government Area of Kaduna State.

**Primary Occupation of Respondents**

The primary occupation is the main source of the people income which influence adoption of new innovation in the study area. The findings indicate that a significant majority of respondents in the study area are primarily crop farmers representing about 66% in Borgu, 73% in Magama, 60% in Mashegu, 83% in Wushishi, and 64% in the pooled result respectively. Other occupations undertaken by respondents include livestock farming, artisanship, and trading. The predominance of crop farming as the primary occupation among respondents underscores the critical role of agriculture in the livelihood strategies in the study area. This reliance on crop farming highlights the vulnerability of these communities to climate change impacts such as altered rainfall patterns, droughts, and extreme weather events. Promoting integrated farming systems that combine crop and livestock farming can improve resource use efficiency and increase resilience in the communities as opined by Adenrele and Sawa (2021).

**Livelihood Experience of Respondents**

Years of engaging in livelihoods is an indicator of experience and persistence for sustainability of the livelihood. It also points to being adept at using opportunities that may arise. Findings shows that the average duration of livelihood experience of respondent in the Niger North Senatorial District has 28 years of livelihood experience. The extensive livelihood experience of respondents implies a deep understanding of local agricultural practices and environmental conditions. The result corroborates the finding from Lansigan et al. (2000), who reported that long farming experience is an advantage for increase in farm productivity in Philippines since it encourages rapid adoption of modern farming innovations.

**Types of Threats Posed by Climate Change in the Study Area**

Types of threats posed by climate change to respondents' livelihood in the past 30 years' data were collected and analysed.

The findings revealed that reduced crop yield and food production is a significant threat, particularly in Magama (56.06%) and Mashegu (51.29%), with 49.22% of respondents across all LGAs, another 83.33% of respondents in Wushishi LGA identified increased flooding and soil erosion, in Borgu LGA 77.14%, 33.59% of respondents across the region identified increased temperatures as a threats, threat of shortage of rainfall and drought was identified particularly in Borgu (62.86%) and Magama (54.55%), respondents in Magama (40.91%) and Mashegu (24.72%) identified rise in pests and diseases directly threatens agricultural productivity The implications for rural households are severe, as water scarcity directly impacts agricultural productivity, reducing crop yields and compromising food security. Livestock, a critical component of rural livelihoods also suffers from inadequate water resources leading to decreased meat and dairy production, pest attack also leads to potential crop failures, reduced yields, and increased costs for pest control measures. This agrees with Falaki et al., (2023) remarked that the degree of the impact of climate change on crop production will depend upon the magnitude of the climate change and other factors since increasing temperature will also increase intensity of pests and diseases. Addressing these challenges requires integrated strategies that not only enhance resilience in agriculture through practices but also integrating policy and practice to mitigate the impacts of climate change on rural livelihoods and foster sustainable development.

**Integration of Climate Change opportunities into Policy and Practice for Sustainable Livelihoods**

The previous findings have presented diverse issues on taking advantage of opportunities in climate change. There is no doubt demonstrable evidence that instead of the narratives on the destructive characteristics of climate change, there are opportunities that can be prospectively anticipated. However, evolving policy from the isolated practices in the study area that can be widely used, transferred to other locations need to be considered. The finding reveals opportunities of climate change in the study area which include water conservation infrastructure, renewable energy, creation of education and enlightment, preparedness of the people, and community based organizations is examined and discussed in the subsections that follow. The analysis, using Henry Garrett's ranking approach, reveals the prioritized climate change opportunities for policy integration across the four selected LGAs in Niger North Senatorial District: Borgu, Magama, Mashegu, and Wushishi. These opportunities were ranked based on their mean Garrett values as presented in Table 3.1, indicating their relative importance as perceived by respondents in each LGA. The pooled results provide an overall ranking across the study area.

**Initiatives for Awareness, interventions and integrating of climate change Opportunities into policy and practice**

The analysis reveals that the most crucial prospect for integrating climate change opportunities into policy and practice across the Niger North Senatorial District is the initiation and interventions of the Federal and State Governments (FG and SG) aimed at creating awareness and opportunities to harness the benefits of climate change for sustainable livelihoods. This prospect, which received the highest pooled mean Garrett value of 71.68, was consistently prioritized across all the LGAs, ranking first in Borgu, Mashegu, and Wushishi, and second in Magama is shown in Table 1. The strong consensus among respondents underscores the perceived necessity for proactive government involvement in fostering climate change opportunities at the grassroots level. The integration of this prospect into policy frameworks would necessitate the development of robust outreach programmes.

According to Alagidede et al., (2016), the pessimistic school of thought or adherents to environmental conservatism claim that environmental sustainability is compatible with economic growth and argue that social scientists, government and non-state actors should not remain passive on climate change.

**Support for construction and adoption of renewable energy for Sustainability of Livelihoods**

The second most significant opportunity identified in the study, with a pooled mean Garrett value of 70.07, is the formulation and implementation of policies by State and Local Government authorities to facilitate the construction and the adoption of solar power technologies to sustain livelihood activities as these represents a strategic shift towards renewable energy, reducing the reliance on fossil fuels and enhancing energy security in these communities. This opinion ranked highest in Magama, and ranked second in Borgu, Mashegu, and Wushishi as shown in Table 3.1.

Findings in this study is similar to Dinar et al., (2012) who opined that actions should be taken to help communities with the ecosystem moderate, cope with, or take advantage of actual or expected changes in climatic conditions, such actions include policies and measures to reduce exposure to climate change and extremes, and the strengthening of adaptive capacity.

**Community Preparedness to take Advantage of Opportunities of Climate Change**

Opportunities can be available but the community needs to be sufficiently utilized to maximize the opportunities. Therefore, preparedness and readiness are necessary. Opinion that preparedness of the people to take advantages of opportunities in climate change is of essence as it's enhance sustainability of their livelihoods. This opinion ranked third as shown in Table 3.1, with a pooled mean Garrett value of 63.85. Although this prospect was ranked slightly lower in individual LGAs, it still emerged as a significant factor, particularly in Borgu and Mashegu. The findings imply that while there is general agreement on the importance of community preparedness for taking advantage of climate change opportunities in Niger North Senatorial District, the weakness indicates a need for enhanced community engagement and to integrate climate change prospects into actionable and effective policies. It is also crucial to focus on educational and participatory programmes that increase community awareness and involvement. Similarly, in India, the work of Thamil and Divya (2020) revealed that participating in community-based adaptation initiatives, such as disaster risk reduction projects, early warning systems, and climate-resilient livelihood programme, empowers communities to build resilience, enhance adaptive capacity, and reduce vulnerability to climate change impacts.

**Table 1: Garrett value and ranking of climate change opportunities to be integrated into policy and practice for sustainable livelihoods**

| How to integrate climate change prospects into policy and practice | Borgu Garrett value | | | Magama Garrett value | | | Mashegu Garrett value | | | Wushishi Garrett value | | | Pooled result Garrett value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sum | Mean | Rank | Sum | Mean | Rank | Sum | Mean | Rank | Sum | Mean | Rank | Sum | Mean | Rank |
| FG and SG should initiate interventions and programmes that will create awareness and opportunities to harness the opportunities in climate change for sustainability of livelihood activities | 2398 | 68.51 | 1st | 4893 | 74.14 | 2nd | 19340 | 71.37 | 1st | 896 | 74.67 | 1st | 27527 | 71.68 | 1st |
| SG and LG authorities should implement policies that will enhance/support communities, cooperative groups and individuals to construct and adopt solar power energy for sustainability of livelihoods | 2324 | 66.40 | 2nd | 4953 | 75.05 | 1st | 18777 | 69.29 | 2nd | 854 | 71.17 | 3rd | 26908 | 70.07 | 2nd |
| Community preparedness to take advantage of opportunities of climate change | 2047 | 58.49 | 4th | 4316 | 65.39 | 4th | 17329 | 63.94 | 3rd | 826 | 68.83 | 4th | 24518 | 63.85 | 3rd |
| Community-based organizations must lead in advancing opportunities from climate change prospects | 1922 | 54.91 | 5th | 4353 | 65.95 | 3rd | 17068 | 62.98 | 4th | 812 | 67.67 | 6th | 24155 | 62.90 | 4th |
| Climate related NGOs should partner with rural dwellers | 1913 | 54.66 | 6th | 4230 | 64.09 | 5th | 16964 | 62.60 | 5th | 826 | 68.83 | 4th | 23933 | 62.33 | 5th |
| SG should make a framework to construct ponds, dam, and lake for communities use for sustenance of their livelihood and domestic activities | 2250 | 64.29 | 3rd | 3408 | 51.64 | 6th | 15733 | 58.06 | 6th | 868 | 72.33 | 2nd | 22259 | 57.97 | 6th |

**Note: FG =Federal government; SG = State government; LG = Local government.**

**Community Based Organizations lead advancements in opportunities from climate change**

Community based organizations (CBOs) are organizations within the community, it could be women, youths or elderly organized groups which forms the key actors that are prepared and ready to take advantages in opportunities, the CBO play important roles as they understand the customs and norms of the community and for self-commitment as partner in the innovations. This opinion ranked fourth with a pooled mean Garrett value of 62.90. This prospect was particularly emphasized in Magama and Mashegu LGAs, where it received higher rankings, highlighting the crucial function CBOs serve in these study area.

The findings in the study is similar to Asare-Nuamah and Botchway (2019) findings that accurate bottom-up knowledge on the level of farmers' climate change awareness and perception enables policy-makers and managers to understand and re-think climate change policies at the local level, which is essential to address agricultural risks in climate change hotspots.

**Climate-related non-governmental organization partnering Community based organizations**

Integrating climate resilient policies into practice require acceptance by individual in communities that climate related NGOs should partner with rural dwellers. The prospect of partnerships between climate-related non-governmental organizations (NGOs) and rural communities ranked fifth with a pooled mean Garrett value of 62.33 as shown in Table 3.1. The successful integration of NGOs into local adaptation frameworks hinges on the establishment of robust partnerships that are rooted in mutual understanding and respect for local customs and knowledge systems, this opinion which trait theory in psychology rests on the idea of the people. According to Everton and Pfaff (2022), Personal trait theory emphasizes individual differences in social change based on individual traits, that is, modes of behaviour and exposure that are manifested consistently, traits are dynamic in nature with experience.

**State Government should make a framework to construct water conservation infrastructures for sustenance of livelihoods.**

The construction of ponds, dams and lakes is crucial for water conservation and management, providing a reliable water source for irrigation, livestock, and other agricultural activities, which are the backbone of rural economies in the study area, though ranked lowest overall with a pooled mean Garrett value of 57.97 as shown in Table 3.1., it is however, not just beneficial but essential for sustaining livelihoods. Therefore, Governments should integrate this into broader climate adaptation policies, thereby enhancing the resilience of vulnerable communities. According to Alagidede et al., (2016), the pessimistic school of thought or adherents to environmental conservatism claim that environmental sustainability is compatible with economic growth and argue that social scientists, government and non-state actors should not remain passive on climate change. They contend that Government should be proactive in providing water conservation structures to harvest water from different sources which are consequent of climate change for diverse uses.

## CONCLUSION AND RECOMMENDATION

Harnessing climate change opportunities and integrating climate resilient policies into practice in the study area will curb the menace of climate change and enhance sustainability of livelihoods in the study area. Therefore, it is recommended that Local Government Authority should integrate and implement comprehensive policies that will increase harnessing opportunities in climate change in the study area. These policies include Government and climate change NGOs should support the people with adequate knowledge and funding to utilize technologies that optimize the opportunities in climate change such rain water harvest, damming rain run off-water and use of solar energy for sustainability of their livelihoods.

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# UTILIZATION OF FARM INPUT AMONG YAM FARMERS IN ZONE B OF NIGER STATE, NIGERIA

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## ABSTRACT

This study examined the utilization of farm inputs among yam farmers in Bosso and Paikoro Local Government Areas of Niger State, Nigeria. A multistage sampling technique was employed to select 110 yam farmers on which structured questionnaires was administered via kobo tool box. Primary data were analyzed using descriptive statistics such as frequency counts, percentages and mean and OLS regression. Findings from this study revealed that that most respondents (90%) were married, with an average age of 35 years. More than half (55.5%) of the respondents had formal education, averaging six years of schooling, while 61% had access to extension services. Commonly used inputs included seeds, labor, hoes, and cutlasses, while herbicides, pesticides, and tractors were underutilized due to cost, limited access, and lack of knowledge. The regression analysis revealed that farm size ($p < 0.01$), access to credit ($p < 0.05$), government support ($p < 0.05$), and extension services ($p < 0.05$) had a significant positive influence on farm input utilization. Conversely, input cost ($p < 0.01$) and weather conditions ($p < 0.05$) had a significant negative impact on input usage. The study concludes that farm input utilization among yam farmers is influenced by socio-economic and institutional factors, while being constrained by limited finance and infrastructure. It was recommended that government should enhance access to credit, subsidizing input costs, improving extension services, and strengthen farmer education to increase input utilization and boost yam production in the region.

**Keywords:** Utilization, Farm inputs, Yam, Farmers, Niger State

## INTRODUCTION

Yams, belonging to the Dioscorea genus, encompass a wide variety of species distributed worldwide. They serve as a crucial crop and dietary staple for millions globally, offering essential nutrients such as carbohydrates and fiber (Amadou, 2020). Common varieties include white yam (Dioscorea rotundata), water yam (Dioscorea alata), yellow yam (Dioscorea cayenensis) and lesser yam (Dioscorea esculenta), alongside numerous uncultivated wild species. In regions like Nigeria and West Africa, yam cultivation holds significant socio-economic importance by ensuring food security, generating income and creating employment opportunities for small-scale farmers. Globally, yam ranks as the second most significant tuber crop after cassava in terms of production (International Institutes of Tropical Agriculture (IITA), 2023).

West Africa is the world's largest yam producing region, with Nigeria leading in global production, yielding over 45 million metric tons annually (Nweke and Ugwu, 2016; IITA, 2023). However, the crop faces several production challenges. Yam tubers, characterized by high moisture content (60–85%) and varying dry matter (7–40%), are prone to rapid deterioration, which limits their shelf life. Despite being rich in carbohydrates and serving as a significant energy source, yam tubers are low in protein and fat content (Oyekale and

Adeola, 2019). Other constraints include low yields, pest and disease pressures, and limited access to modern agricultural inputs (Birch-Thomsen and Petersen, 2017).

The efficient utilization of farm inputs is fundamental to improving agricultural productivity, ensuring food security and promoting sustainable development (Pretty *et al.,* 2018). Farm inputs include essential resources such as seeds, fertilizers, pesticides, machinery, equipment and labour (Food and Agriculture Organization (FAO), 2019). These inputs optimize crop yields, control pests and diseases, and enhance mechanized operations (Diaz-Ambrona *et al.,* 2021). However, input utilization is influenced by economic conditions, technological advancements, environmental concerns and social dynamics (Alene *et al.,* 2020). Therefore, yam farmers must strategically manage inputs to maximize benefits, while minimizing costs and environmental impacts (Reinbott *et al.,* 2021).

However, despite the benefits of farm inputs, their utilization among yam farmers in Nigeria remains low (Oyekale and Adeola, 2019). Key barriers include high input costs, limited access to information, and inadequate extension services. Demographic factors, such as land tenure systems and gender roles, also influence input adoption decisions (Nweke and Ugwu, 2016). Research shows that adopting improved agronomic practices, alongside quality seeds, fertilizers, and pesticides, can significantly increase yam yields and improve farmers' livelihoods (Houndji, 2019). However, indiscriminate input use, such as over-reliance on chemical fertilizers and pesticides, can lead to soil degradation, water pollution, biodiversity loss, and health risks for both farmers and consumers. Achieving a balance between productivity and environmental stewardship is critical for sustainable agriculture.

The critical importance of utilizing agricultural inputs to enhance productivity cannot be overstated (Vandenputte *et al.,* 2019). This strategy is central to achieving sustainable agricultural growth, which is essential for alleviating poverty and promoting global sustainable development. The key to sustained growth lies in the extensive and judicious use of improved agricultural inputs, including hybrid seeds, various types of pesticide (such as insecticides, herbicides and fungicides), and synthetic fertilizers (World Bank, 2013). To boost yam production and ensure food security in the study area, challenges to yam production must be addressed by both the public and private sectors. This involves providing farmers with essential input subsidies and accessible credit facilities to support yam production, given its dependence on factors like land preparation, irrigation, transportation and mechanization (Amadou, 2020).

Meanwhile, the utilization of farm inputs such as fertilizers, improved varieties, and irrigation by yam farmers remains low, despite their potential to increase yields and improve food security (Oyekale and Adeola, 2019). Factors such as limited access to information, high input costs, and inadequate extension services have been identified as barriers to the effective use of farm inputs. Additionally, demographic factors such as land tenure systems and gender dynamics influence farmers' decisions regarding input use. This has constituted a gap in knowledge that need to be filled, hence the following objectives were formulated to describe the socio–economic characteristics of the yam farmers, identify the types of farm input utilized among the yam farmers, determine the extent of input usage among yam farmers and determine the factors influencing the utilization of farm input among yam farmers and examine the constraints associated with the utilization of farm input among yam farmers in the study area.

## METHODOLOGY

### Study Area

This study was conducted in Bosso and Paikoro Local Government Areas (LGAs) of Niger State, Nigeria. The State which was established in 1976 is located in the North-central region with Minna as its capital. It spans an area of 76,363 square kilometers and is home to approximately 5.56 million people, based on 2016 population projections (National Population Commission (NPC), 2006). Niger State shares borders with Zamfara, Kaduna, the Federal Capital Territory (FCT), and Benin Republic. The state's diverse topography, with hills, lowlands, rivers, and vegetation, supports agriculture, the main occupation of over 80% of its population. The average annual rainfall ranges from 1,100mm in the north to 1,600mm in the south, facilitating the cultivation of crops such as yam, cassava, and maize, along with livestock farming (Niger State Bureau of Statistics (NSBS), 2016).

Bosso LGA is located in Niger State with a landmass of approximately 1,592 km². The population, based on the 2006 census, was about 146,359. The LGA is bordered by Shiroro, Paikoro, Katcha, Gbako, and Wushishi LGAs, and it lies within Latitudes 9°39'12.02" – 9°39'12.03" North and Longitudes 6°30'58.00" – 6°30'58.01" East. The population of Bosso is ethnically diverse, primarily consisting of Gwari, Nupe and Hausa people. The area's topography is generally flat with gentle slopes, conducive for agricultural activities, which dominate the local economy. Also, Bosso is home to various educational institutions including tertiary schools (Ajayi and Olaitan, 2020).

Similarly, Paikoro LGA is situated in the Southern part of Niger State. Its headquarters is located in the Paiko town. This region is largely rural, with most residents engaged in agriculture. The major crops produced include yam, millet, maize, and rice, with some livestock farming as well. The LGA is rich in cultural diversity, home to traditional rulers and chieftains. Paikoro LGA is noted for its scenic landscapes, including hills and valleys, and is well connected by roads for trade and economic activities. The region also benefits from its natural resources, contributing to the local economy (NSBS, 2016).

### Sampling procedure and sample size

Multistage sampling procedure was employed to select respondents for the study. The first stage was purposive selection of Bosso and Paikoro Local Government Area of Niger State due to preponderance of yam farmers. The second stage involved random selection of three (3) villages from each of the LGA selected namely; Gidan-mangoro, Shata and Garatu from Bosso LGA, and Jere, Paiko and Adunu from Paiko LGA. The third stage was proportionate selection of 110 respondents using Yamane's sample size determination formula which is mathematically expressed as in equation (1):

$$n = \frac{N}{1+N(e)^2} \qquad \textbf{(1)}$$

Where;
n = samples size
N = finite population
e = limit of tolerable error (level of precision at 0.07 probability)
l = constant

### Method of data collection and analysis

Primary data were used for the study. The data was collected through a structured or designed questionnaire deployed using KoboToolbox. The data elicited from the respondents includes information on the socio-economic characteristics of yam farmers, the types and extent of farm input usage, and the factors affecting farm input utilization among yam farmers in Niger State. The data collected were analyzed using descriptive statistics (mean, percentages and frequency count) and inferential statistics (Ordinary Least Squares (OLS) regression analysis).

## RESULTS AND DISCUSSION

### Socio-economic characteristics of the yam farmers

The socio-economic characteristics of yam farmers described in this study were age, sex, marital status, household size, education, farm size, farm experience, extension service, cooperative society and access to credit. As revealed in Table 1, most (64.5%) of the respondents were between the ages of 35 – 44 years with an average of 35 years. This age group is generally considered to be in their prime working years and can practice crop production effectively. This result is in line with the result of Afolabi and Ajiboye (2020) who reported that majority of rural households in their study area are between the ages of 31 – 40 years. Majority (72.7%) of the respondents were males, while 27.3% were female. This implies that there is a higher proportion of male yam farmers than female in the study area which could be attributed to gender roles. These findings agree with the study of Bello and Obioha (2018) who reported that men are more involved in yam production in his study area as compared to their female counterparts.

**Table1: Distribution of the respondents based on their socio-economic characteristics (n=110)**

| Variables | Frequency | Percentage (%) | Mean |
|---|---|---|---|
| **Age (years)** | | | |
| 25-34 | 14 | 12.7 | 35 |
| 35-44 | 71 | 64.5 | |
| 45-54 | 19 | 17.3 | |
| 55-64 | 6 | 5.5 | |
| **Gender** | | | |
| Male | 80 | 72.7 | |
| Female | 30 | 27.3 | |
| **Marital status** | | | |
| Single | 11 | 10 | |
| Married | 99 | 90 | |
| **Level of education** | | | |
| Non-formal | 49 | 44.5 | 6 |
| Primary | 24 | 21.8 | |
| Secondary | 24 | 21.8 | |
| Tertiary | 13 | 11.8 | |
| **Household size (members)** | | | |
| 3-7 | 47 | 42.7 | 8 |
| 8-12 | 59 | 53.6 | |
| 13-17 | 4 | 3.6 | |
| **Farm size (hectares)** | | | |
| 1.1 – 2.0 | 46 | 41.8 | 2.05 |
| 2.1 – 3.0 | 40 | 36.4 | |
| 3.1 – 4.0 | 16 | 14.5 | |
| > 4.0 | 8 | 7.3 | |
| **Farm experience (years)** | | | |
| 10-19 | 42 | 38.2 | 20 |

| | | |
|---|---|---|
| 20-29 | 56 | 50.9 |
| 30-39 | 12 | 10.9 |
| **Access to credit** | | |
| Yes | 46 | 41.8 |
| No | 64 | 58.2 |
| **Access to extension services** | | |
| Yes | 61 | 55.5 |
| No | 49 | 44.5 |
| **Membership of cooperative** | | |
| Yes | 15 | 13.6 |
| No | 95 | 86.4 |

**Source:** Field Survey, 2024.

More so, as revealed in Table 1, majority (90%) of the respondents were married, while 10% of the respondents were single. This implies that greater proportion of the respondents are married and involved in yam farming to cater for their household needs. Marriage as a social institution is recognized in all cultures of human societies. This assertion is in line with Akinola and Adebayo (2019), who revealed that majority of the respondents in their study area are married. In terms of education, 55.5% of the respondents had formal type of education such as primary, secondary and tertiary education with an average of 6 years spent in school. More than half (53.6%) of the respondents had household size consisting of 8 to 12 members with an average household size of 8 members. This implies a relatively large household size which can contribute enormously to the family labour force need for improving productivity of yam in the study area. These findings are in line with Bello and Obioha (2018) who stated that a family with at least 6 members had access to more family labour which could enhance productivity.

Furthermore, Table 1 revealed that 41.8% of the respondents has farm size between the ranges of 1.1 – 2.0 hectares with a mean value of 2.05 hectares. This implies that many of the yam farmers are operating on a small-scale farming. However, 50.9% had farming experience between the ranges of 20 – 29 years with a mean farming experience of 20 years implying that yam farmers are experienced in yam production. This finding corroborate the study of Olaniyi and Adeola (2020) which reported that majority of farmer in his study area had farming experience between the ranges of 10 – 20 years. Meanwhile, 41.8% of the respondents had access to credit facilities, while more than half (58.2%) had no access to credit facilities. Farmer's access to credit facilitates is a form of additional income that could support the utilization of farm inputs. This finding is in agreement with the study of Okpara and Obasi (2019) who stated that majority of the respondents in his study area had no access to credit facilities in the study area.

Most (61%) of the respondents had access to extension agents which could enable them access production resources disseminated by the extension agent. This finding agrees with the study of Afolabi and Ajiboye (2020) who reported that majority of the farmers in their study area had access to extension services through the extension agent. Majority (86.4%) of the respondents were not members of cooperatives, while only few (13.6%) of the respondents belong to cooperative organization. This implies that greater proportion of the respondents were not member of cooperative society that could have provide the farmers with necessary information and production resources needed for yam farming in the study area. This finding contradicts the work of Olaniyi and Adeola (2020) who reported that majority of the respondents in their study area are members of cooperative organizations.

**Types of farm inputs utilized in yam production among the respondents.**

The findings presented in Table 2 show that seeds (100.0%), labor (100.0%), sacks (100.0%), hoes (100.0%), cutlasses (99.1%), and organic mulch (95.5%) were the most commonly utilized agricultural inputs among yam farmers. In contrast, organic fertilizer (65%), inorganic fertilizer (55%), herbicides (41%), pesticides (30%), insecticides (25%), and tractors (5%) were underutilized in the study area. The results in Table 2 show that all the farmers (100%) use seeds as a key farm input, indicating that seeds are widely acknowledged as essential for cultivating yams, which aligns with the fact that seed yams are fundamental to the production process. This complete utilization reflects findings by Olaleye and Obasi (2020), who reported that seed yams as a crucial factor in yam production due to their significant impact on crop yields and farm output. Similarly, Olaniyi and Adeola (2020) stated that without the proper use of seed yams, yam farming productivity is significantly reduced, leading to lower yields and income. More so, 100% of the respondents rely on labor as a crucial input for their farming operations. This universal dependence underscores the essential role of labor in yam cultivation, which is inherently labor-intensive. Critical farming activities such as land preparation, planting, weeding, and harvesting demand substantial human effort, making labor a vital component for the successful production of yams, particularly in rural areas.

Similarly, 100% of the respondents use hoes in their yam farming practices. The hoe is a central tool due to its effectiveness in performing various farming tasks, such as soil preparation, weeding, and planting. This finding aligns with Oyekale and Adeola (2020), who reported that the widespread use of hoes among farmers is due to their affordability, accessibility, and the absence of more advanced farming equipment. Furthermore, the hoe provides precise control over planting and crop management. Additional 99.1% of respondents use a cutlass, with only 0.9% not utilizing this tool. This highlights the significant role of the cutlass in yam cultivation, emphasizing its necessity for tasks such as land clearing and weeding. The majority of yam farmers (95.5%) use organic mulch, with only 4.5% not employing this practice. Organic mulch, such as straw, leaves, and compost, is favored for its ability to improve soil structure, conserve moisture, control weeds, and enhance soil fertility through the decomposition of organic materials. This widespread use of organic mulch underscores its importance and the high value farmers place on its benefits for improving crop yields.

All respondents (100%) use sacks in their farming practices, which is essential for the storage and transport of agricultural products. Sacks protect crops from damage and contamination during handling, storage, and transportation. The universal use of sacks underscores their significance in managing the logistics of yam farming, as they are affordable, convenient, and facilitate organized storage, which is crucial for maintaining the quality and market readiness of harvested yams. While 30% of farmers use pesticides, while 70% do not. Pesticides are commonly used to control pests and diseases, thereby protecting crop yields. The relatively low usage of pesticides suggests that some farmers rely on alternative pest control methods or avoid chemical treatments due to concerns such as cost, health, or environmental impact. Additionally, 25% of respondents use insecticides, while 41% use herbicides. These chemicals help control insects that transmit diseases and inhibit unwanted weeds, reducing competition for water, nutrients, and light. The relatively low adoption of these chemical inputs may indicate that farmers prefer alternative methods such as manual weed control or integrated pest management (IPM), which combines biological, cultural, and chemical strategies to manage pests and weeds in a more sustainable manner.

**Table 2**: **Distribution table showing the types of farm inputs used among the respondents**

| Farm inputs used | Frequency | Percentage | Mean of quantity | Mean of price |
|---|---|---|---|---|
| Seed | 110 | 100 | 620.36 | 937.45 |
| Sack | 110 | 100 | 12.44 | 320.91 |
| Hoe | 110 | 100 | 4.25 | 4928.18 |
| Labour | 110 | 100 | 5.96 | 3232.80 |
| Cutlass | 109 | 99.1 | 3.47 | 2976.36 |
| Organic mulch | 105 | 95.5 | 7.49 | 0 |
| Organic fertilizer | 72 | 65.5 | 81.85 | 6944.26 |
| Inorganic fertilizer | 60 | 55 | 44.38 | 40168.54 |
| Herbicide | 45 | 41 | 2.95 | 5928.57 |
| Pesticide | 33 | 30 | 2.67 | 6000.00 |
| Insecticide | 28 | 25 | 2.57 | 5528.57 |
| Tractor | 5 | 4.5 | 1.00 | 53333.33 |

**Source: Field survey, 2024**

**Factors influencing the utilization of farm inputs among yam farmers**

The result presented in Table 4 shows the Ordinary Least Squares (OLS) regression analysis of the factors influencing the utilization of farm inputs in yam production. The analysis revealed a Pseudo-$R^2$ of 0.6698, indicating that approximately 67% of the variation in farm input utilization can be explained by the independent variables included in the model. The F-statistic of 10.25 was significant at the 1% probability level, suggesting that the model fits the data well. The analysis included eighteen independent variables, nine of which were found to be statistically significant at varying probability levels. These significant variables include extension services, technology innovation, infrastructure, cost of farm inputs, knowledge/awareness, farm size, access to credit, government policies, and climate/weather. The findings highlight the importance of these factors in influencing the likelihood of utilizing farm inputs among yam farmers.

Extension services were found to be positive and significant at the 10% probability level, meaning that a unit increase in extension services is associated with a higher probability of utilizing farm inputs. This result suggests that greater access to extension services enhances farmers' exposure to modern production inputs and capacity-building initiatives, which in turn leads to improved input utilization. This finding is consistent with Ajayi and Olaitan (2020), who reported that extension services are crucial for enhancing agricultural productivity through better adoption of agricultural practices and input use.

**Table 4: the distribution table of factors influencing the of utilization of farm inputs**

| Variables | Coefficient | Standard Error | t-value |
|---|---|---|---|
| Age | -0930243 | .0636541 | -1.46 |
| Gender | .8834562 | .8433584 | 1.05 |
| Marital status | -.0031358 | .0513503 | -0.06 |
| Access to credit | 7.758739 | 2.083707 | 3.72*** |
| Education | .753737 | .6875377 | 1.10 |
| Cooperative membership | -.4045275 | .8069068 | -0.50 |

| | | | |
|---|---|---|---|
| Government policy | 3.693468 | 2.083707 | 3.11*** |
| Cost of farm inputs | -1.223953 | .6098914 | -2.01** |
| Knowledge/awareness | 2.678357 | 1.262017 | 2.12** |
| Climate/weather | -2.838763 | .2834288 | -10.02*** |
| Extension service | 2.151545 | 1.302415 | 1.65* |
| Farm size | .1318311 | .0639281 | 2.06** |
| Cultural practices | .4224734 | .5353263 | 0.79 |
| Technology and innovation | 1.208932 | .6219116 | 1.94* |
| Availability of farm inputs | -1.847163 | 1.353437 | -1.36 |
| Infrastructure | 2.466815 | 1.437262 | 1.72* |
| Access to market | .7007978 | .4963001 | 1.41 |
| Soil condition | -.252179 | .8067265 | -0.31 |
| Constant | 36.55462 | 5.523308 | 6.62*** |
| R-squared | 0.6698 | | |
| F-statistics | 10.25*** | | |

**Source: Field survey, 2024**

**Decision rule: ***, **, and * implies significant at 1%, 5% and 10% level of probability respectively.**

Moreover, technology and innovation also had a positive and significant relationship with farm input utilization at the 10% level. The result indicates that the introduction of new technologies, including digital platforms and mobile phones, facilitates better access to market information and production techniques, thereby improving input utilization. Adebisi and Oladejo (2020) found that the use of mobile phones and other digital technologies greatly improved access to information and inputs, which aligns with the findings of this study.

Infrastructure, including roads, storage facilities, and irrigation systems, was another significant factor influencing input utilization at the 10% level. The availability and quality of infrastructure ensure that farmers can access and transport inputs efficiently, which encourages their use in farming activities. This finding underscores the importance of investing in rural infrastructure to support agricultural development.

Knowledge and awareness of farm inputs were positively associated with input utilization at the 5% probability level. Farmers who are more knowledgeable about the benefits and proper use of inputs like fertilizers, improved seeds, and pest control methods are more likely to use these inputs effectively. Educating farmers about the proper application of farm inputs can therefore lead to higher productivity and better agricultural practices.

Farm size was another significant factor, with a positive and significant relationship at the 5% level. Larger farms typically require more inputs to increase production, and farmers with larger landholdings are more likely to adopt intensive farming practices, including the use of various farm inputs. This result is in line with the findings of Alene *et al.* (2020), who suggested that larger farm sizes are associated with higher levels of input utilization.
On the other hand, the cost of farm inputs had a negative and significant impact on input utilization at the 5% level. As the cost of inputs increases, the probability of their utilization decreases, suggesting that high input costs reduce farmers' willingness or ability to invest in necessary inputs. This finding is consistent with Olaleye and Adebayo (2020), who observed that high input costs can limit farm profitability and discourage investment in inputs, thereby hindering agricultural productivity.

Access to credit was found to have a positive and significant relationship with farm input utilization at the 1% significance level. Farmers who have access to credit are more likely to afford inputs like fertilizers, seeds, and machinery, which are essential for improving agricultural productivity. This finding supports the work of Okpara and Obasi (2019), who emphasized that credit is a critical factor in agricultural enterprises, enabling farmers to purchase inputs for better output. Government policies also showed a positive and significant impact on input utilization at the 1% level. Favorable policies, such as subsidies on fertilizers and other farm inputs, tax reductions, and the provision of extension services, can encourage the use of farm inputs. This finding highlights the importance of government support in promoting agricultural development by making inputs more affordable and accessible. Climate and weather conditions were found to negatively influence farm input utilization at the 1% significance level. Unfavorable climate conditions, such as droughts, floods, and extreme temperatures, reduce the effectiveness of farm inputs and, in some cases, discourage their use. This finding underscores the vulnerability of agriculture to climate variability, emphasizing the need for climate-resilient farming practices and policies that mitigate the effects of adverse weather conditions.

## CONCLUSION AND RECOMMENDATIONS

The study concludes that improving farm input utilization among yam farmers can significantly enhance food security, agricultural productivity, and farmers' economic well-being. Key factors such as extension services, access to credit, technology, government policies, knowledge, and climate resilience need strengthening. The main barriers identified include the high cost of inputs, lack of funds, limited credit access, inadequate farmland, and lack of knowledge. To address these, the study recommends regular training by extension agents, investment in agricultural technologies, easier access to credit, supportive government policies (such as subsidies), and strategies to mitigate climate impacts like crop insurance and climate-smart agriculture.

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# EFFECTS OF FUEL SUBSIDY REMOVAL ON BROILER PRODUCTION IN KARU AND KEFFI LOCAL GOVERNMENT AREAS NASARAWA STATE, NIGERIA

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**ABSTRACT**
This study assessed the effects of fuel subsidy removal on broiler production in Karu and Keffi Local Government Areas, Nasarawa State, Nigeria. Multi-stage sampling technique was employed to select 96 respondents. Primary data were collected with the aid of structured questionnaire through KoboToolbox. Meanwhile, data collected were analyzed using descriptive (such as percentages, means and frequency count) and inferential statistics (such as multiple regression). The findings revealed that the average age of broiler farmers was 45 years, with most (65.6%) of them were married, having an average household size of five and 12 years of formal education. The multiple regression analysis result revealed that the fuel price (-0.0982) was negative and statistically significant at 10% level of probability, implying that a higher fuel cost would to decline in broiler production. In conclusion, fuel subsidy removal had negative and significant effects on broiler production and the farmers. Therefore, the broiler farmers should adopt cost-effective strategies to mitigate the rising cost of fuel and the government consider implementing targeted subsidies of agricultural inputs particularly that of broiler to mitigate the adverse effects of fuel subsidy removal.
**Keywords**: Broiler production, Fuel subsidy, Removal, Effects, Input

## INTRODUCTION

The removal of fuel subsidies has long been a contentious issue in Nigeria, sparking debates among supporters and critics alike. Various Nigerian administrations have attempted to eliminate fuel subsidies, but the process has consistently faced obstacles due to its potential impact on citizens' livelihoods and the widespread public disapproval it often provokes (Akanle *et al.,* 2014). The primary consequence of subsidy removal is an increase in petrol prices, which in turn raises transportation costs and triggers inflation. Initially, Nigeria introduced fuel subsidies in the 1970s as a response to the 1973 oil shock. A partial subsidy removal was enacted in 1986, but it was not comprehensive. In 2012, the government abruptly ceased fuel subsidies, a decision that led to massive protests. Faced with strong opposition, the government reinstated the subsidy later that same year (Ozili and Obiora, 2023).

Since then, Nigeria's spending on fuel subsidies has escalated, reaching ₦4 trillion (approximately US$6.088 billion) in 2022—representing 23% of the ₦17.126 trillion (US$25.87 billion) government budget. By 2023, this financial burden led the government to fully eliminate the subsidy. The primary motivations were to curb corruption, given the lack of transparency in subsidy funds, and to redirect resources to other sectors to stimulate the economy, create jobs, and reduce dependence on imported fuel (Ozili & Obiora, 2023). However, the removal of fuel subsidies has had significant consequences for the general populace. As petrol is vital for power generation and transportation in Nigeria, increases in fuel prices raise transportation costs, the cost of goods and services, and overall inflation. Small-scale industries and businesses reliant on fuel have been particularly affected (Siddig *et al.,* 2014). Broiler farming, a key component of Nigeria's poultry sector, has not been spared from these impacts.

Poultry production involves the breeding of domesticated birds, including chickens, turkeys, quails and geese, primarily for meat, feathers, and eggs. Among these, broiler chickens—bred specifically for meat—are the most widely farmed (Food and Agricultural Organization, 2017). Poultry meat and eggs are important sources of high-quality proteins, minerals and vitamins for humans (Salami *et al.,* 2021). The poultry industry also plays a vital role in the economy, contributing significantly to food security and employment. Broiler production, in particular, is a rapidly expanding sector in Nigeria, largely driven by small-scale farmers. It contributes to the national GDP and provides a reliable source of income for many households. Currently, Nigeria is the largest producer of poultry and the fourth-largest meat producer in Africa, with poultry accounting for 30% of Nigeria's agricultural GDP (Chiekezie *et al.,* 2022).

The success of broiler farming is highly dependent on feed, primarily comprising maize and soybeans. Due to the high nutritional requirements of broilers, feed constitutes 60–70% of production costs. Consequently, the rising cost of feed is a significant challenge for poultry farmers in Nigeria (Mallick *et al.,* 2020). According to Oladokun and Johnson (2012), one of the main issues faced by poultry farmers in Nigeria is the high cost of feed ingredients. This challenge has been exacerbated by the removal of fuel subsidies, which has increased fuel prices and subsequently raised transportation costs, leading to higher feed and input costs for broiler production. The price hike impacts the entire supply chain, from input acquisition to final product delivery, affecting both production volume and profitability.

The rapid growth of Nigeria's poultry sector, particularly in Nasarawa State, underscores the importance of addressing the challenges faced by small-scale farmers, who form the backbone of the industry. Nasarawa State's favorable climate and land availability make it a hub for broiler farming, contributing to food supply and local economies. Despite these advantages, small-scale farmers are increasingly vulnerable to fluctuations in input costs, especially in light of the recent fuel subsidy removal. High fuel prices lead to increased feed costs and other production expenses, which could potentially reduce the number of farmers entering the broiler industry and force some existing producers out of business.

Nigeria's government has been criticized for failing to implement adequate preparatory measures to mitigate the effects of fuel subsidy removal on sensitive sectors like agriculture. Experts have suggested that countries successful in eliminating fuel subsidies did so by carefully planning and conducting detailed impact assessments beforehand. In Nasarawa State, small-scale broiler farmers face growing challenges related to rising costs of feed, medication and other essential resources, a gap that needs to be addressed through research and policy interventions. Meanwhile, extensive research has explored the impact of fuel subsidy removal on the Nigerian economy at large, there is a lack of studies focused on its specific effects on broiler production in Nasarawa State. This study aims to fill that gap by investigating how the fuel subsidy removal has affected broiler farming in the region. Thus, the specific objectives of the study are to describe the socio-economic characteristics of the broiler farmers and determine the effects of fuel subsidy removal on broiler production in the study area.

## METHODOLOGY

### Study Area

The study was conducted in Karu and Keffi Local Government Areas (LGAs) of Nasarawa State, Nigeria located in the Middle Belt region, covering an area of 27,116.8 square kilometers with a population of 1,863,275 (National Population Commission (NPC), 2006). Nasarawa State lies between Latitudes 7˚45' – 9˚25' North and Longitudes 7˚ - 9˚37' East. It is bordered by Benue, Taraba, Plateau, Kaduna, Kogi and the Federal Capital Territory (Nengak and Osagbemi, 2011). The region has a tropical sub-humid climate, with a rainy season from May to October and a dry season from November to April. Average temperatures range from 20˚ to 34˚C (Olufemi *et al.,* 2020). The State's vegetation is typical of the Guinea savanna, with fertile soils supporting crops like rice, sorghum and cassava (Abah *et al.* 2016). Agriculture benefits from its proximity to Nigeria's capital, which enhances the market for agricultural products (Ugwu and Enna, 2015).

Meanwhile, Karu LGA, east of the Federal Capital Territory, covers land area of 2,620 square kilometers and had a population of 216,230 (NPC, 2006). It is known for fertile soils and favorable farming conditions. The indigenous tribes include Gwari, Gade, Gwadara, Ganagana, Koro, and Bassa (Kanayo-chukwu, 2019). Keffi LGA covers land area of 138 square kilometers and had a population of 92,664 (NPC, 2006). Agriculture dominates the area, with crops such as maize, rice, beans and soybeans widely grown. The Fulani community engages in livestock farming. The major ethnic groups are Fulani, Eggon, Mada, Hausa and Yaskwe (Abugu *et al.,* 2021).

### Sampling procedure and sample size

Multistage sampling procedure was used to select respondents for this study. The first stage involved the use of purposive selection of Karu and Keffi Local Government Areas (LGAs) due to predominance of broiler farmers. In the second stage, three communities were selected from each of the LGAs using random sampling technique. Third stage involved proportionate selection of the broiler farmers based on the list of registered broiler farmers obtained from Nasarawa State Agricultural Development Program (NSADP). A total of 96 broiler farmers was selected as sample size for the study.

### Method of data collection and analysis

Primary data was used for this study and was collected from respondents with the aid of a structured questionnaire complemented with an interview schedule. Skilled enumerators assisted the researcher in the collection of data using Kobotoolbox. The data collected were analyzed using both descriptive statistics (frequency count, percentage and mean) and inferential statistics (multiple regression analysis). Price of fuel at the time of data collection was used as proxy for subsidy removal, while the value of output was used as proxy for broiler production.

**Model Specification**

**Multiple Regression Analysis**

The multiple regression analysis was used to determine the effects of fuel subsidy removal on broiler production. The model as applied by Muhammad *et al.* (2020) is implicitly expressed as:

$$Y = f(X_1, X_2, X_3, X_4 \ldots\ldots\ldots\ldots X_{14}) \quad (1)$$

The explicit functional forms of the multiple regression model are:

**Linear:**

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \ldots\ldots\ldots\ldots + \beta_{14}X_{14} + e \quad (2)$$

**Cobb-Douglas**:

$$\ln Y = \beta_0 + \beta_1\ln X_1 + \beta_2\ln X_2 + \beta_3\ln X_3 + \beta_4\ln X_4 + \ldots\ldots\ldots\ldots + \beta_{14}\ln X_{14} + e \quad (3)$$

**Semi-log:**

$$Y = \beta_0 + \beta_1\ln X_1 + \beta_2\ln X_2 + \beta_3\ln X_3 + \beta_4\ln X_4 + \ldots\ldots\ldots\ldots + \beta_{14}\ln X_{14} + e \quad (4)$$

**Exponential**:

$$\ln Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \ldots\ldots\ldots\ldots + \beta_{14}X_{14} + e \quad (5)$$

Where:

Y = Broiler production (value of the output measured in Naira was used as proxy)
$X_1$ = Age (years)
$X_2$ = Marital status (married=1, otherwise=0)
$X_3$ = Household size (number of people)
$X_4$ = Education (number of years spent in school)
$X_5$ = Farming experience (years)
$X_6$ = Farm Size (hectares)
$X_7$ = Land ownership (land ownership=1, no ownership=0)
$X_8$ = Bird stocks (numbers)
$X_9$ = Extension contacts (number of visit)
$X_{10}$ = Cooperative membership (member=1, not member =0)
$X_{11}$ = Farm income (Naira)
$X_{12}$ = Fuel costs (Naira)
$X_{13}$ = Medication cost (Naira)
$X_{14}$ = Feed (Naira)
ln = Natural logarithms
$\beta_1 - \beta_{14}$ = coefficients of the independent variables
$\beta_0$ = Intercept
e = Error term

**RESULTS AND DISCUSSION**

**Socio-economic characteristics of the respondents**

The results in Table 1 revealed that majority (82.3%) of the broiler farmers were aged within the range of 21 – 60 with an average age of 45 years, suggesting they are in their productive phase of life conducive to handling labour-intensive tasks. This finding agrees with the study of Kalio (2020) who reported that majority (71.2%) of the broiler farmers in his study area fall within the age bracket of 31 – 60 years. The majority (74%) of the broiler farmers were male, indicating male dominance in broiler farming likely due to their physical strength. This report agrees with the result of Olorunwa (2018) who reported that male dominate broiler farming business in his study area. More so, most (65.6%) of the broiler farmers were married which is vital for the provision of family labour in farm operations. This finding is in line with the study of Chiekezie *et al*. (2018) who reported that most broiler farmers in their study area were married. Household sizes were moderate, averaging around five members. Education levels were high, with 93.8% having formal education, particularly secondary education, which is beneficial for understanding advanced farming techniques. This finding agrees with the study of Kalio (2020) who reported that majority of broiler farmers in his study area attained secondary education. Farming experience varied, with over half (57.3%) had less than 11 years of broiler farming experience which is sufficient to supports efficient farm management. Farm size was generally small, averaging 1.5 hectares, with most land acquired through purchase.

Furthermore, as revealed in Table 1, most (65.6%) of the broiler farmers had birds within the range of 501 – 1000 birds with an average of 694 birds. This implies that the farmers are operating at a medium-scale aimed to support household needs and for commercial sales. This finding is in agreement with the findings of Obi-Nwandikom *et al*. (2021) who reported that the mean bird stock size was 696 birds in their study area. Less than half (46.9%) of the broiler farmers had contact with extension agents, indicating moderate access to extension service. Also, most (67.9%) of the broiler farmers were member of cooperative membership which could facilitates access to information and collective problem-solving.

**Effects of fuel subsidy removal on broiler production**

The results of multiple regression estimate on the effects of fuel subsidy removal on broiler production in the study area is presented in Table 2. The double-log functional form of the multiple regressions was chosen as the lead equation due to high values of adjusted R-squared and F-statistics which is significant at 1% level of probability. The coefficient of determination ($R^2$) value is 0.9923 implying that about 99% variation in the value of output from broiler production was explained by the independent variables included in the model. However, based on the t-value from the regression estimates, six variables (land ownership, bird stock, farm income, fuel costs, medication costs and feed costs) out of the fourteen independent variables specified in the model were found to be significant.

The land ownership (0.09168) was positive and significant at 1% probability level. This implies that as number of land owned by the broiler farmers increases by a unit, the value of output obtained will increases at about 9%. Thus, value of output is found to be increasing with an increase in land ownership which could be due to the fact that, farmer who own farmlands could realize more output and income, and invest in other inputs. The bird stock (0.9847) is positive and significant at 1% probability level. This implies that as the number of bird stock by the broiler farmers increases by a unit, the value output obtained will increases at about 98%. This close relationship underscores the fact that, the more bird a farmer successfully rears, the higher the output and, consequently, the income. Therefore, scaling up of production by increasing the number of birds can significantly boost farm income.

**Table 1: Distribution of respondents based on their socio-economic characteristic (n = 96)**

| Variable | Frequency | Percentage | Mean |
|---|---|---|---|
| **Age (years)** | | | |
| 21 – 40 | 39 | 40.7 | 45 |
| 41 – 60 | 40 | 41.6 | |
| > 60 | 17 | 17.7 | |
| **Gender** | | | |
| Female | 25 | 26.0 | |
| Male | 71 | 74.0 | |
| **Marital status** | | | |
| Single | 13 | 13.5 | |
| Married | 63 | 65.6 | |
| Widowed | 17 | 17.7 | |
| Divorced | 3 | 3.1 | |
| **Household size (number)** | | | |
| 2 – 4 | 42 | 43.8 | 5 |
| 5 – 7 | 46 | 47.8 | |
| 8 – 10 | 8 | 8.3 | |
| **Education (levels)** | | | |
| Primary | 5 | 5.2 | 12.5 |
| Secondary | 43 | 44.8 | |
| Tertiary | 38 | 39.6 | |
| Adult | 4 | 4.2 | |
| Non formal | 6 | 6.3 | |
| **Farming experience (years)** | | | |
| < 11 | 55 | 57.3 | 14 |
| 11 – 20 | 27 | 28.1 | |
| 21 – 30 | 11 | 11.5 | |
| > 30 | 3 | 3.1 | |
| **Farm size (hectares)** | | | |
| < 2.1 | 86 | 89.6 | 1.50 |
| 2.1 – 4.0 | 10 | 10.4 | |
| **Bird stock (numbers)** | | | |
| < 501 | 30 | 31.3 | 694 |
| 501 – 1000 | 63 | 65.6 | |
| > 1000 | 3 | 3.1 | |
| **Extension contact** | | | |
| No | 51 | 53.1 | |
| Yes | 45 | 46.9 | |
| **Cooperative membership** | | | |
| No | 31 | 32.3 | |
| Yes | 65 | 67.7 | |

**Source: Field Survey, 2024**

The off-farm income (0.0136) is positive and significant at 1% probability level. This implies that as the farm income of the broiler farmers increases by a unit, the value of output increases by about 1%. This implies that the higher the off-farm income earn by the broiler farmers, the higher the value of output realized. Thus, the broiler farmers are likely to invest more in their production activities through their off-farm income generation which could lead to an increase in output.

The fuel costs (-0.0982) is negative and significant at 1% probability level. This implies that as cost of fuel increases by a unit, the value of output decreases by 10%. This indicates that as fuel costs rise due to the removal of fuel subsidy, broiler farmers experience a reduction in their production output. Therefore, negative relationship exists between fuel costs and value of output in broiler production which conforms to the a *priori expectation*. Thus, there is a significant negative effects of fuel subsidy removal on broiler production in the study area.

**Table 2: Regression estimates on effects of fuel subsidy removal on broiler production**

| Variables | Linear Coef. (t-value) | Semi-log Coef. (t-value) | Cobb-Douglas Coef. (t-value) | Exponential Coef. (t-value) |
|---|---|---|---|---|
| Age | -3.3315 (-0.52) | .00663(1.05) | .00708(0.11) | -184.7702(-0.33) |
| Marital status | 150.1425 (1.34) | .08088 (0.73) | .00318 (0.06) | -198.2625(-0.44) |
| Household | -8.2044(-0.22) | .01397(0.37) | -.02348(-0.64) | 49.2722(0.15) |
| size | 17.37895 (1.24) | .00906(0.66) | .01916(1.45) | 135.306(1.18) |
| Education | -1.87115 (-0.23) | .01245(1.55) | .00699(0.27) | -22.9838(-0.10) |
| Experience | -100.7961 (-1.27) | -.00203(-0.03) | -.02083(-0.63) | 55.2997(0.19) |
| Farm size | 193.945(3.09***) | -.00127 (-0.02) | .09168 (2.75***) | 518.9875(1.80*) |
| Land | 2.04711 | .00094 (9.61***) | .9847(64.24***) | 1349.991(10.16) |
| ownership | (20.57***) | .02491 (2.08**) | .00348(0.47) | -11.0113(-0.17) |
| Birds | 7.452334 (0.61) | .02680 (1.71) | .00651(0.49) | -21.6396(-0.19) |
| Extension | 131.8363 (0.83) | .1.76e7(3.14***) | -.0136(4.21***) | -87.36(-3.12***) |
| Cooperative | .000018 (0.32) | -.00018 (-0.64) | -.0982 (-2.67***) | 168.48(0.32) |
| Farm income | -.1616265 (-0.54) | -.0000346 (-1.07) | -.0483 (-4.72***) | -9.5212(-0.11) |
| Fuel costs | -.042608 (-1.29) | -9.57e-06 (-0.37) | -.24088(-2.05**) | 1189.971(1.17) |
| Medication | .02442 (0.9) | 5.1039 (8.43) | -.44796(-0.46) | -18242.55(-2.14) |
| costs | -921.3028 (-1.50) | 0.8330 | 0.9923 | 0.6984 |
| Feed costs | 0.9098 | 0.8041 | 0.9910 | 0.6462 |
| Constant | 0.8943 | | | |
| R-squared | | 28.86** | 746.07*** | 13.39*** |
| Adjusted R- | 58.39*** | | | |
| Squared | | | | |
| F-Statistics | | | | |

**Source: Field Survey, 2024**
**Note: Figures in parenthesis are the t-values**
*****, ** and * implies significant at 1%, 5% and 10% level of probability**

The medication costs (-0.0483) is negative and significant at 1% probability level. This implies that as the costs of medications increase by a unit, the value of output obtained decreases at about 5%. This indicates that as medication costs rise due to the removal of fuel subsidy, broiler farmers experience a reduction in their production output. Therefore, good health management practices become difficult leading to increased incidence of disease and higher mortality rate thereby reducing the output. The feed costs (-0.24088) is negative and significant at 5% probability level. This implies that as the costs of feed increases by a unit, the value of output obtained decreases at about 24%. This indicates that as feed costs rise due to the removal of fuel subsidy, broiler farmers experience a reduction in their production output. Thus, farmers are likely to scale back production in response to rising costs, looking at the critical role that feed play in determining the viability of broiler farming operations.

## CONCLUSION AND RECOMMENDATIONS

Based on the findings of this study, the broiler farmers are young, educated and experienced in broiler production. They are operating on a medium scale of production. Broiler production is a viable enterprise, but impacted by the removal of fuel subsidies due to rising costs of production inputs. Thus, fuel subsidy removal had negative and significant effects on broiler production and the farmers. It was recommended therefore that, government and relevant stakeholders should provide targeted support to reduce costs, improve market opportunities and engage farmers in policy decisions to ensure sustainable broiler production. The broiler farmers should adopt cost-effective strategies to mitigate the rising cost of fuel and the government consider implementing targeted subsidies on agricultural inputs particularly that of broiler to mitigate the adverse effects of fuel subsidy removal.

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# DETERMINANTS EFFECTS AND PRODUCTIVITY DIFFERENTIALS AMONG THE ABP CREDIT RICE FARMERS IN EBONYI AND KEBBI STATES, NIGERIA

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## ABSTRACT

This study compared determinants effects and productivity differential among the Anchor Borrowers' Programme beneficiary rice farmers in Ebonyi and Kebbi States Nigeria. The study described the socio-economics and demographic characteristics; analyzed the productivity level; compared the productivity and identify the problems limiting small scale rice farmers' access to ABP credit. A total of 336 ABP beneficiary rice farmers comprising of 163 respondents in Ebonyi and 173 in Kebbi respectively were selected through multi-stage sampling techniques. Data were collected through structured questionnaire. Data were analysed using descriptive statistics, TFP index and Oaxaca Blinder decomposition method. Results showed that the average age of the respondents were 47 and 43years, while 96.32% and 92.49% of them were males and 92.02% and 92.49% married in Ebonyi and Kebbi States, respectively. The mean household sizes of respondents are 9 and 14 persons, respectively. The TFP index result revealed that ABP credit has significant effect on the productivity of rice farmers. Results for threefold Oaxaca-Blinder decomposition revealed that -161.88% between states differential gap in productivity accounted for by -107.03% of endowment effect, -74.13% of structural effect, while 19.26% accounted for the interaction effect respectively. Inadequate awareness, high interest rate and bureaucratic bottlenecks were the most prominent constraints to the ABP beneficiary rice farmers across the 2 states. It was concluded that the farmers were productive in the study areas and ABP performed relatively well in both Ebonyi and Kebbi States in terms of productivity level and with the positive performance of ABP in the area, the study recommended that Government should consolidate on this performance by increasing funding for the programme and farmers' should form cooperative societies in order to pool their resources together for their benefit and give them better chances of inclusiveness in programme of this similar nature.

**Keywords:** Anchor Borrowers' Programme, Productivity, Oaxaca Blinder decomposition, Differentials

## INTRODUCTION

Rice is the most important staple food for about 2.6 billion people in the world and the second highest farm produce after maize (Food and Agricultural Organisation Statistics (FAOSTAT), 2017). It is a significant staple food in Nigeria, with an estimated annual consumption of over 7.5 million metric tons (MT) (Oluwasola *et al.,* 2021). Despite being one of the top producers of rice in Africa, Nigeria still imports over 3.5 million MT of rice annually to meet domestic demand (CBN, 2021). The Nigerian government has identified rice production as a crucial component of its agricultural transformation agenda, with a target of achieving self-sufficiency in rice production by 2025 (FMARD, 2020).

According to the National Bureau of Statistics (NBS, 2020), Rice production in Nigeria has undergone significant changes in recent years in which the total land area under rice production increased from 2.6 million hectares in 2010 to 3.5 million hectares in 2019, representing a growth rate of 34.6%. Similarly, the total output of rice increased from 2.6 million MT in 2010 to 5.9 million MT in 2019, representing a growth rate of 127.7%. However, despite these increases, Nigeria is still low in terms of rice productivity, with an average yield of 2.6 MT per hectare compared to the global average of 4.4 MT per hectare (FAO, 2019). Several challenges such as insecurity, theft, insect pest infestation, flood, draught and diversion of accessed loan for other purposes have continued to impede the growth of rice production in Nigeria (Okafor*et al.,* 2020). In response to these, Nigerian government brought in policies and programme to supporting rice production through the Anchor Borrowers' Programme (APB) and the Presidential Fertilizer Initiative (PFI)to provide credit facilities and subsidized inputs to farmers to improve their productivity in a view to boostinglocal production of rice, maize, wheat and cassava in the country Federal Ministry of Agriculture and Rural Development (FMARD, 2020). In spite of these enormous endowments Nigeria is still not able to satisfy the rice demand by her populace. Studying the nexus between ABP credit and agricultural productivity of farmers in Nigeria is important for improving the effectiveness of government interventions aimed at promoting rice productivity. It is against this background that this study focused on the following objectives; describe the socio-economic and demographic characteristics of the ABP rice farmers, determined the productivity level of ABP rice farmers, examine the effects of ABP on the productivity rice farmers and identify the problems limiting small scale rice farmers access to ABP credit in Ebonyi and Kebi States.

## METHODOLOGY

### The Study Area

This study was carried out in Ebonyi and Kebbi States, Nigeria. EbonyiState is in south Eastern region, lies between latitudes 6°15' N and 11° 30' North of the equator and longitudes 8°05'E and 7°20' East of the Greenwich Meridian (Ebonyi State Geographic Information System (ESGIS), 2017). Going by the population growth rate in Nigeria of 2.8 % (World Bank, 2016), the population of the State was projected to 3,313,289 as at 2023. Kebbi State is located in north-western geopolitical zone of Nigeria, lies between latitudes 10°8′ and 13°15′ north of the equator and longitudes 3°30′ and 6°02′ east of the Greenwich Meridian). With the population growth rate of 2.8% the population of the State was projected to be 4,440,000 as at 2023(World Bank, 2016). The peoples of these States are predominately farmers which grown crops such as rice, maize sorghum, millet, groundnutand also rears animals likecattle’s, sheep and goat.

### Sampling Procedure and Sample Size

Multi-stage sampling procedure was used in sampling ABP beneficiary rice farmersfor this study. In the first stage, Ebonyi and Kebbi States were purposively selected for the study given that they are the major rice producing states in the southern and northern Nigeria respectively. The Second stage involves random selection of two Local Government Areas (LGAs) in each of the selected States. Third stage involves random selection of three villages from each of the selected LGAs giving a total of 12 villages in the study area. Yamane formula was employed to obtain 173 and 163 of respondents forEbonyi and Kebbi States respectively, giving a total of 336 sample size of ABP beneficiary rice farmers for this study. The formulae were presented in equations (1) as: $n = \frac{N}{1+N(e)^2}$

(1)

Where:
n = Sample size, N=Finite population ande = Limit of tolerable error (0.05),1= Unit/Constant.

**Method Data Collection**

Primary data were used for this study and were collected using structured questionnaire complimented with interview schedule between November 2019 toDecember 2019 with the aid oftrained enumerators and extension agents.

**Method Data Analysis**

Data collected were analyzed using descriptive and quantitative techniques. Descriptive statistics such as frequency distribution table percentages were used to analyse socio-economic and demographic characteristics of the ABP rice farmersand identified the problems limiting small scale rice farmers access to ABP in the States. Total Factor Productivity (TFP) index was used to determine thelevel ofproductivity ofrice farmers. The quantitative techniques used are as described in equation (3) followingSyverson (2011) as modifiedby Salisu*et al.* (2022) was expressed as:

$TFP_t=A_t=Y_t/K_t^{\alpha}kL_t^{\alpha}IM_t$ (3)

Where;

TPF=Total Factor Productivity,

$A_t$=Factor neutral shifter,

$Y_t$=Total Annual Output (measured in terms of real revenue from annual sales),

$K_t$=Capital input, (Naira)

$M_t$=Total Material inputs (measured in terms of total expenditure on input less labour and capital inputs),

$L_t$= Labour input (measured in terms of total wages to family and hired labour)

The Oaxaca–Blinder (OB) decomposition method was used to compare the productivity ABP beneficiary rice farmers in the study area and also to explain the differential between the ABP rice farmers in Ebonyi and Kebbi States in terms of productivity. The first step of the decomposition procedure is to obtain the determinants of productivity using the following production function in its implicit form, in equation (4)

$Y_g = \alpha_j x_j + \mu_g + \beta$ (4)

Where; Y = a measure of productivity, g = Group dummy of the Ebonyi and Kebbi rice farmers, $x_i$ = Dimensional vector of covariates, α = Intercept, β = Coefficient of the group variable, μ = the random error term which is assumed to be independently and normally distributed.

For comparison of productivity among the farmers in the two States, the empirical and explicit form of equation fitted to the data is expressed in equation (5)

$Y=\alpha+\beta 0+\beta_1 ABPCRE+\beta_2 LAB+\beta_3 FERT+\beta_4 IMS+\beta_5 FSZ+ \beta_6 GEN + \beta_7 ELH+ \beta_8 AGE+ \beta_9 MC+ \beta_{10} HHS+.\beta_{11} EXP+. B_{12} LO + e$ (5)

Where;

Y = Total factor productivity value of the rice farmer

$\beta_0$= Coefficient of intercept

$\beta_1$-$\beta_{12}$= Coefficients of independent variables

ln = Natural log

ABPCR = Anchor borrowers' programme credit accessed (Naira)

LAB= Labour (Man-day)

FERT= Fertilizer (kg)

IMS=Improved seed (kg)

FSZ= Farm size (Hectare)

GEN= Gender (1 for male, 0 for female)
ELH= Level of education (Years)
AGE= Age (Years)
MC=Member of cooperative society (0 for non members, 1 for members)
HHS= Household size (Number)
EXP = Farm experience (Years)
LO=Land ownership (0 is for rent, 1 is for owner) and
e= Error term.

The second step was to understand the cause of the estimated productivity gap observed between the Ebonyi and Kebbi ABP beneficiary rice farmers. Therefore, –Blinder (OB) decomposition technique uses the amount of mean productivitydifferences based on the group gap expressed in equation (6) (Oaxaca, 1973). .

$$G = E(Y_e) - E(y_k) \quad (6)$$

Where;

G =Gap observed between them, $E(y_e)$ and $E(y_k)$ represent the expected values of productivity by Ebonyi and Kebbi rice farmers respectively.

However, the general Oaxaca–Blinder (OB) decomposition method is given by equation (7)

$$OB = E(Y_e) - E(Y_k) = [E(X_e)\beta_e] - [E(X_k)\beta_k] \quad (7)$$

Where;

$E(Y_e) - E(Y_k)$ = mean productivity differential between Ebonyi and Kebbi farm household; $E(X_e) - E(X_k)$ = expected variable factors of Ebonyi and Kebbi farm household that contributed to productivity differentials and $\beta_e$ and $\beta_k$ = parameters of Ebonyi and Kebbi farmers estimated.

## RESULTS AND DISCUSSION

### Socioeconomic and demographic characteristic of ABP rice farmers in the study area

The results presented in Figure 1 showed that the mean age of ABP rice farmers in Ebonyi and Kebbi States were47 and 43 years respectively. This revealed that rice farmers in both States were still strong and agile to intensify their productivity. This confirms the report of Ayinde*et al.* (2017) that that majority of ABP rice farmers' beneficiaries in KwaraState, were in their productive years of farming.

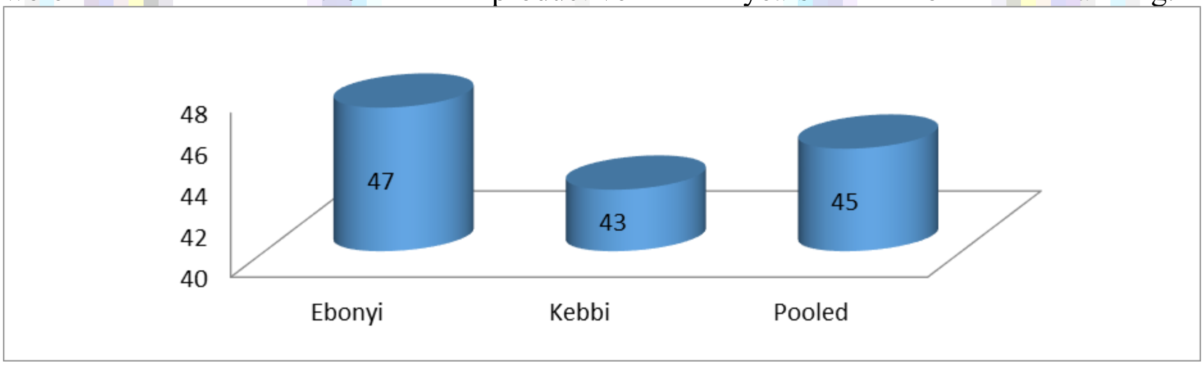


**Figure 1:** Mean age of ABP beneficiary rice farmers
Sources: Field survey, (2019).

The results presented in Figure 2. revealed that majority (96.32%) and (92.49%) of ABP rice farmers in Ebonyi and Kebbi States, respectively were males. This result corroborates that ofOlughu (2019) that larger proportion of ABPbeneficiaries in Kaduna State were males.

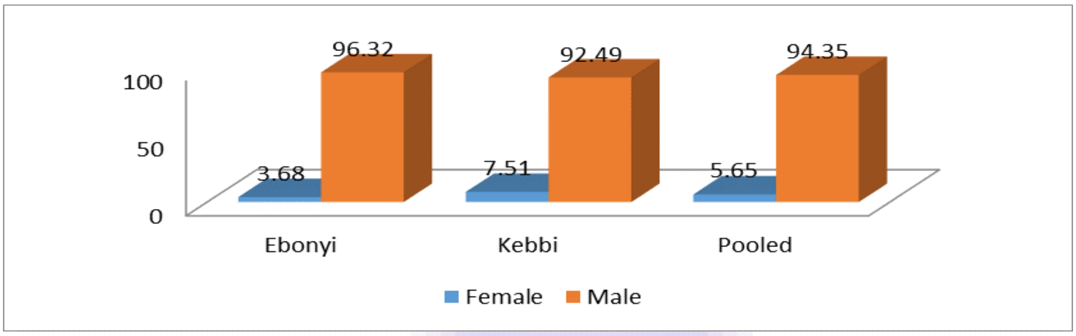


**Figure 2:** Gender distributions of ABP beneficiary rice farmers
Sources: Field survey, (2019)

The results presented in Figure 3 revealed that majority (92.49%) and (92.02%) of rice farmers in Kebbi and EbonyiStates were married with advantage of providing family labour. This finding agrees with Nwalieji (2016) on comparative profit analysis of rice production enterprise among farmers in Anambra and Ebonyi States who revealed that larger percentages of farmers are married.

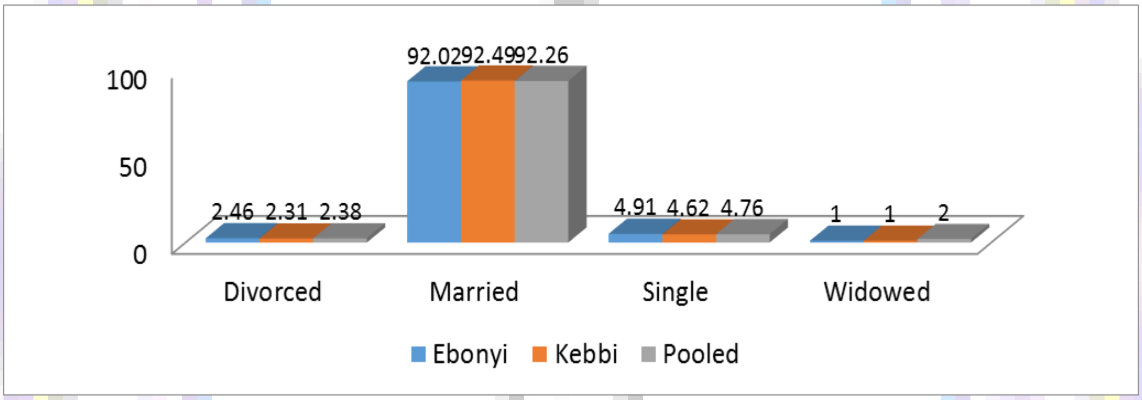


**Figure 3:** Distributions of marital status of ABP beneficiary rice farmers
Sources: Field survey, (2019).

The results presented in Figure 4 also indicated that the mean household sizes of the ABP rice farmers in Kebbi State was 14 persons which is higher than that of Ebonyi State that stood at 9 persons. This implies that they have access to unpaid family labour that can enhance their productivity.

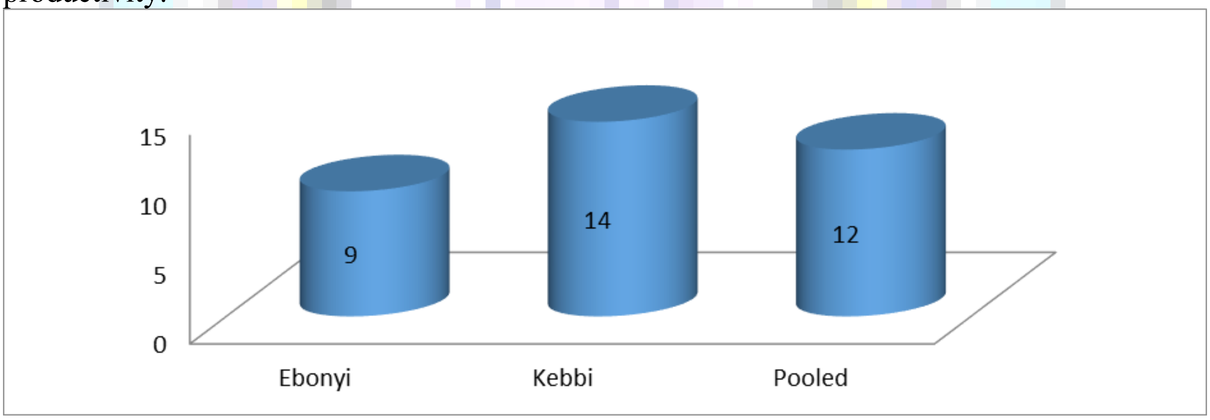


**Figure 4:** Mean household size distributions of ABP beneficiary rice farmers
Sources: Field survey, (2019).

The total factor productivity index result presented in Table 1 revealed that the mean productivity index for the ABP rice farmerbeneficiaries in Ebonyi State was 5.07 with the least and highest values estimated as 1.16 and 16.65 respectively. The mean productivity level for Kebbi counterpart rice farmers was estimated to be 6.69 with the least and highest values estimated as 1.76 and 17.48 respectively. This shows that, the productivity level for Kebbi farmers were slightly higher than that of their Ebonyi counterparts. This difference could probably be attributed to the difference in the agro-climatologically conditions, vegetation, quantities of inputs used and output obtained, prevailing market prices of inputs and the corresponding output. This implies that the ABP beneficiary rice farmers in the study areas were productive given that the TFP index is greater than one. This result is similar to that of Mohammad (2017) who reported a TFP index of 6.02 for crop farmers in North-Eastern, Nigeria.

**Table .1: Productivity analysis of rice farmers in the study area**

| Category | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Ebonyi farmers' productivity | 5.07 | 3.26 | 1.16 | 16.65 |
| Kebbi farmers' productivity | 6.69 | 4.44 | 1.76 | 17.48 |
| Pooled result productivity | 5.90 | 3.99 | 1.16 | 17.48 |

Source: Field survey, (2019).

Three-fold O-B decomposition techniques was adopted to decompose State level differences based on the socio-economic, socio-demographic and institutional factors to explain differences in productivity of the rice farmers inEbonyi and KebbiStates. The first panel of the decomposition result as presented in Table 2 shows the mean productivity by groups and the difference. It shows that the mean rice productivity for Ebonyi and Kebbi rice farmers was 5.0691 and 6.6879 resulting to a productivity difference of -1.6188 (-161.88%) was accounted for by -107.03% ,74.13% and 19.28% of endowments, coefficients and interaction effects, respectively. The productivity difference obtained was statistically significant at 1% level of significance. This result thereby suggests that the

productivity of the ABP beneficiary rice farmers in Ebonyi is significantly different from that of their Kebbi State counterpart. Given that the value of productivity difference was negative, it implies that Ebonyi farmers were significantly less productive than their Kebbi counterpart.

Furthermore, the second panel of the decomposition result is divided into three parts. The first part which is the farmers' endowment reflects the mean change in the level of productivity of the rice farmers in Ebonyi if they had the same level of endowment as the farmers in Kebbi. The result shows that a significant decrease of 1.0703 at 1% level of significance would be recorded in the productivity difference if the Ebonyi farmers have the same level of endowment as their Kebbi counterparts. This implies that the difference in endowment was a significant cause of the difference in the productivity of the rice farmers in the two states.

As recorded in the results. The third part is the interaction term which measures the simultaneous effect of differences in the endowments and coefficients of the farmers' characteristics. Results showed that the interaction was not significantly responsible for the difference in the productivity level between the two groups of ABP beneficiary rice farmers.

**Table 2: Productivity difference among ABP beneficiary rice farmers in Ebonyi and Keb States**

| **1** | **Productivity differentials** | | | | | |
|---|---|---|---|---|---|---|
| **Indicator** | **Category** | **Coefficient** | **Z-value** | | | |
| Differential | Ebonyi farmers | 5.0691 | 19.29*** | | | |
| | Kebbi farmers | 6.6879 | 19.61*** | | | |
| | Difference | -1.6188 (-161.88%) | -3.76*** | | | |
| **2** | **Aggregate decomposition** | | | | | |
| Decomposition | Endowments | -1.0703 (-107.03%) | -2.86*** | | | |
| | Coefficients | -0.7413 (-74.13%) | -1.85* | | | |
| | Interaction | 0.1928 (19.26) | 0.56 | | | |
| **3** | | **Detailed decomposition** | | | | |
| | **Endowments effects** | | **Structural effects** | | **Interaction** | |
| **Variables** | **Coefficient** | **Z-value** | **Coefficient** | **Z-value** | **Coefficient** | **Z-value** |
| ABP credit | -0.0706 | -1.09 | -0.5984 | -1.97* | 0.1618 | 1.22 |
| Farm size | -0.0815 | -0.95 | -1.6092 | -1.3 | 0.1634 | 1.18 |
| Labour | -0.6356 | -2.63*** | -0.9898 | -1.02 | 0.1163 | 0.96 |
| Fertilizer | -0.3094 | -2.41** | 0.5154 | 1.18 | -0.1836 | -1.12 |
| Seed | 0.0230 | 0.31 | 1.3278 | 1.14 | -0.1363 | -1.03 |
| Gender | -0.0254 | -0.84 | -1.9329 | -1.56 | -0.0801 | -1.09 |
| Education | 0.0547 | 1.17 | 0.6367 | 1.07 | 0.0538 | 0.87 |
| Age | -0.0002 | -0.02 | -0.4944 | -0.35 | -0.0002 | -0.02 |
| Membership of cooperative organization | -0.0180 | -0.14 | -0.2825 | -0.32 | 0.0926 | 0.32 |
| Household size | 0.0006 | 0.01 | -0.3101 | -0.76 | 0.0003 | 0.01 |
| Access to extension services | -0.0066 | -0.18 | -0.0105 | -0.06 | -0.0004 | -0.06 |
| Farm experience | 0.0005 | 0.02 | -0.2545 | -0.37 | -0.0002 | -0.02 |
| Land ownership | -0.0069 | -0.14 | 0.4849 | 1.16 | 0.0059 | 0.14 |
| Marital status | 0.0051 | 0.16 | 0.0903 | 0.09 | -0.0005 | -0.08 |
| Constant | | | 2.6859 | 1.06 | | |

Sources: Field survey, (2019). Figures in parentheses are percentages.
***, ** and * = 1%, 5% and 10% levels of significance respectively

The threefold decomposition analysis reported that the gap in the mean productivity of the Ebonyi and Kebbi rice farmers is accounted for by the differences in the level of endowment and coefficients of their characteristics whichis crucial for developing and appropriating the right intervention measures and policies aiming at reducing productivity inequalities. If the productivity gap is due to differences in the effect of the determinants, then, the redistribution of endowments factors would be critical to improve productivity of Ebonyi farmers, since the impact of the endowment factors were found to be significant among the farmers. Behavioral and awareness programs would also be necessary interventions to close the gap between the two groups since the effect of level of the determinants were found to be significant among the farmers. In essence, then redistribution of endowments factors and improvement in the level of the determinants among the Ebonyi farmers would be an effective policy to reducing their productivity inequalities.

**Problems Limiting Small Scale Rice Farmers' Access to ABP**

The results presented in Table 3 revealed that inadequate awareness on procedures of loan application was ranked 1st as the major problem limiting small-scale rice farmers in Ebonyi and Kebbi States.This was followed by high interest rate charge by the bank which ranked 2nd. Access to credit facilities serve a great purpose of enabling farmers to procure required inputs toward improved productivity and livelihood. Conversely, inadequate credit tends to discouragefarmers and reduce cultivation to a sizable hectare. This finding agreed with Olughu (2019) who reported that lack of awareness of procedures and high interest rates were the major constraints faced by ABP beneficiaries in Kaduna State.

**Table 3. Distribution of respondents according to problems limiting small scale rice farmers' access to ABP credit**

| Variables | Ebonyi State (n=173) | | Kebbi State (n=163) | | Pooled (n=336) | |
|---|---|---|---|---|---|---|
| | Freq (%) | Rank | Freq (%) | Rank | Freq (%) | Rank |
| Inadequate awareness of the procedure of loan application | 120 (73.62) | 1st | 126 (72.83) | 1st | 246 (73.21) | 1st |
| High interest rate charge by the bank | 104 (63.80) | 2nd | 112 (64.74) | 2nd | 216 (64.29) | 2nd |
| Bureaucratic bottleneck (delays in processing the loan) | 91 (55.83) | 3rd | 97 (56.07) | 3rd | 188 (55.95) | 3rd |
| Collateral requirement | 71 (43.56) | 4th | 71 (41.04) | 4th | 142 (42.26) | 4th |
| Unavailability of the bank in my location | 59 (36.20) | 5th | 64 (36.99) | 5th | 123(36.61) | 5th |
| Untimely disbursement | 37 (22.70) | 6th | 40 (23.12) | 6th | 77 (22.92) | 6th |
| Literacy requirement in banking transaction | 25 (15.34) | 7th | 30 (17.34) | 7th | 55 (16.37) | 7th |
| Lack of insurance by farmers | 16 (9.82) | 8th | 18 (10.40) | 8th | 34 (10.12) | 8th |
| Unfriendly nature of bank staff | 10 (6.13) | 9th | 15 (8.67) | 9th | 25 (7.44) | 9th |

Sources: Field survey, (2019).

**CONCLUSION AND RECOMMENDATION**

The study concluded that the Anchor Borrower programme had positive effect on the productivity of the benefficiary rice farmers in Ebonyi and Kebbi states. The ABP rice farmers in Kebbi State are more productive than their counterpart in Ebonyi States. Based on the outcome of this study, it was recommended that FGN should consolidate on this performance by increasing funding for the programme and farmers should form cooperative societies in order to pool their resources together for their benefit and give them better chances of inclusiveness in programme of this similar nature in future.

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# ADOPTION OF VITAMIN A BIO-FORTIFIED CASSAVA VARIETIES AMONG RURAL FARMERS IN NIGER STATE, NIGERIA

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## ABSTRACT

The study examined adoption of vitamin A bio-fortified cassava varieties among farmers in Niger State, Nigeria. Three-stage random sampling procedure was used to select 165 cassava farmers used for the study. Primary data were collected from the respondents with the aid of structured questionnaire deployed through the use of Kobocollect Mobile App. Data collected were analyzed using descriptive statistics and adoption index. The result obtained revealed that study revealed that the level of adoption of vitamin A bio-fortified cassava variety is low (38.72%). The study also revealed that access to media, contact with extension agents, access to vitamin A bio-fortified cassava stem, amongst others, are the determinants of adoption of vitamin A bio-fortified cassava variety in the study area. It is therefore recommended that awareness about the new cassava technology should be prioritized to sensitize the farmers, and stems of these cassava varieties should be readily made available to farmers to take advantage of the benefit of the innovation.

**Keywords:** Adoption, Vitamin A, Bio-fortified cassava, Varieties

## INTRODUCTION

The main goal of the Nigeria agricultural development programme and policies is to increase agricultural production especially in area of food crop such as cassava, maize, sorghum, rice cowpea. Adoption of improved cassava varieties had been found to accelerate production output, economic growth (Ayinde, 2017). Therefore, cassava is an important factor in food security, poverty alleviation, rural-urban drift and unemployment reduction (Ubokwe, 2022). Cassava (*Manihot spp*) is a food crop that produce economic yield under the marginal production conditions (low soil fertility, low input use and poor management) which made it the preferred crop for resource poor farmers (Food and Agriculture Organization (FAO), 2019). Its role as major economic and food security crop has generated a significant research interest at national and international levels over the past two decades. The International Institute of Tropical Agriculture (IITA) (2023) for instance, has given high priority to research on improvement of cassava germplasm for Africa's diverse production ecology.

Thus, in the year 2022, the IITA released three improved cassava varieties which are pro Vitamin A. These varieties are UMUCACSS52 termed Headmaster – IBA152810; UMUCASS53 termed Security – IKN130010 and UMUCASS54 termed No hunger – IBA164773 (IITA, 2023). The adoptions of these varieties are expected to increase output of root tuber production, improve farmers' income and well-being. Bio-fortified staples are most needed because of high prevalence of Vitamin A deficiency (Oparinde *et al.,* 2016). These three varieties released can perform well in different cassava production region of Nigeria with high yield, high dry matter and good disease resistance (Ubokwe, 2022). The roots of these varieties are yellow and contain some levels of Vitamin A that can check Vitamin A deficiency among the growing population.

The improved Bio-fortified Vitamin A cassava varieties has the relative advantages over other cassava varieties due to its high yield, disease and pest resistance, early maturity and high dry matter content connected with better agronomic practices (Ubokwe, 2022). This makes it a crop grown for commercial market that brings income to the farmers, improve their living standard and revenue to the government thereby reducing poverty and enhancing economy of the nation (IITA, 2023). Therefore, there is the need to examine the adoption of these vitamin A bio-fortified cassava varieties among rural farmers in the study area.

Adoption is a decision to make full use of new ideas as the best course of action available (Muhammed, 2024). Farmers' willingness to use a new innovation after learning about its potential is very critical. According to Owolabi (2019), the adoption of improved agricultural technologies is an important means for poverty alleviation and ensuring food security in developing countries (Owolabi, 2019). Adoption of bio-fortified vitamin A cassava varieties is crucial for assessing the success and effects of bio-fortification initiatives in addressing nutritional deficiencies. Therefore, adoption of bio-fortified vitamin A cassava have been reported to have significant effects on income and nutritional status of farmers in Nigeria, particularly in the study area.

In spite of the yield potential and nutritional value of the bio-fortified Vitamin A cassava varieties over other prevalent varieties in terms of increased income and household nutrient intake, the pace of its adoption has not been impressive among farmers particularly in the study area. More so, since the introduction of the bio-fortified vitamin A cassava varieties in the country by IITA, few independent studies have been conducted to ascertain its adoption among rural farmers particularly in the study. This has constituted a gap in knowledge that need to be filled which necessitated this study, hence the following objectives to: describe the socio-economic characteristics of the cassava farmers, examined the adoption of bio-fortified vitamin A cassava varieties and its level of adoption in the study area.

## METHODOLOGY

### Study area

The study was conducted in Niger State which is located in North-central Nigeria. The State lies between Latitude 8º20´ - 11º30´ North and Longitude 3º 30´ - 8º20´ East of the equator. Niger State is bordered to the North by Kaduna State and Federal Capital Territory (FCT), Kebbi State to the West, Kogi State to the South, and Kwara State to the Southwest and has a common international boundary with Republic of Benin along New Bussa, Borgu Local Government Area. It has a total land area of 74,224 km$^2$ accounting for about eight percent of Nigeria land area (National Bureau Statistics (NBS), 2022). The State lies in the Guinea Savannah vegetation zone of the country with favourable climate conditions for crop (such as yam, maize, sorghum, millet, cowpea, soybean, rice and groundnut) and livestock (like goats, sheep, cattle and poultry) production. Farming is the main occupation in the State, while most of the communities in the State are predominantly agrarian.

**Sampling procedure and sample size**

In order to select the respondents for this study, three-stage sampling procedures was adopted. The first stage was purposive selection of one Local Government Area (LGA) from each of the three Agricultural Zones, I, II, and III based on preponderance of cassava farming in the area. The second stage was random selection of three (3) rural farming communities from each LGA to get a total of nine (9) rural farming communities. The third stage was proportionate selection of the rural farmers based on list of registered cassava farmers obtained from Agricultural Development Programme (ADP) office of the State with respect to each community selected using Yamane sample size determination formula. A total of 165 cassava farmers was used for the study.

**Method of data collection and analysis**

Primary data were collected from the respondents with the aid of structured questionnaire deployed through KoboCollect Mobile App. Trained enumerators assisted the researcher during the data collection process. The data collected were analyzed using descriptive statistics (such as frequency count, percentages and mean) and adoption index.

**Model specification**

**Adoption Index**

The level of adoption of Bio-fortified Vitamin A cassava by the respondents will be measured using adoption index adopted and modified by Zanu *et al.* (2012). The adoption index is specified as:

$$AI = \frac{TAF}{MSO} \times 100$$

Where;

AI = Adoption Score

TAF = Total Adoption Score by individual farmer

MSO = Maximum Score Obtainable

The respondents' scores was categorized as follows:

(i) Low adopters (less than 34%)

(ii) Partial adopters (34 – 67%)

(iii) High adopters (68 – 100%)

**RESULTS AND DISCUSSION**

**Socio-economic Characteristics of the Respondents**

The results of the socio-economic status of the respondents as presented in Table 1 revealed that the majority (92.7%) of the respondents were male farmers, while 7.3% were female farmers. This implies male dominance in cassava production in the study area. This result corroborates that of Gebre *et al.* (2021) who reported that that males dominate the work force in Nigeria's agricultural communities. Thus, males are the dominant gender among the bio-fortified vitamin A cassava producers. Also, majority (96.4%) of the respondents were within the age range of 31 – 60 years with a mean age of 48 years. This implies that most of the respondents are in their mid-age but still actively involved in cassava production. This finding is in line with the study of Nwajiuba *et al.* (2017) who reported that the average age of cassava farmers in Nigeria was about 45 years old. Majority (82.4%) of the respondents had farming experience within the range of 11 – 40 years with a mean farming experience of 31 years. This implies that greater proportion of the cassava farmers are experienced and have been into cassava farming for a long period of time. This finding contradicts the study of Oladele (2020) who reported that, the average farming experience of cassava farmers in his study area is 15 years.

In terms of education, most (60.6%) of the respondents acquired formal education (primary, secondary and tertiary) implying a moderate level of education which is an important factor in determining productivity in cassava production. This also shows that education level varied greatly among different age groups as farmers with higher level of education were more likely to adopt the improved varieties than those with a lower level of education. This finding agrees with the study of Fandohan *et al.* (2018) who reported that cassava farmers in Northern Nigeria varies across age group with majority attaining primary education. More so, majority (92.1%) of the respondents had household size within the range of 1 – 10 members with mean household size of 12 members. This implies a relatively large household size which could serve as source of family labour in cassava production. Most (60.6%) of the respondents had farm size with the range of 3.1 – 5.0 hectares with a mean farm size of 3.5 hectares implying that the cassava farmers are operating at a medium scale. This finding is in line with the study of Omonona *et al.* (2015) who reported that the average farm size of cassava farmers who adopted improved varieties in their study area was 3.2 hectares.

**Table 1: Distribution of respondents based on their socio-economic characteristics (n=165)**

| Variables | Frequency | Percentages | Mean |
|---|---|---|---|
| **Gender** | | | |
| Female | 12 | 7.3 | |
| Male | 153 | 92.7 | |
| **Age (years)** | | | |
| < 31 | 2 | 1.2 | 48 |
| 31 – 40 | 31 | 18.8 | |
| 41 – 50 | 75 | 45.5 | |
| 51 – 60 | 53 | 32.1 | |
| > 60 | 4 | 2.4 | |
| **Farming experience (years)** | | | |
| 1 – 10 | 3 | 1.8 | 31 |
| 11 – 20 | 32 | 19.4 | |
| 21 – 30 | 46 | 27.9 | |
| 31 – 40 | 58 | 35.2 | |
| > 40 | 26 | 15.8 | |
| **Educational Status** | | | |
| None formal | 65 | 39.4 | |
| Primary | 38 | 23.0 | |
| Senior Secondary | 42 | 25.5 | |
| Tertiary | 20 | 12.1 | |
| **Household Size** | | | |
| 1 – 5 | 72 | 43.6 | 12 |
| 6 – 10 | 80 | 48.5 | |
| > 10 | 13 | 7.9 | |
| **Farm size (hectare)** | | | |
| < 3.1 | 57 | 34.6 | 3.5 |
| 3.1 – 5.0 | 100 | 60.6 | |
| > 5.0 | 8 | 4.8 | |

**Source: Field Survey, 2024**

**Adoption of Bio-fortified Cassava Varieties by the Respondents**

The results of the adoption of bio-fortified vitamin A cassava varieties by the respondents is presented in Table 2. The result revealed that the most (63.0%) of the respondents adopted UMUCACSS_53 cassava variety, while 27.9% adopted UMUCACSS_52 and 7.3% of the respondents adopted UMUCACSS_54 as the least. This implies that UMUCACSS_53 is the most preferred bio-fortified vitamin A cassava variety among the cassava farmers in the study area.

**Table 2: Distribution of respondents based on adoption of bio-fortified cassava varieties (n=165)**

| Varieties | Frequency | Percentages |
|---|---|---|
| UMUCACSS 52 | 46 | 27.9 |
| UMUCACSS 53 | 104 | 63.0 |
| UMUCACSS 54 | 12 | 7.3 |

**Source: Field Survey, 2024**

**Adoption Level of Bio-fortified Cassava Varieties by the Respondents**

Table 3 revealed the results of bio-fortified vitamin A cassava varieties adoption level by the respondents based on the adoption scores in the study area. The result shows that UMUCACSS_53 cassava variety recorded moderate level of adoption, while UMUCACSS_52 and UMUCACSS_54 recorded low level of adoption. However, the mean aggregate score of the bio-fortified vitamin A cassava varieties revealed generally low level of adoption. This implies that the bio-fortified vitamin A cassava variety adoption among the cassava farmers in the study area is generally low. This finding is in line with the study of Ezezika *et al.* (2019) who reported that the adoption level of pro-vitamin A cassava in Taraba State was relatively low. Also, Mamud (2021) reported that pro-vitamin A bio-fortified cassava adoption level was relatively low (at about 20%) in his study area.

**Table 3: Distribution of respondents based on adoption level of bio-fortified cassava varieties**

| Varieties | Adoption scores | Adoption levels |
|---|---|---|
| UMUCACSS 52 | 27.9 | Low |
| UMUCACSS 53 | 63.0 | Moderate |
| UMUCACSS 54 | 7.3 | Low |
| **Mean aggregate Score** | **32.7** | **Low** |

**Source: Field Survey, 2024**

**CONCLUSION AND RECOMMENDATIONS**

In light of the findings, the study concluded that the cassava farmers were in their active age of production, experienced and educated with relatively large household. Different varieties of the bio-fortified vitamin A cassava varieties was adopted by the farmers in the study area. However, there was moderate level of adoption of UMUCACSS 53 bio-fortified vitamin A cassava variety as compared to others that recorded low adoption. In general, there was low level of adoption of the bio-fortified cassava varieties in the study area. The study therefore recommended that more sensitization should be conducted by extension agency on the significance of the bio-fortified vitamin A cassava varieties in order to achieve high level of adoption. More so, policy makers should endeavor to provide resources or packages that will assist farmers who are practicing bio-fortified vitamin A cassava farming

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# PERCEIVED EFFECTS OF COVID-19 ON AGRICULTURAL ACTIVITIES OF RURAL HOUSEHOLDS IN NIGER STATE, NIGERIA

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## ABSTRACT

The study examined the perceived effects of COVID-19 on agricultural activities of rural households in Niger State, Nigeria. A multistage sampling procedure was employed to select 148 respondents for the study. Primary data used for the study were obtained through structured questionnaire and analysed using descriptive statistics such as frequency counts, percentages and mean. The result obtained revealed that planting of cereals (54.7%), legumes (56.1%), root and tuber (41.2%), and vegetables (42.6%) were the major crop production activities engaged by the respondents during the COVID-19 pandemic in the study area. Also, majority (41.9%) of the respondents engage in small ruminant animals' production and poultry production in the study area. The knowledge of wearing nose mask due to covid-19 ($\bar{X}$=2.46), knowledge of covid-19 vaccine ($\bar{X}$=2.40), knowledge on covid-19 symptoms ($\bar{X}$=2.39) and knowledge on covid-19 status ($\bar{X}$=2.39) ranked 1$^{st}$, 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ respectively, among the knowledge level of the respondents about COVID-19. Meanwhile, increase in demand for farm produce ($\bar{X}$=3.40), limitation in social networking ($\bar{X}$=3.39), agricultural activities have brought down to standstill ($\bar{X}$=3.34) and loss of farm produce in storage ($\bar{X}$=3.31) ranked 1$^{st}$, 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ respectively, as the perceived effects of COVID-19 on agricultural activities by the respondents in the study area. It was concluded that farmers were more engage in cereals, legumes, root and tuber production during the lockdown as well as small ruminant and poultry production as the agricultural activities. The study recommended that rural household should be given necessary financial support through Government or NGOs in terms of affordable loans, so that they can quickly adjust to the threats posed by COVID-19 in the study area.

**Keywords:** Perceived, Effects, COVID-19, Agricultural Activities, Rural Household

## INTRODUCTION

The role of agriculture in the lives of individuals is very crucial. Agriculture is significant in the advancement of science and technology for the development of food, raw materials and income for mankind (Muhammed *et al.,* 2023). It is the gateway to achieve food, natural raw material (plant and animal origin) and income for the survival of most countries especially the developing nation. The influence of agricultural activities on a nation and its citizens could be seen from the provision of basic human needs for educational, technological and economic advancement

(Adegoke, 2018). Thus, agricultural production is affected by many factors among which include natural disasters like pandemic disease

Coronavirus (COVID19) is a pandemic disease which spread very fast and is deadly to the entire Universe. Preceding pandemic diseases such as Ebola, Spanish flu and bird flu among others have similar characteristics with COVID 19 have claimed millions of lives globally (World Bank, 2020). Even with the known little cure to some of the pandemic diseases that are still much around, thousands of lives are still lost globally on yearly basis. Coronavirus disease which originated from Wuhan city in china is transmitted via respiratory droplets with mild, non-specific symptoms such as fever, cough; shortness of breath, muscle pain and tiredness (World Bank, 2020).

More serious cases can lead to severe pneumonia and acute respiratory distress syndrome as well as death. No cure has yet been found despite several medical research to gain a better understanding about the novel disease. As at 8th of May, 2020, coronavirus caused about 4.01 million confirmed cases and 276, 216 deaths worldwide (World Bank, 2020). This means that death occurrence is about 6.9% of the total confirmed cases. On the other hand, the number of recovered cases as at the same date was 1,385,184 cases, representing about 34.5% of the total positive confirmed cases. What makes the entire world to panic is that most crucial aspect of an epidemic or pandemic remains human suffering and loss of lives with significant macro-economic consequences on the economy (Pan *et al.,* 2020).

Nigeria as a nation first witnessed the outbreak of Covid-19 in Lagos State on the 27th February, 2020 and as at 10th of May 2020, it has spread to about 34 States including the Federal Capital Territory except Cross Rivers and Kogi States. Thus, after the first recorded index case in Lagos State, the cases have risen to over four thousand, three hundred and ninety-nine (4,399) in the entire country with total discharged of 779 and death rate of 143 as at 10th May, 2020 (Nigeria Centre for Disease Control (NCDC) ,2020). This implies that death rate is about 3.3%, while recovery rate is about 17.7% of the total confirmed cases. The alarming rate of increase in corona virus cases in Nigeria has led the Federal Government to immediately close all the boarders of the country, business activities and institutions of learning amongst others in order to prevent the fast spread of the deadly virus.

The macroeconomic implication of the Government actions is not far fetch as it has led to rise in unemployment, because companies were force to downsize their workers as production is not at optimum (Daudu *et al.,* 2020). Workers who lose jobs due to closure of businesses do no longer earn income and therefore lower consumption, eventually depressing aggregate demand. Similarly, there is rise in inflation level of goods and services. For instance, the prices of staple food such as; ‘garri’, yam, palm-oil, tomatoes and rice amongst others increases by at least 100% (Obayori, 2020). This is because farmers do not have access to market to sell their products as a result of the total or partial lockdown imposed on many States of the federation.

Given the background above, the current study seeks to examine the effects of the novel coronavirus disease (COVID-19) on agricultural activities in Niger State, Nigeria. Every disease affects not only people’s health but comes with direct or indirect effects on the socio-economic status, food security, dietary intake and agricultural activities generally. Agriculture is one of the most essential sectors in human development and it is related to food security (Abdelhedi and Zouari, 2020). Studies have shown that an outbreak of diseases (for examples: Spanish Flu, Asian Flu, Hong Kong Flu, HIV/AIDS, SARS, Ebola and Swine Flu) has always been accompanied with a decrease in agricultural activities leading to hunger and malnutrition with a great impact on the economy, environment and human activity (Siche, 2020).

COVID-19 outbreak has worsened the trend of agricultural activities, insecurity of food and it is likely to continue if urgent steps are not taken. Furthermore, given the high level of unpredictability in the trend of the COVID-19 infection's spread and the severity of the effects at both the international and national level, a comprehensive analysis of the pandemic effect on agricultural activities has not yet adequately been research on probably due to the fact that the pandemic is still spreading worldwide. This has constituted a gap in knowledge which need to be fill and becomes important to understand the immediate effects of COVID-19 on agricultural activities among rural households in Niger State, Nigeria. It is against this backdrop the study examined the agricultural activities engaged by the rural households during COVID-19; assessed the knowledge level of the rural households about COVID-19 and examined the perceived effects of COVID-19 on agricultural activities of the rural household in the study area.

## METHODOLOGY

### Study area

The study was conducted in Niger State which is located in North-central Nigeria. The State lies between Latitude 8º20′ - 11º30′ North and Longitude 3º 30′ - 8º20′ East of the equator. Niger State is bordered to the North by Kaduna State and Federal Capital Territory (FCT), Kebbi State to the West, Kogi State to the South, and Kwara State to the Southwest and has a common international boundary with Republic of Benin along New Bussa, Borgu Local Government Area. It has a total land area of 74,224 $km^2$ accounting for about eight percent of Nigeria land area (National Bureau Statistics (NBS), 2022). The State lies in the Guinea Savannah vegetation zone of the country with favourable climate conditions for crop (such as yam, maize, sorghum, millet, cowpea, soybean, rice and groundnut) and livestock (like goats, sheep, cattle and poultry) production. Farming is the main occupation in the State, while most of the communities in the State are predominantly agrarian.

### Sampling procedure and sample size

Multistage sampling procedure was employed to select respondents for the study. The first stage was random selection of one Local Government Area (LGA) from each of the three Agricultural Zones I (Lapai), II (Bosso) and III (Kontagora) of Niger State. The second stage involved random selection of three (3) villages from each of the LGA selected. The third stage was proportionate selection of 148 registered rural farming households based on list of obtained from Niger State Agricultural Mechanization and Development Authority (NAMDA) with respect to each community selected using Yamane sample size determination formula. The Yamane's formula is mathematically expressed as in equation (1):

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where;

n = samples size

N = finite population

e = limit of tolerable error (level of precision at 0.05 probability)

l = constant

### Method of data collection and analysis

Primary data were used for the study and it was collected from the respondents with the aid of structured questionnaire complemented with an interview scheduled. Trained enumerators assisted the researcher during the data collection process. The data collected were analyzed using descriptive statistics (such as frequency count, percentages and mean). Meanwhile, 3 – point Likert rating type scale of high knowledge = 3, moderate knowledge = 2 and low knowledge = 1 was used to measure the knowledge level of the respondents about COVID-19, while 5 – point Likert rating scale of strongly agreed = 5, agreed = 4, undecided = 3, Disagreed = 2 and strongly disagreed = 1. The mean score value of 2.0 was used as decision rule where value of ≥ 2.0 implies high knowledge, while value of < 2.0 implies low knowledge. Also, the mean score value of 3.0 was used as decision rule where value of ≥ 3.0 implies agreed, while value of < 3.0 implies disagreed.

## RESULTS AND DISCUSSION

### Agricultural Activities engaged by the Rural Households

Table 1 revealed the result of various agricultural activities by the rural households during the pandemic of COVID-19 season in the study area. All (100.0%) the respondents indicated that they had access to their farm for farming purposes during the COVID-19 pandemic in the study area. The result further revealed that planting of cereals (56.1%), legumes (54.7%), root and tuber (42.6%) and vegetables (41.2%) were the major crop production activities engaged by the rural farming households during the COVID-19 pandemic due to the necessities of these produce among the farming households in the study area. Also, 41.9% of the rural households engaged in small ruminant animals and poultry production to cater for their households needs as there were no other economic activities during the pandemic in the study area. This result agrees with the work of Beltrami (2020) who reported that the economic activities of the rural farmers in his study area were crop production and livestock rearing especially during period of pandemic.

**Table 1: Distribution of the respondents based on agricultural activities engaged**

| Variables | Frequency | Percentage (%) |
|---|---|---|
| **Agricultural activities** | | |
| Access to farm during COVID-19 | 148 | 100.0 |
| **Crop production** | | |
| Cereals | 83 | 56.1 |
| Legumes | 81 | 54.7 |
| Root and tuber | 63 | 42.6 |
| Vegetables | 61 | 41.2 |
| Plantation | 5 | 3.4 |
| **Animal production** | | |
| Small ruminant animals | 62 | 41.9 |
| Poultry | 62 | 41.9 |
| Large ruminant animals | 29 | 19.6 |
| Silviculture | 13 | 8.8 |
| Capture fish | 13 | 8.8 |
| Culture fish | 3 | 2.0 |
| **General agriculture** | | |
| Landscaping | 35 | 23.6 |
| Flowers and ornamentals | 9 | 6.1 |
| Horticulture | 3 | 2.0 |

**Source: Field Survey, 2022**

**Knowledge Level of Rural Households about COVID-19**

The result in Table 2 revealed that there was high knowledge level of COVID-19 pandemic in the study area. The knowledge of wearing nose mask due to COVID-19 ($\bar{X}$ = 2.46), knowledge of COVID-19 vaccine ($\bar{X}$ = 2.40), knowledge on COVID-19 symptoms ($\bar{X}$ = 2.39) and knowledge on COVID-19 status ($\bar{X}$ = 2.39) ranked 1st, 2nd, 3rd and 4th, respectively among the high knowledge level about COVID-19 by the respondents. The knowledge of wearing nose mask due to covid-19 ranked first among the respondents implying that there was high knowledge level among the respondents for the need of wearing nose mask to reduce the spread of the COVID-19 among the people in the study area. The knowledge of COVID-19 vaccine ranked second implying that there was high knowledge level among the respondents of covid-19 vaccine distributed free of charge by the government in other to prevent the inoculation of the virus in the body of the people and also to cure those who are already tested positive of the virus. Furthermore, knowledge of COVID-19 symptoms ranked third implying there was high knowledge level among the respondents of the symptoms of COVID-19 such as high temperature, dry cough, nasal congestion etc. Also, the respondents are fully knowledgeable of COVID-19 status as those who tested positive were confined in an isolation centres and those who are tested negative were enlighten more on how to prevent the spread of COVID-19 among the people in the study area. This finding agrees with the study of Daudu *et al.* (2020) who reported that the respondents in their study area are highly knowledgeable of COVID-19 pandemic, COVID-19 status and the preventive measures.

**Table 2: Distribution of respondents based on their knowledge level of COVID-19**

| Variables | HK | MK | LK | Mean | Remark | Rank |
|---|---|---|---|---|---|---|
| Knowledge of wearing nose mask due to Covid-19 | 69(46.6) | 78(52.7) | 1(0.7) | 2.46 | HK | 1st |
| Knowledge of Covid-19 vaccine | 61(41.2) | 85(57.4) | 2(1.4) | 2.40 | HK | 2nd |
| Knowledge on Covid-19 symptoms | 59(39.9) | 88(59.5) | 1(0.7) | 2.39 | HK | 3rd |
| Knowledge on Covid-19 | 65(43.9) | 76(51.4) | 7(4.7) | 2.39 | HK | 4th |
| Knowledge on Covid-19 status | 55(37.2) | 92(62.2) | 1(0.7) | 2.36 | HK | 5th |
| Knowledge of ways to prevent Covid-19 spread | 63(42.6) | 73(49.3) | 12(8.1) | 2.34 | HK | 6th |
| Knowledge of Covid-19 test | 60(40.5) | 77(52.0) | 11(7.4) | 2.33 | HK | 7th |
| Knowledge of temperature reading | 52(35.1) | 88(59.5) | 8(5.4) | 2.30 | HK | 8th |
| Knowledge of deadly impact of Covid-19 | 55(37.2) | 79(53.4) | 14(9.5) | 2.28 | HK | 9th |
| Knowledge of restriction in movement due to Covid-19 | 47(31.8) | 93(62.8) | 8(5.4) | 2.26 | HK | 10th |
| Knowledge on social distancing due to Covid-19 | 50(33.8) | 86(58.1) | 12(8.1) | 2.26 | HK | 11th |
| Knowledge of lockdown due to Covid-19 | 53(35.8) | 77(52.0) | 18(12.2) | 2.24 | HK | 12th |

**Source: Field Survey, 2022**

**Note:** HK = High Knowledge, MK = Moderate Knowledge and LK = Low Knowledge.

**Perceived Effects of COVID-19 Disease on Agricultural Activities by the Rural Households**

Perception is 'an orientation toward certain objects, persons, or situations that is emotionally charged and relatively persistent'. Perception is learned, and regarded as a more specific expression of a value or belief or it results from the application of a general value to concrete objects or situations. Thus, Table 3 revealed the perceived effects of corona virus disease on agricultural activities. The most prominent effects of corona virus disease on agricultural activities are that COVID-19 has led to increase in demand for farm produce ($\bar{X}$ = 3.40), COVID-19 has led to limitation in social networking ($\bar{X}$ = 3.39), COVID-19 has bring down agricultural activities to standstill ($\bar{X}$ = 3.34) and COVID-19 has led to loss of farm produce in storage ($\bar{X}$ = 3.31) ranked 1st, 2nd, 3rd and 4th respectively.

Covid-19 has led to increase in demand for farm produce ranked first implying that there is an increase in demand of farm produce by the respondents due to restriction in economic activities and lockdown. There is also limitation in social networking due to Covid-19 which rank second among the effects of corona virus diseases on agricultural activities. This implies that there is restriction in movement of people during the COVID-19 pandemic and this has seriously affected the level of social networking in the study area. Covid-19 has brought down agricultural activities to standstill ranked third implying that there was initial global standstill in agricultural activities as result of the outbreak of the diseases and the restriction of people movement which brings down agricultural activities in the study area.

Covid-19 has led to loss of farm produce in storage ranked fourth among the perceived effects of corona virus diseases on agricultural activities as most of the respondents indicated that their farm produce was wasted due to COVID-19 pandemic because of the restriction in movement and social networking. Thus, they were unable to sell their harvested farm produce which led to storage lost among the farming households in the study area. This result is in line with the work of Jribi *et al.* (2020) who reported that there was high restriction among people in their study area due to the outbreak of corona virus diseases in other to minimize the spread of virus.

**Table 3: Perceived effects of corona virus disease on agricultural activities**

| Variables | SA (%) | A (%) | U (%) | D (%) | SD (%) | WM | Remark | Rank |
|---|---|---|---|---|---|---|---|---|
| Covid-19 has led to increase in demand for farm produce | 26(17.6) | 39(26.4) | 51(34.5) | 32(21.6) | 0(0) | 3.40 | A | 1st |
| Covid-19 has led to limitation in social networking | 29(19.6) | 40(27.0) | 39(26.4) | 40(27.0) | 0(0) | 3.39 | A | 2nd |
| Bring down agricultural activities to standstill | 12(8.1) | 53(35.8) | 57(38.5) | 26(17.6) | 0(0) | 3.34 | A | 4th |
| Covid-19 has led to loss of farm produce in storage | 34(23.0) | 26(17.6) | 40(27.0) | 48(32.4) | 0(0) | 3.31 | A | 5th |
| Covid-19 has increase food insecurity | 18(12.2) | 45(30.4) | 53(35.8) | 28(18.9) | 4(2.7) | 3.30 | A | 6th |
| Reduction in the contribution of crop production to the economy | 22(14.9) | 36(24.3) | 54(36.5) | 36(24.3) | 0(0) | 3.30 | A | 7th |
| Covid-19 has led to reduce demand for farm produce | 21(14.2) | 47(31.8) | 28(18.9) | 51(34.5) | 1(0.7) | 3.24 | A | 8th |
| Farm input were too expensive or inaccessible | 5(3.4) | 55(37.2) | 53(35.8) | 35(23.6) | 0(0) | 3.20 | A | 9th |
| Covid-19 affects livestock production supply chain | 8(5.4) | 42(28.4) | 68(45.9) | 30(20.3) | 0(0) | 3.19 | A | 10th |
| Covid-19 have led to low yield | 18(12.2) | 41(27.7) | 39(26.4) | 46(31.1) | 4(2.7) | 3.16 | A | 11th |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| of crop | | | | | | | | |
| Loss of employment due to covid-19 | 20(13.5) | 45(30.4) | 58(39.2) | 25(16.9) | 0(0) | 3.14 | A | 12th |
| Covid-19 causes poor access to production inputs | 12(8.1) | 31(20.9) | 68(45.9) | 37(25.0) | 0(0) | 3.12 | A | 13th |
| Restriction in movement of goods and services | 9(6.1) | 34(23.0) | 69(46.6) | 36(24.3) | 0(0) | 3.11 | A | 14th |
| Covid-19 affects labour supply in production | 20(13.5) | 28(18.9) | 47(31.8) | 53(35.8) | 0(0) | 3.10 | A | 15th |
| Low income generation from agricultural activities | 16(10.8) | 27(18.2) | 52(35.1) | 53(35.8) | 0(0) | 3.04 | A | 16th |
| Covid-19 has led to decrease in production | 19(12.8) | 21(14.2) | 52(35.1) | 52(35.1) | 4(2.7) | 2.99 | DA | 17th |
| Covid-19 affects crop production supply chain | 12(8.1) | 28(18.9) | 55(37.2) | 49(33.1) | 4(2.7) | 2.97 | DA | 18th |
| Poor livelihood status of the rural people | 5(3.4) | 35(23.6) | 51(34.5) | 57(38.5) | 0(0) | 2.92 | DA | 19th |

**Source: Field Survey, 2022**

**Note:** SA = Strongly Agreed, A = Agreed, U = Undecided, D = Disagreed and SD = Strongly Disagreed

## CONCLUSION AND RECOMMENDATIONS

Based on the result emanating from this study, it can be concluded that the respondents were actively involved in agricultural activities. They were more engaged in cereals, legumes, root and tuber production during the lockdown as well as small ruminant and poultry production. The respondents had high knowledge level that the use of nose mask due to COVID-19 is the prominent preventive measure against spreading the disease outbreak. However, increase in demand for farm produce and limitation in social networking was the most perceived effects of corona virus diseases on agricultural activities among the rural farming households in the study area. The study recommended that rural household should be given necessary financial support through Government or NGOs in terms of affordable loans, so that they can quickly adjust to the threats posed by COVID-19 in the study area.

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# SYSTEMATIC REVIEW ON WOMEN PARTICIPATION IN POST-HARVEST PROCESSING OF MAIZE USING INDIGENOUS TECHNOLOGIES IN NIGER STATE, NIGERIA

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## ABSTRACT

This review assesses women's participation in post-harvest maize processing using indigenous technologies in Niger State, Nigeria, focusing on techniques employed, the extent of involvement, and associated challenges. The review revealed that women are integral to post-harvest activities, including de-husking, shelling, drying, and storage, often relying on traditional methods characterized by labour intensity, time consumption, and substantial post-harvest losses. The review also showed that socio-cultural factors, limited access to improved technologies, inadequate training and financial constraints significantly hinder women’s efficiency and productivity. The findings revealed the need for interventions such as the provision of improved technologies, gender-sensitive capacity-building programmes, financial support and infrastructure development to enhance women’s participation and productivity in post-harvest maize processing.

**KEYWORDS**: Participation; Post-harvest; Processing; Maize and Indigenous

## INTRODUCTION

Agriculture has long been the backbone of Nigeria's economy, serving as a vital source of livelihood for a substantial portion of its population. The sector contributes significantly to employment, rural development and food security (Adewumi *et al.,* 2019). According to the World Bank (2021), agriculture accounted for approximately 21% of Nigeria's Gross Domestic Product (GDP) in the year 2020. The cultivation of staple crops like maize, yam, cassava and millet forms the foundation of food production, while cash crops such as cocoa, oil palm, and rubber have contributed to export earnings and foreign exchange (Akinyele and Ogunlade, 2020). The economic significance of agriculture extends beyond production to encompass post-harvest processing, marketing, and distribution, thereby linking rural communities to broader economic networks (Adesina, 2017). Meanwhile, focus of the review is post-harvest processing among rural women.

Post-harvest processing serves as a bridge between farm production and the consumer market, infusing agricultural products with enhanced value and shelf life. The overarching goals of processing include preservation, value addition and transformation (Falola *et al.*, 2021). Preservation measures are implemented to counteract spoilage caused by factors such as pests, humidity and microbial activity. Value addition involves improving product quality, nutritional content and marketability. Transformation, on the other hand, takes raw commodities and converts them into processed goods ready for distribution and consumption. Nigeria's rich culture contributes to a diverse array of traditional and indigenous post-harvest processing techniques (Adewumi *et al.*, 2019). These time-tested methods have been refined and passed down through generations, harnessing local resources and knowledge. Techniques such as sun drying, threshing using hand tools, and stone grinding for milling exemplify the utilization of indigenous knowledge to achieve effective post-harvest processing (Akinyele and Ogunlade, 2020). These practices often harmonize with the local environment and socio-cultural practices, showcasing the integration of traditional wisdom with practical agricultural needs.

Maize serves as a staple food crop that forms the foundation of diets across various socio-economic strata in Nigeria. It is consumed in various forms, including whole kernels, milled flour, and processed products. Maize's versatility extends to its use as livestock feed, contributing to the livestock sector that complements the dietary needs of Nigerians. The crop's widespread cultivation and consumption contribute to nutritional diversity, as maize is a source of essential nutrients, including carbohydrates, dietary fiber and certain vitamins (Bello-Bravo *et al.*, 2020). Despite maize's significance, the passage from farm to fork is fraught with challenges, and post-harvest losses remain a persistent concern. These losses occur during harvesting, handling, transportation, and storage, leading to reduced quantities and quality of maize reaching consumers. According to the Food and Agriculture Organization (FAO) (2021), post-harvest losses for maize in Nigeria can range from 10% to as high as 30% of the total harvest. The lack of adequate storage facilities, inefficient processing methods and inadequate transportation infrastructure contribute to these losses.

Women, comprising a significant portion of Nigeria's agricultural workforce, play significant role in post-harvest processing. Their involvement spans multiple stages of the processing chain, including cleaning, drying, threshing, milling, and packaging. These responsibilities align with traditional gender roles, reflecting women's role as nurturers and providers within the household (Adewumi *et al.*, 2019). Women's contributions are particularly pronounced in activities requiring attention to detail and meticulous care, such as cleaning and packaging, which are crucial for maintaining product quality and safety (Adewumi *et al.*, 2019). The involvement of women in post-harvest processing is not only integral to the transformation of raw produce but also has far-reaching implications for food security and household livelihoods (Adesina, 2017). Effective post-harvest processing ensures that a greater proportion of harvested crops reach consumers, reducing losses and enhancing overall food availability. Furthermore, women's engagement in these activities contributes to income generation, poverty reduction, and economic empowerment, strengthening the socio-economic fabric of rural communities (Adesina, 2017). Based on the foregoing the review assesses previous studies on indigenous post-harvest maize processing techniques and level of levels of women participation in post-harvest maize processing

## METHODOLOGY

This systematic review employed a qualitative synthesis of relevant literature and empirical studies to evaluate women's participation in maize post-harvest processing using indigenous technologies in Niger State, Nigeria. A structured process was adopted, including literature identification, selection, data extraction, and thematic analysis. Databases such as Google Scholar, PubMed, and ResearchGate were searched using keywords like "women participation," "post-harvest maize processing," "indigenous technologies," and "Niger State, Nigeria." Additional sources included government reports, conference proceedings, and publications from agricultural research institutes. To ensure the findings reflected current trends, studies published between 2000 and 2023 were prioritized.

Studies were included if they examined women's roles in maize post-harvest processing in Nigeria, focused on indigenous technologies such as manual shelling, traditional drying techniques, or local milling methods, and provided qualitative or quantitative data on levels of women's participation. Data extraction focused on key themes such as indigenous technologies, participation levels, socio-economic factors, challenges, and outcomes. A predefined template was used to organize data based on relevance to the review objectives. The data were analyzed thematically to identify patterns in indigenous technologies, the extent of women's involvement, and factors influencing their participation. Comparative analysis was conducted to highlight variations across communities and regions in Niger State.

**Indigenous post-maize processing techniques available**

Agunga *et al.* (2018) assessed the indigenous post-harvest storage and processing methods of selected grains and legumes in Eastern Kenya. The study find that women are responsible for the majority of post-harvest processing activities, such as cleaning, shelling, and grinding. The study added that the use of indigenous post-harvest processing techniques can result in significant loss of nutritional value and increase the risk of contamination. The study recommended that training and education on improved post-harvest processing techniques can help to reduce waste, improve food safety, and increase the value of crops. Similarly, Ukoha *et al.* (2019) examined the indigenous post-harvest practices and constraints in the production of improved maize in Akwa Ibom State, Nigeria. The study found that the majority of farmers used traditional methods for post-harvest processing, including drying, de-husking, threshing, winnowing and storage. The most common storage method was bags, and the most common pest control method was the use of pesticides. The study also found that a number of challenges faced by farmers during post-harvest processing, including lack of access to improved technologies, lack of training, and lack of access to credit.

Ahamefule *et al.* (2020) found that the most common post-harvest processing methods used by farmers in the study area were manual de-husking, manual shelling, and manual drying. These traditional methods were found to be time-consuming, labour-intensive, and resulted in significant post-harvest losses. The study also found that farmers faced challenges such as lack of access to credit, lack of market information, and high costs of transportation. The study recommended the adoption of improved technologies for post-harvest processing, as well as training for farmers to improve their knowledge and skills. Agber *et al.* (2019) added that the post-harvest maize processing techniques used by farmers in the Ika communities of Delta State were manual winnowing, drying, threshing, grinding, and storage in sacks and woven baskets. The study also found that post-harvest losses were significant, primarily due to inadequate storage facilities and poor drying techniques. The study recommended improved drying, storage, and processing technologies, as well as better education and extension services for farmers.

Ogunsoye *et al.* (2018) assessed post-harvest operations and management of grains by smallholder farmers in Igbemo area of Ondo State, Nigeria. The findings from this study show that the main post-harvest processing techniques used by farmers in the Igbemo area were winnowing, threshing, drying, and storage in jute bags or woven baskets. Post-harvest losses were mainly due to inadequate storage facilities, high temperatures, and pest infestation. The study recommended the use of improved post-harvest processing equipment and facilities, as well as improved management practices. Anosike (2017) found that the main post-harvest processing techniques used by farmers in the Nsukka agricultural zone were manual winnowing, manual threshing, drying, and storage in locally made storage facilities. The study also found that the farmers experienced significant post-harvest losses, with an average loss of 26% of the maize harvest. The study recommended the use of improved storage facilities and improved drying methods to reduce post-harvest losses.

**Level of women participation in indigenous maize processing**

Rutto *et al.* (2016) examined gender roles and participation in maize production, processing and utilization in two States of Nigeria. This study found that in terms of post-harvest processing, women in the study area were responsible for harvesting, removing the cobs from the stalks, transporting the cobs to the home, and shelling. Women were also responsible for storing the maize in a safe place. Men were primarily responsible for threshing and winnowing, and in some cases, shelling. Gashu and Agnew (2012) reported that while women were responsible for harvesting, removing husks, and drying, men were responsible for threshing, winnowing, storage, and marketing. In addition, the study found that gender roles in maize production and post-harvest management were influenced by several factors, including age, educational level, and access to resources. Chendu *et al.* (2014) showed that gender roles in post-harvest processing of cassava and maize were heavily influenced by socio-cultural factors, including age, educational level, and marital status. The study also found that men were more likely to be involved in post-harvest processing of cassava and maize, while women were more likely to be involved in marketing the products.

Olatidoye and Aighewi (2012) examined gender roles and participation in post-harvest handling of fruits and vegetables in Lagos State, Nigeria. The findings of this study showed that women were the primary participants in post-harvest handling of fruits and vegetables in Lagos State. The study also found that men were more likely to be involved in transportation and marketing of the products, while women were more likely to be involved in harvesting and sorting. Additionally, the study found that age and level of education were significant factors in determining gender roles in post-harvest handling. Baldé and Akpo (2021) added that gender roles in post-harvest fish handling in northern Benin were influenced by factors such as age, education level, and location. The study also found that women played a vital role in post-harvest fish handling activities, such as cleaning, washing, and sun drying. Men were more likely to be involved in marketing and transporting the fish. The study concluded that there was a need for improved training and capacity building for both men and women to improve post-harvest fish handling.

**DISCUSSION OF THE REVIEW**

The findings from reviewed studies highlight the integral role of indigenous post-harvest maize processing techniques and women's participation in these activities, emphasizing their socio-economic and cultural significance. Women are central to post-harvest maize processing, taking on labor-intensive tasks such as de-husking, shelling, drying, and winnowing, often employing traditional, manual methods. These techniques, while locally adapted, are time-consuming, labor-intensive, and prone to significant post-harvest losses, as highlighted in studies by Agunga *et al.* (2018) and Ukoha *et al.* (2019). Challenges such as inadequate storage facilities, pest infestation, and high costs of transportation exacerbate these losses. Despite their active involvement, women face constraints like limited access to improved technologies, training, and credit, underscoring the need for targeted interventions. The gender-specific roles in post-harvest processing reflect socio-cultural norms, with women primarily responsible for tasks such as cleaning and sorting, while men often handle threshing and transportation (Rutto *et al.,* 2016; Gashu and Agnew, 2012). Factors like age, education, and marital status also influence these roles, as noted by Chendu *et al*. (2014).

**CONCLUSION AND RECOMMEDATION**

The systematic review showed the pivotal role of women in post-harvest maize processing using indigenous technologies in Niger State, Nigeria. Women are deeply involved in labour-intensive tasks such as de-husking, shelling, drying and winnowing, often relying on traditional methods that are time-consuming and prone to significant losses. Socio-cultural factors, lack of access to improved technologies, and inadequate training constrain their efficiency and productivity. Despite these challenges, women's participation remains essential for food security and rural livelihoods. The study recommended that research institutes should **d**evelop and disseminate affordable, user-friendly and culturally acceptable technologies to reduce labour intensity of indigenous technology, enhance efficiency, and minimize post-harvest losses. Organize training programmes for women on modern post-harvest processing methods, focusing on reducing losses and improving the nutritional and economic value of processed maize.

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# EFFECTS OF POINT OF SALE (POS) SERVICES ON RICE FARMING ACTIVITIES IN RURAL COMMUNITIES OF NIGER STATE, NIGERIA

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## ABSTRACT

The study was conducted to examine the effects of Point of Sale (POS) Services on rice farming activities in rural communities of Niger State, Nigeria. Specifically, the study examined level of rice farmers' utilization of POS services in rural communities and nature of POS financial services benefited by rice farmers in the rural communities. Multi-stage sampling techniques were employed to select 225 respondents on which primary data were elicited from the respondent with the aid of a structured questionnaire complemented with interview schedule using kobo toolbox. Data collected were analyzed using binary probit regression and Ordinary Least Square regression. The study revealed that marital status ($P<0.05$), education ($P<0.01$), farm experience ($P<0.01$) and relative advantage ($P<0.01$) were the major factors that influenced the POS services utilization in rural communities. More so, frequency of payments using POS services ($P<0.01$), security of transactions via POS services ($P<0.01$), Transaction efficiency ($P<0.01$) and amount of credit received through POS-related financial services ($P<0.05$) were the major factors that influenced rice production in rural communities The recommended that efforts should be made by financial institutions to further enhance the accessibility and reliability of POS services in rural communities.

**Key words:** POS; Services; Rice; and Farming

## INTRODUCTION

Efficient payment systems play a pivotal role in the economic development of nations, serving as a cornerstone for seamless and secure financial transactions (Asante, 2018). The careful oversight and promotion of such systems by monetary authorities have been integral to fostering robust economies worldwide. However, the Nigerian payment system, deeply entrenched in cash transactions, has faced challenges in delivering the necessary levels of efficiency and effectiveness vital for sustainable economic growth. The implications of this cash-centric approach extend beyond mere convenience, encompassing security concerns, counterfeiting risks, fraud vulnerabilities, and logistical inconveniences (Central Bank of Nigeria (CBN), 2016). In response to the imperative of reducing the volume of physical cash in circulation and mitigating the associated risks, the CBN took a proactive stance by introducing electronic payment systems (Ahiakpor *et al.,* 2020). These innovative systems, including payment cards such as smart cards and various paper-based instruments, heralded a new era of financial transactions within the country. This strategic move aimed to enhance the safety and convenience of transactions while fostering the broader adoption of digital payment methods, ultimately contributing to a more secure and efficient financial ecosystem.

The introduction of electronic payment systems initiated a wave of transformative e-payment initiatives in Nigeria. Central to these efforts were the establishment of switching companies, pivotal in enabling seamless interconnectivity across various financial institutions. Additionally, innovative payment instruments like Point of Sale (POS) terminals and Automated Teller Machines (ATMs) emerged, providing consumers with convenient and secure alternatives to cash transactions. As a result, the adoption of electronic payment systems gained momentum, with noteworthy growth witnessed in the utilization of these advanced financial technologies (Salimon, 2016). Rice farming, as a critical agricultural activity in Nigeria and many other nations, plays a pivotal role in ensuring food security and supporting rural livelihoods. The integration of POS services into the Nigeria Banking sector presents a unique and underexplored opportunity to transform traditional farming practices.

The existing research has predominantly concentrated on urban retail settings, emphasizing how POS services facilitate electronic transactions, enhance inventory management, and improve overall business efficiency (Afolabi, 2016; Adepoju, 2019). These studies highlight the positive impact of POS adoption on revenue generation, customer satisfaction, and SME development, shedding light on its benefits in the commercial sector. However, despite the increased adoption of POS services in various sectors, there remains a critical gap in knowledge regarding their potential effects within rural rice farming communities. The potential challenges and barriers that may arise in the implementation of POS services within the rice farming context remain uncharted territory. Hence, the research problem at hand revolves around the absence of empirical research that delves into the effects of POS services on rice farming activities in rural communities. The lack of comprehensive studies on this subject poses a significant gap in understanding the potential benefits, challenges, and implications of integrating POS systems into traditional agricultural practices. Based on the foregoing the study aimed to the factors influencing POS utilization in rural communities and effects of POS services on rice production activities in rural communities.

## RESEARCH METHODOLOGY

The study was conducted in Niger State. The State is in the Guinea Savannah Ecological Zone of Nigeria. In terms of landmass, it is the largest state in Nigeria. It covers a total land area of 74. 244sq.km, which is about 9.3% of Nigeria's total land area (Kolapo and Adeyera, 2021). It is located within Longitude 3º30' and 7º20' East and Latitude 8º 20' and 11º30' North, with a population of about 3,950,249 (NPC, 2006) and with a growth rate of 3.2%, the State has an estimated population of 6,306,546 in 2022 (NSGIS, 2015).

Multi-stage sampling techniques were employed to select 225 respondents on which primary data were elicited from the respondent with the aid of a structured questionnaire complemented with interview schedule using kobo toolbox. Data collected were analyzed using descriptive statistics (such as mean, frequency distribution count and percentages).

**Binary probit regression model**

Explicitly it was expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 ------ \beta_{19} X_{19} + ei \quad (1)$$

Where:

Y = Level of utilization (High=1 and low=0)

$X_1$= Sex (male=1, female=0)
$X_2$=Marital status (married=1, single=0)
$X_3$= Household size (number)
$X_4$ = Age (years)
$X_5$ = Farming occupation (yes =1, if otherwise =0)
$X_6$= Farming experience (years)
$X_7$ =Education (years)
$X_8$= Farm size (hectares)
$X_9$= Extension contacts per year (number)
$X_{10}$ = Cooperative membership (number)
$X_{11}$ = Access to credit (Amount received)
$X_{12}$= Annual income (₦)
$X_{13}$ = Access to POS terminal (1 if yes and o if otherwise)
$X1_4$ = Knowledge level (Categorical variable, High 1, if otherwise 0)
$X_{15}$=Access to source of energy and power (1 if yes and 0 if otherwise)
$X_{16}$= Relative advantages (high =1, low=0)
$X_{17}$= Compellability (high =1, low=0)
$X_{18}$= Distance to POS point (Km)
$X_{19}$= Training on POS utilization (high =1, low=0)
U = Error term

**Ordinary least square regression (OLS) model**

1. Linear:

$$Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + e \quad (2)$$

2. Double logarithmic/Cobb-Douglass:

$$\ln Y = \ln\beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + \beta_{10} \ln X_{10} + \beta_{11} \ln X_{11} + \beta_{12} \ln X_{12} + e \quad (3)$$

3. Exponential

$$\ln Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + e \quad (4)$$

4. Semi-logarithmic:

$$Y = \ln\beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + \beta_{10} \ln X_{10} + \beta_{11} \ln X_{11} + \beta_{12} \ln X_{12} + e \quad (5)$$

Y = Rice output (Kg)
$X_1$= Credit received from POS (Amount received in ₦)
$X_2$= Frequency of cash withdrawal (No)
$X_3$= Frequency of payment (No)
$X_4$ = Security of transactions (number of failed POS transactions per month)
$X_5$ = Digital literacy and training (number of trainings received)

$X_6$= Utilisation of POS Services (percentage of farmers using POS services)
$X_7$ = Transaction efficiency (Time taken to complete tractions in minutes)
$X_8$= Frequency of POS Transactions (No)
$X_9$= Distance to nearest POS terminal (km)
$X_{10}$ = Cost of POS transactions (₦)
$X_{11}$ = Amount withdrawn from POS (₦);
$X_{12}$ = number of d POS services benefited (No)

## RESULTS AND DISCUSSION

### Factors influencing POS utilization in rural communities

The result of Probit regression model presented in Table 1 showed the factors that influenced the utilisation of POS services in rural communities. The model's diagnostic statistics revealed that the overall fit of the model is strong, with a Pseudo $R^2$ value of 0.3588 and an LR $chi^2$ value of 100.66, indicating that the included variables explain a significant portion of the variation in POS services utilization. The Prob > chi2 value of 0.000 further showed the model's significance; indicating that the entire model fit the study. The coefficient of marital status (1.956) was positive and statistically significant at 0.05 probability level. This suggests that being married increases the likelihood of utilising POS services in rural communities. Married individuals may have greater financial responsibilities, such as managing household expenses, which could lead respondents to use POS services more frequently for convenience and efficiency. The need to support family and manage various transactions may drive married individuals to utilise POS services. This is similar to the study of Ogbonna *et al.* (2022) who reported that married individuals were more likely to utilise financial technologies, including POS systems. The researchers attributed this trend to the increased financial responsibilities associated with marriage, such as managing household expenses, children's education, and healthcare. Married individuals often require more frequent and efficient access to financial services to meet their responsibilities, making POS services a convenient option for handling cash transfers and payments.

**Table 1: Factors influencing POS utilization in rural communities**

| Factors | Coefficient | Standard Error | z-value |
|---|---|---|---|
| **Age** | 0.0202 | 0.0168 | 1.2.0 |
| **Marital status** | 1.956 | 0.969 | 2.02** |
| **Household size** | -0.0027 | 0.0037 | -0.73 |
| **Education** | 0.3976 | 0.0894 | 4.45*** |
| **Experience** | 0.7002 | 0.2503 | 2.79*** |
| **Extension** | -2.4114 | 2.0346 | -1.19 |
| **Credit** | 2.0712 | 1.6409 | 1.26 |
| **Relative advantage** | 1.5366 | 0.4261 | 3.61*** |
| **Distance to POS stand** | -0.0296 | 0.0038 | -7.72*** |
| **Compatible with norms** | -1.4258 | 2.0857 | -0.68 |
| **Constant** | 28.8135 | 2.6732 | 10.78*** |
| **LR chi2(10)** | 100.66 | | |
| **Prob > chi2** | 0.000 | | |
| **Pseudo R2** | 0.3588 | | |
| **Log likelihood** | -89.95218 | | |

Source: Field survey, 2024

Education is another significant factor influencing POS utilization, with a positive coefficient of (0.3976) which is statistically significant at 0.01 probability level. This indicated that higher level of education significantly increases the likelihood of using POS services. Educated individuals are more likely to understand the benefits of digital financial services, feel comfortable using technology, and appreciate the convenience and security that POS services offer. Education often correlates with better financial literacy, which could explain the increased utilisation of POS services among educated individuals in rural areas. This substantiates with the study of Akinola *et al*. (2020) who reported direct relationship between education and adoption of new innovations.

Experience also plays a significant role in POS services utilization, with a positive coefficient of (0.7002) which is statistically significant at 0.01 probability level. This implies that individuals with more experience in their respective fields are more likely to use POS services. Experience may be related to better financial management skills, greater exposure to digital financial tools, and better understanding of the advantages of using POS services for transactions. Experienced individuals may have a greater need for efficient financial tools to manage their business or personal finances, leading to higher POS utilization. This is in conformity with the finding of Diop *et al*. (2022) on determinants of mobile money adoption among rural farmers in Nigeria. The study revealed that factors such as age ($P<0.01$), education level ($P<0.01$), access to mobile phones ($P<0.01$) and financial literacy ($P<0.10$) were the significant predictors of mobile money usage among farmers

The coefficient of relative advantage is also a significant predictor of POS utilization, with a positive coefficient of (1.5366) which is statistically significant at 0.01 probability level. This indicates that individuals who perceive POS services as offering a relative advantage over their previous practices are more likely to use them. Relative advantage refers to the perceived benefits of using POS services, such as convenience, speed, security, and accessibility. When individuals recognise these benefits, they are more inclined to utilise POS services. This agrees with the study of Odusanya *et al.* (2021**)** on the utilisation of financial technology services in rural Nigeria, the study found that perceived relative advantage was a significant factor influencing the utilisation of POS services. Respondents reported that the convenience, speed of transactions, and enhanced security of POS systems were major reasons they transitioned from traditional cash-based transactions to POS usage.

Distance to the nearest POS stand is a significant factor with a negative coefficient of (-0.0296) and statistically significant at 0.01 probability level. This inverse relationship suggests that as the distance to the nearest POS stand increases, the likelihood of using POS services decreases. Accessibility is a critical factor in the utilisation of POS services in rural areas, where infrastructure and transportation can be significant barriers. If a POS stand is located far from an individual's residence or place of work, the inconvenience of traveling that distance may deter them from using the service, leading to low usage. In a related study Kiplimo *et al*. (2018) reported that distance to sources of innovations had inverse relationship with it adoption.

**Effects of POS services on rice production in rural communities**

Table 2 presents the regression analysis results of the effects of POS services on rice production in rural communities across four different functional forms. Among the four models, the **Double log** model was chosen as the lead equation due to the number of significant variables which are in line with *a priori* expectation and R-squared value. The computed **R-squared value was 0.8544**. This indicates that approximately **85%** of the variation in rice production can be explained by the independent variables in the Double Log model, making it the most robust model for further discussion of the results. The model's Prob > F value of 0.0000 revealed that it was fit for the study, implying that the included variables collectively have a significant effect on rice production.

The coefficient of frequency of payments using POS services was positive (0.4701) and statistically significant at 0.01 probability level. This indicates that increased frequency of POS transactions significantly enhances rice production. The convenience and speed of POS transactions likely allow farmers to manage their resources and time more efficiently, leading to improved productivity. The ability to make frequent and timely payments using POS services facilitated smoother operations, such as timely purchase of inputs, payment for labour, and other essential activities critical for maintaining or increasing rice yields. The result of this study corroborate the study of Darlington-Akabwai *et al*. (2021) who stated that digital financial services facilitated better access to agricultural inputs and improved marketing opportunities for farmers, leading to enhanced productivity and income levels.

The security of transactions via POS services is another significant factor, with a coefficient of 0.5930 and statistically significant at 0.01 probability level. The positive relationship implies that the perceived security of POS transactions can boost rice production. Secured transactions reduce the risk of theft or loss associated with cash handling, which is particularly important in rural settings where formal banking facilities may be limited. As a result, farmers can focus more on their agricultural activities. Odusanya *et al*. (2021) reported that security of POS transaction enhances the utilization of POS services among rural farmers enhancing their productivity.

**Table 2: Effects of POS services on rice production in rural communities**

| POS services effect | Linear | Double Log | Semi Log | Exponential |
|---|---|---|---|---|
| **Transaction efficiency** | 1.3598 (0.42) | 0.4838 (3.14)*** | 0.1336 (2.89)*** | 5.2207 (0.4800) |
| **Security of transaction** | 3.7346 (1.77)* | 0.5930 (4.28)*** | 0.1233 (4.09)*** | 16.9061 (1.73)* |
| **Credit received** | 0.0002 (2.31)** | 0.1241 (2.21)** | -2.30e-06 (1.68)* | 12.6945 (3.21)*** |
| **Frequency of payment using POS** | 5.1987 (5.21)*** | 0.4701(4.97)*** | 0.0818 (5.75)*** | 27.9126 (4.20)*** |
| **Cost of POS Transaction** | -0.0126 ( -0.86) | -0.0746 (-1.92)* | -0.0003 ( -1.45) | 5.7226 (1.33) |
| **Distance to POS stand** | 0.8676 (0.75) | -0.0768 (-0.79) | 0.0182 (1.10) | -0.7852 (-0.11) |
| **No of POS services utilized** | -0.6738 (-0.54) | 0.3727 (2.12)** | 0.0298 (1.68) | -0.1349 (-0.01) |
| **Constant** | 38.8056 (1.70)* | 3.4802 (3.88)*** | 2.8994 (8.90)*** | 130.3109 (2.07)** |

| | | | | |
|---|---|---|---|---|
| **Prob > F** | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **R-squared** | 0.7798 | 0.8544 | 0.7533 | 0.6738 |
| **Adj R-squared** | 0.7534 | 0.8304 | 0.7292 | 0.6302 |

Source: Field survey, 2024, Figures in Parenthesis are t-values

Transaction efficiency also has a significant positive effect on rice production, with a coefficient of 0.4838 and statistically significant at 0.01 probability level. Efficient POS transactions save time and reduce the labour involved in financial management, allowing farmers to allocate more resources and attention to their core agricultural activities. The ease and speed of completing transactions through POS systems likely contribute to better resource allocation, enhancing overall farm productivity. Also, the amount of credit received through POS-related financial services is significant, with a coefficient of 0.1241 and significant at 0.05 probability level. Access to credit is important for respondents, enabling them to invest in necessary inputs such as seeds, fertilizers, and equipment. The ability to obtain credit through POS services provides a vital financial lifeline, supporting higher level of production leading to increased yields. Lastly, the number of POS services utilized by farmers also shows a positive and significant relationship with rice production, with a coefficient of 0.3727 and significant at 0.05 probability level. Utilizing a variety of POS services, such as checking account balances, making payments, and transferring funds, likely allows for better financial management, which in turn supports more effective farm operations and higher production level

## CONCLUSION AND RECOMMEDATIONS

Based on the findings of the study it can be conclude, marital status, education, farming experience and relative advantage were the major factors influencing POS services utilization in the study area. Also, transaction efficiency and security of transaction were the effects of POS services on rice production in rural communities while distance to POS stand had inverse relationship with utilization of POS services. Since transaction efficiency and security are highly valued by farmers, financial institutions should prioritize these aspects by ensuring that POS services are reliable, fast and secure. Upgrading the security infrastructure of POS services to protect farmers from fraud and unauthorized transactions is crucial.

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# A PRELIMINARY ASSESSMENT OF FISH BIODIVERSITY PATTERNS ACROSS SPATIAL SCALES AT BARO RIVER PORT, NIGER STATE

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## ABSTRACT
The Baro River Port ecosystem harbours significant biodiversity, comprising 28 species from 18 families and 13 orders, playing a crucial role in ecological balance and local livelihoods. This study assesses fish species composition, taxonomic diversity, and biodiversity indices across five sampling sites. The results revealed α-diversity values ranging from 13 to 22 species per site, β-diversity with the highest species turnover (13 species) between Station 1 and 4, and a γ-diversity of 28 species across the geographic spectrum. Dominant families include Cichlidae, Mochokidae, and Characidae, with notable species such as Oreochromis niloticus, Synodontis schall, and Alestes baremoze. These findings highlight considerable spatial variability in richness and taxonomic composition, underscoring the importance of preserving diverse habitats and implementing site-specific conservation strategies to ensure ecosystem resilience and sustainability.
**Keywords:** species composition, biodiversity indices, taxonomic diversity, species abundance, species turnover

## INTRODUCTION
Baro River Port, located along the Niger River in Niger State, Nigeria, is a vital economic and ecological hub (Baba and Abdulrahman, 2024). It supports regional fisheries, provides essential nutrition and livelihoods for local communities, and plays a crucial role in food security. However, its rich biodiversity faces increasing threats from anthropogenic pressures, including overfishing, pollution, and habitat degradation (Béné *et al.*, 2016). The Niger River basin, encompassing Baro Port, is home to more than 200 fish species and serves over 100 million people. This network of rivers, wetlands, and floodplains harbours diverse ecosystems, with fish populations acting as ecological indicators. Their abundance, distribution, and community composition provide insights into environmental conditions, making them critical for monitoring ecosystem health (Andersen *et al.*, 2005; Chilaka, 2023). Understanding fish biodiversity across spatial scales is essential for assessing ecosystem health and guiding conservation strategies. By analyzing α-diversity (local richness), β-diversity (species turnover), and γ-diversity (regional richness), researchers can evaluate patterns of biodiversity distribution and habitat heterogeneity. Despite its ecological importance, limited research has explored these aspects at Baro Port, leaving gaps in knowledge critical for effective habitat management (Oikonomou and Stefanidis, 2020). This study aims to fill this gap by carrying out a preliminary assessment of fish biodiversity at five sampling sites in Baro Port. Examining diversity patterns across spatial scales will provide valuable data for sustainable conservation practices and help safeguard this critical ecosystem.

# METHODOLOGY

## Study Area

The study was conducted at five sampling (landing) sites within Baro River Port, with each site representing distinct habitat conditions. These sites were carefully chosen to capture a wide range of environmental variability, including differences in water depth, flow rates, vegetation cover, and substrate types. By selecting sites with diverse characteristics, the study aimed to provide a comprehensive understanding of the fish biodiversity present across different ecological niches within the port area. This approach helps to assess how habitat heterogeneity influences fish community composition and biodiversity patterns at Baro River Port.

## Data Collection

Fish were sampled using the catch assessment of local fishermen, and species were identified taxonomically. Biodiversity indices, including α-diversity (species richness at individual sites), β-diversity (species turnover between sites), and γ-diversity (total diversity), were calculated. Fish sampling was carried out monthly in August and September 2024. Samples were collected randomly from the landing sites where fishermen deposited their catches. Each sample was assessed for classification (Reed and Agriculture, 1967; Idodo-Umeh, 2003; Babatunde and Aminu, 2004).

## Analytical Framework

identifying and counting the various fish species, using standard taxonomic keys, Species abundance data were utilized to calculate various diversity metrics, including species richness, alpha, beta, zeta and gamma diversity to provide a reasonable understanding of the community structure. These metrics were then analysed to identify ecological patterns such as species distribution, dominance relationships, and overall ecosystem health.

# RESULTS

## Taxonomic Composition

Table 1 is β-diversity matrix which revealed significant turnover, particularly between S1 and S4, and γ-diversity was calculated at 28, showcasing overall species richness in the area. Table 2 contains the taxonomic composition and biodiversity metrics of fishes at Baro River Port. A total of 28 fish species were recorded across seven orders and 15 families. Notable species include Cichlidae: *Oreochromis niloticus*, and *Coptodon zillii;* Mochokidae: *Synodontis schall*, *Synodontis nigrita;* and Characiformes: *Alestes baremoze, Brycinus macrolepidotus*. The diversity metrics calculated thereof include: α-diversity ranged from 13 (S1) to 22 (S4), indicating site-specific richness. Table 2 also showed species abundance with the highest abundance recorded for *Synodontis schall* (51 individuals at S1 and S5), and *Oreochromis niloticus* (31 individuals at S4). The study identified 28 fish species across seven taxonomic orders, representing diverse ecological groups. Key species included *Oreochromis niloticus*, *Synodontis schall* (high abundance) and *Fontitrygon garouaensis* (site-specific occurrence). Biodiversity across spatial scales revealed that α-diversity varied from 13 species at S1, to 22 species at S4, reflecting local habitat conditions. With reference to β-diversity, species turnover was highest between S1 and S4 (13 species), and lowest between S4 and S5 (5 species).

Considering γ-diversity, a total of 28 species were recorded across all sites, indicating the regional biodiversity of Baro River Port.

**Table 1: β-diversity matrix of S1 – S5 sampling sites at Baro River Port**

| SAMPLING SITE | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|
| **S1** | | | | | |
| **S2** | 8 | | | | |
| **S3** | 7 | 11 | | | |
| **S4** | 13 | 17 | 12 | | |
| **S5** | 8 | 16 | 13 | 5 | |

## DISCUSSION

The patterns in biodiversity observed, highlights the ecological significance of Baro River Port. S4 was highest in α-diversity which summarises the structure of a biotic community, identifies areas of maximum diversity, indicates a regional decline, or may reflect favourable habitat conditions (Maghsoudlou *et al.,* 2024; Quell, 2022). At the same time, species turnover between sites underscores habitat heterogeneity and stability. It is an essential factor in understanding how ecosystems respond to environmental changes (ecological succession), human activities and climate shifts, helping to reveal patterns of biodiversity and the resilience of a biological community. Species turnover has significant implications for biodiversity conservation as it highlights the consequence of maintaining diverse habitats that support various species in contemporaneous terms; these dynamics also influence the management strategies in conservation as different turnover rates may demand different management strategies (Shurin, 2007; Chaudhary and Costello, 2023). On the other hand, Zeta diversity (a metric that quantifies the extent of overlap in the taxa composition across multiple communities) supports understanding patterns in biodiversity study, assesses the contribution of individual species, relates diversity to space and can be used to scale species endemism (Hui and McGeoch, 2014; Latombe *et al*., 2017). This study showed that seven of the 28 species overlapped between the sites, which has implications for interspecific competition and ecological redundancy.

In this study, some species have shown superior abundance, which translates to dominance. In ecosystems, species are classified by their ecological roles and impacts. "Rivets" are species that collectively support ecosystem stability, akin to rivets in an airplane. "Drivers" have a significant, disproportionate impact on ecosystem functionality, while "passengers" play less influential roles. While many species contribute similarly, a few are critical for maintaining ecosystem integrity (Peterson *et al*., 1998; Vellend, 2001; Avolio *et al*., 2019; Falk *et al*., 2019). The implications of the results for habitat management are many: for effective conservation, protecting high-diversity zones such as S4 is critical for maintaining ecological stability-sustainable practices, including monitoring fishing activities, and mitigating habitat degradation to ensure long-term sustainability. Further studies are required to assess temporal changes in biodiversity and the impact of anthropogenic activities on spatial patterns of the Baro River Port.

**Table 2: Fish species composition, taxonomy and biodiversity indices of Baro River Port at five sampling sites**

| | | | | SAMPLING SITE | | | | | ζ-diversity |
|---|---|---|---|---|---|---|---|---|---|
| **ORDER** | **FAMILY** | **GENUS** | **SPECIES** | **S1** | **S2** | **S3** | **S4** | **S5** | |
| Anabantiformes | Channidae | Paranchanna | *Paranchanna africana* | | | 2 | | | |
| Characiformes | Alestidae | Alestes | *Alestes baremoze (gare)* | | | | 5 | 4 | |
| | | | *Alestes imberi* | | | | 7 | 4 | |
| | | | *Alestes nurse* | | | 3 | 3 | 8 | |
| | | Brycinus | *Brycinus macrolepidotus* | | | | 2 | 2 | |
| | | Hdrocynus | *Hdrocynus forskahlii* | | | | 3 | 1 | |
| | Citharinidae | *Citharinus* | *Citharinus citharus* | 8 | 5 | 2 | 9 | 8 | * |
| Cichliformes | Cichlidae | *Chromidotilapia* | *Chromidotilapia guntheri* | 2 | 1 | 15 | 3 | 2 | * |
| | | *Coptodon* | *Coptodon zilli* | 7 | | 8 | 17 | 7 | |
| | | *Oreochromis* | *Oreochromis niloticus* | 13 | 2 | 15 | 31 | 13 | * |
| | | *Sarotherodon* | *Sarotherodon galilaeus* | 2 | | 6 | 2 | 2 | |
| Myliobatiformes | Dasyatidae | *Fontitrygon* | *Fontitrygon garouaensis* | | 1 | | | | |
| Osteoglossiformes | Gymnarchidae | Gymnarchus | *Gymnarchus niloticus* | | | | 2 | 1 | |
| | Mormyridae | *Mormyrus* | *Mormyrus macrocephalus* | | 2 | | | | |
| | | | *Mormyrus rume* | | 8 | 1 | 3 | | |
| Polypteriformes | Polypteridae | Polypterus senegalus | *Polypterus senegalus senegalus* | | | | 2 | 2 | |
| Siluriformes | Clariidae | *Clarias* | *Clarias anguillaris* | 10 | | 5 | 2 | 10 | |
| | | | *Clarias gariepinus* | 12 | 2 | 15 | 21 | 12 | * |
| | | *Heterobranchus* | *Heterobranchus longifilis* | 2 | 1 | 14 | 18 | 2 | * |
| | Clarotidae | Clarotes | *Clarotes laticeps* | | | 10 | | | |
| | | | *Clarotes macrocephalus* | | 2 | | | | |
| | Cyprinidae | *Labeo* | *Labeo coubie* | 2 | 3 | 16 | | 2 | |
| | | | *Labeo senegalensis* | 1 | 18 | 8 | | 1 | |
| | Malapteruridae | Malapterurus | *Malapterurus electricus* | | | 1 | 1 | | |
| | Mochokidae | *Synodontis* | *Synodontis membranaceous* | 10 | 2 | | 4 | 10 | |
| | | | *Synodontis nigrita* | 32 | 15 | 18 | 13 | 32 | * |
| | | | *Synodontis schall* | 51 | 35 | 25 | 27 | 51 | * |
| | Pangasiidae | Pangasius | *Pangasius hypothalamus* | | 1 | 11 | 4 | | |
| | Schilbeidae | Schilbe | *Schilbe mystus* | | | | 4 | 3 | |
| | | | α-diversity (sites) | 13 | 15 | 18 | 22 | 21 | |
| | | | γ-diversity | | | 28 | | | |

## CONCLUSION

Baro River Port supports diverse fish populations that are vital for biodiversity conservation and fisheries. This study highlights the need for habitat-focused management to sustain ecosystem services and promote biodiversity.

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# SOME ASPECTS OF THE BIOLOGY OF SNAKE HEAD FISH (*Parachanna obscura*) GUNTHER 1861 IN CONCRETE TANKS

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**ABSTRACT**
This study examined some aspects of the biology of *Parachanna obscura* raised in concrete tanks measuring 2m x 2m x 1m, a complete randomized design was used. Two hundred (200) samples of the fish were collected from Fokpo village in Lavun Local Government Area of Niger State and used for this study. They were kept in captivity for six (6) months (between May and November, 2019) and were fed with commercial diet (*Aqualis*) and clupeids. There were variations in the sizes of *P. obscura* in the three tanks. *Parachanna obscura* in tank 1 had the highest standard length (mean = 19.14) followed by tank 3 (mean = 16.65) while the lowest was tank 2 (mean = 13.98). Total length was also highest in tank 1 (mean = 22.52) followed by tank 3 (mean = 19.60) and lowest in tank 2 (mean = 16.50). Weight also followed the trend with highest in tank 1 (mean = 89.74) and lowest in tank 2 (mean = 33.06). from other tanks. Fifty (50) fishes were kept in another tank which were used to study their biology Results of fecundity showed variations across the months of study with values ranging from 500 - 5000 with lowest number being in June and highest number in November. The fish also showed variations in the number of eggs with larger samples producing eggs than smaller ones. All the water quality parameters were within the acceptable ranges which favour fish growth and survival. The findings of the present study show that the species undergoes different stages of gonadal development, the size of fish determine the size of eggs or ovary sacs. Thus study established that there is relationship between weight and fecundity of *Parachanna obscura*. It is recommended that, other study of the biology of *P. obscura* such as food and feeding habit, age and growth be carried out, stocking density of the *P. obscura* needs to be critically studied, trials need to be carried out in bigger concrete tanks and even earthen ponds and there is need to investigate into the right feed for *P. obscura*
**Keywords:** Snake Head Fish (*Parachanna obscura*), Fecundity, Gonads, Concrete Tanks

## INTRODUCTION
Snakehead fish species constituted a significant component of catches in most freshwater bodies of Asia and Africa. Thirty-five (35) different species have been reported in Asia as against three species so far identified in Africa (CIFA, 2012). In both continents, Channidae are of considerable economic importance as food and aquarium fish. *Parachanna obscura* (Gunther) and *Parachanna africana* (Steindachner) are the two available species in West Africa (Syndenham, 1976). Snakehead culture is one of the fastest growing aquaculture industries in

Asia (Marimuthu *et al.* 2009); however, the intensive culture of snakeheads is yet to be developed in Africa. African snakehead (*P. obscura*) has long been considered as a good candidate for aquaculture (Kpogue *et al.* 2012). Successful domestication of any fish species demands a thorough knowledge of its reproductive biology (Malhotra *et al.* 1978). Studies on reproductive biology is a basic requisite for better conservation and management strategies of fishery resources (Muchlisin *et al.* 2010), for examination of basic life history and for evaluating the impacts of environmental variability on the dynamics of fish populations (Schlosser 1990).

Information on the reproductive system is also essential for the development of the commercial aquaculture of an aquatic species. For any meaningful progress to be achieved in captivity, basic information on reproductive biology of the species must be available. (Roja, 2011) stated that studies on reproduction, including the assessment of maturation cycle, size at first maturity, sex ratio, spawning periodicity, fecundity and reproductive load of a fish species, permit quantification of the reproductive capacity of individual fish which are essential for rational and sustainable management of fisheries. Although few studies on reproductive biology of *P. obscura* had been conducted in Nigeria (Odo *et al.* 2012; Isangedighi and Umoumoh 2011; Olurin and Savage 2011). There exists no such documented information on *P. obscura* raised in captivity. There is also paucity of information on stages of gonad development and histology of *P. obscura*. Hence, the study examined some aspects of the reproductive biology *P. obsucra,* and the objective was to determine size composition, fecundity and gonad development of *P. obscura* in captivity.

**MATERIALS AND METHODS**

The experiment was conducted at the old teaching and research farm on Bosso Campus, Federal University of Technology Minna, Niger State. The study was conducted fokpo, Lavun Local Government Area of Niger state on Latitude 9º11' 60.00'N and Longitude 5º35' 59.99'E. Niger state is located in the guinea savanna vegetation zone in North Central of Nigeria. *Parachanna obscura* was identified with the aid of manuals according to Idodo-Umeh (2003) and Olaosebikan and Raji (2004) based on morphometric and meristic counts parameters. The fish samples were collected from Fokpo village on tributaries of River Kaduna landing sites. The Samples were caught using drag net. The total number of fish used for the experiment was one hundred and fifty (150).


**Figure 1: Map showing fish sample site (Fokpo)**

Three concrete tanks, each measuring 2 m x 2 m x 1m, were used for this study. The ponds were drained and bottom completely washed, left to dry and then filled with freshwater. Each tank was flooded with water to a depth of 0.5 m and this depth was maintained throughout the period of experiment. Live *Parachanna obscura* were acclimatized for 48 hours and stocked in the three concrete tanks with stocking densities of 50 fish per tank. Fish samples were dissected to ascertain or identify the various food materials in the stomachs, which was to serve as guide on the kind of feed to be used during the period of study. Fifty (50) fish samples were stocked in another concrete tank, which were used to study their biology. They were fed with crushed fish meal (clupeids) twice daily for two (2) weeks. Afterwards they were fed with crushed fish mixed with 2 mm commercially formulated diet (Aqualis) twice daily for two (2) months. The feeds were later alternated on the course of feeding fish. The fish on a daily basis were fed to satiation which was indicated by non - picking of the feed. The standard length (distance from the tip of the snout to the caudal peduncle), total length (distance from the tip of the snout to the longer portion of the caudal fin) and body weight of each sample were measured and taken respectively.

Length of fish was measured in centimeters using measuring board and weights were taken in grams using sensitive electronic balance (LP 302a, LARK Model). Sampling for such measurements was done monthly between May 2019 and November 2019. Samples were dissected to determine the sex by cutting away the abdominal wall to expose the gonads, which were removed and weighed to the nearest 0.1g. Gonads were classified and described into stages I - VI based on a modified version of Ali (1999). The ripe ovaries were preserved in Gilson's fluid for two weeks (Ali, 1990), and periodically agitated to loosen the oocytes from the surrounding tissues. This was then decanted, air dried at ambient temperature and weighed in grams (g) for estimation of fecundity (Akpan *et al*., 2004). Egg weight for each sample was taken and sub-samples weighed up to 0.1g, measured into three places and the eggs in those sub - samples counted, the average of the three sub -samples was used to estimate the total number of eggs in each samples. This is in line with the method of Isangedighi, and Umoumoh (2011) according to the following formula:

$F = \frac{1}{2} (N_1 / W_1 + N_2 / W_2 + N_3 / W_3) \times TOW$

Where:

$N_1$, $N_2$ and $N_3$ = Oocyte number for each sub - sample

$W_1$, $W_2$ and $W_3$ = Weight of each sub - samples

TOW = total ovary weight

Water quality parameters were monitored monthly in concrete tanks throughout the period of the experiment. Samples were collected from each tank and used to determined total alkalinity (TA), temperature, pH (potential hydrogen ion), dissolved oxygen (DO). The analysis was carried out at Water Resources and Aquaculture, Fisheries Technology (WAFT) at Federal University of Technology Minna (FUT Minna), Niger State.Descriptive statistics was used to compute minimum, maximum values, mean and standard deviation of data collected. Analysis of variance (ANOVA) was used to test for significant difference ($p < 0.05$). New Duncan Multiple Regression Test (DMRT) was used to separate means. Special Package for Social Sciences (SPSS) Version 20 and Microsoft Office Excel 2013 were used as statistical packages.

## RESULTS AND DISCUSSION

The size composition of one hundred and fifty (150) samples of *Parachanna obscura* distributed in three concrete tanks is presented in Table 1. There were variations in the sizes of the *P. obscura* used during the study. On the overall, standard length range from 11.00 cm - 23.30 cm of mean 16.59, total length of range 13.00 cm - 27.30 cm with 19.54 as mean while the weight range between 16.56 g - 168.38 g with mean 60.51. *Parachanna obscura* in tank 1 had the highest standard length (mean = 19.14) followed by tank 3 (mean = 16.65) while the lowest was tank 2 (mean = 13.98). Total length was also highest in tank 1 (mean = 22.52) followed by tank 3 (mean = 19.60) and lowest in tank 2 (mean = 16.50). Weight also followed the trend with highest in tank 1 (mean = 89.74) and lowest in tank 2 (mean = 33.06). There were significant differences ($p > 0.05$) in standard length, total length and weight of *P. obscura* used for the study.

The description of stages of gonad maturity of *Parachanna obscura* used for the study is represented on Table 2. There are different developmental stages of gonads recorded during this study. Out of the six stages of classification, only five stages (II, III, IV, V and VI). The several of stages of gonad maturity of *Parachanna obscura* based on size used for the study is represented on Table 3. There were variations in the gonad size, total length and weight of *P. obscura*. The ripe and running ovulated stage (V) recorded highest gonad size (13.30g), total length (28.50 cm) and weight (249.09g), while early vitellogenic stage (II) recorded the lowest total length (22.70 cm) and weight (85.44g) with the exception of gonad weight being lowest in the post-ovulatory spent stage (VI) with 0.36g.

The monthly mean fecundity of *Parachanna obscura* is depicted in figure 2. There were variations in monthly fecundity of *P. obscura* used during the period of study. There was increase in mean fecundity across the month; November had the highest (5,000) followed by October (3,000) then September (1,900) while the lowest was June (500). The mean fecundity and weight of *Parachanna obscura* is depicted in figure 3. There were variations in fecundity of *P. obscura* with weight during the period of study. *Parachanna obscura* with the highest weight (235g) recorded the highest mean fecundity (5000) followed by 210.5g with 3000 as mean fecundity then 175.1g with 1900 as mean fecundity while the lowest was 68.5g with mean fecundity of 500.

**Table 1: Size composition of *Parachanna obscura* in concrete tanks**

| Parameter | Overall n = 150 | Tank 1 n= 50 | Tank 2 n = 50 | Tank 3 n = 50 |
|---|---|---|---|---|
| **Standard Length (cm)** | | | | |
| **Minimum-Maximum** | 11.00 - 23.30 | 15.90 - 23.30 | 11.00-17.50 | 14.00-20.50 |
| **Mean ± SD** | 16.59 ± 2.70 | 19.14 ± 2.06$^{a}$ | 13.98±1.39$^{c}$ | 16.65±1.55$^{b}$ |
| **Total Length (cm)** | | | | |
| **Minimum - Maximum** | 13.00 - 27.30 | 19.0 - 27.30 | 13.00 - 20.50 | 16.50 - 24.30 |
| **Mean ± SD** | 19.54 ± 3.13 | 22.52 ± 2.38$^{a}$ | 16.50 ± 1.61$^{c}$ | 19.60 ± 1.72$^{b}$ |

| | | | | |
|---|---|---|---|---|
| **Weight (g)** | | | | |
| **Minimum - Maximum** | | 41.33 - 168.38 | 15.56 - 59.82 | 24.89 - 112.87 |
| **Mean ± SD** | 15.56 - 168.38 | 89.74 ± 34.51[a] | 33.06 ± 10.02[c] | 58.72 ± 18.38[b] |
| | 60.51 ± 32.81 | | | |

**Gonad Maturity**

The description of stages of gonad maturity of *Parachanna obscura* used for the study is represented on table 2. There are different developmental stages of gonads recorded during this study. Out of the six stages of classification, only five stages (II, III, IV, V and VI), that is from developing to spent stages were observed and described.

**Table 2: Stages of gonad maturity**

| Gonad stage | Characteristic |
|---|---|
| **I (Virgin)** | - |
| **II (Developing / resting, early vitellogenic)** | The gonad is transparent and yellow in colour |
| **III (Maturing late vitellogenic)** | Yellowish orange visible oocytes, granular in appearance |
| **IV (Ripening and advance maturation)** | Clear deep orange, blood vessels very prominent, large spherical oocytes observed |
| **V (Ripe and running, ovulated)** | Pinkish to reddish yellow distended ovary with very prominent blood vessels |
| **VI (Spent, post - ovulatory)** | Flaccid few residual oocytes observed |

The various of stages of gonad maturity of *Parachanna obscura* based on size used for the study is represented on table 3. There were variations in the gonad size, total length and weight of *P. obscura*. The ripe and running ovulated stage (V) recorded highest gonad size (13.30g), total length (28.50 cm) and weight (249.09g), while early vitellogenic stage (II) recorded the lowest total length (22.70 cm) and weight (85.44g) with the exception of gonad weight being lowest in the post-ovulatory spent stage (VI) with 0.36g.

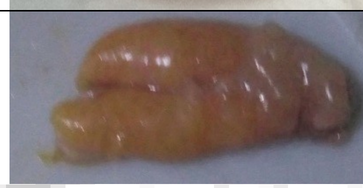
**Fecundity and weight of *Parachanna obscura* used for the study**

The mean fecundity and weight of *Parachanna obscura* is depicted on figure 3. There were variations in fecundity of *P. obscura* with weight during the period of study. *Parachanna obscura* with the highest weight (235g) recorded the highest mean fecundity (5000) followed by 210.5g with 3000 as mean fecundity then 175.1g with 1900 as mean fecundity while the lowest was 68.5g with mean fecundity of 500.2

**Fecundity of *Parachanna obscura* used for the study**

The monthly mean fecundity of *Parachanna obscura* is depicted on figure 2. There were variations in monthly fecundity of *P. obscura* used during the period of study. There was increase in mean fecundity across the month; November had the highest (5,000) followed by October (3,000) then September (1,900) while the lowest was June (500).

**Table 3: Gonads of various sizes of *Parachanna obscura* at different stages of maturity**

| Stage | Gonad | Gonad size (g) | Total Length (cm) | Weight (g) |
|---|---|---|---|---|
| II (Early vitellogenic developing state) |  | 0.56 | 22.70 | 85.44 |
| III (Late vitellogenic maturing stage) |  | 4.81 | 23.00 | 102.90 |
| IV (Ripening and maturation stage) |  | 11.27 | 25.20 | 153.00 |
| V (Ripe and running ovulated stage) |  | 13.30 | 28.50 | 249.09 |

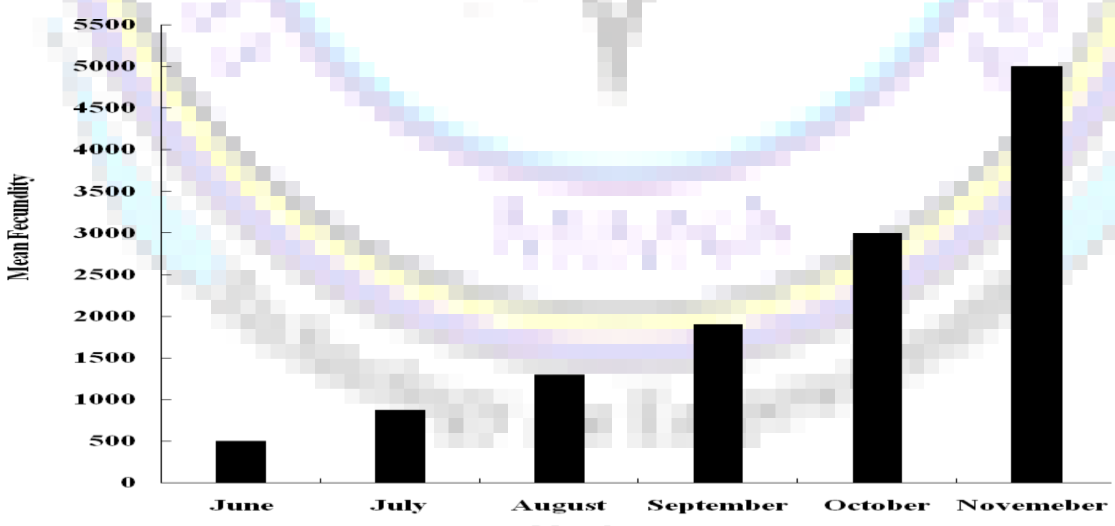


Figure 2: Monthly mean fecundity of *Parachanna obscura*

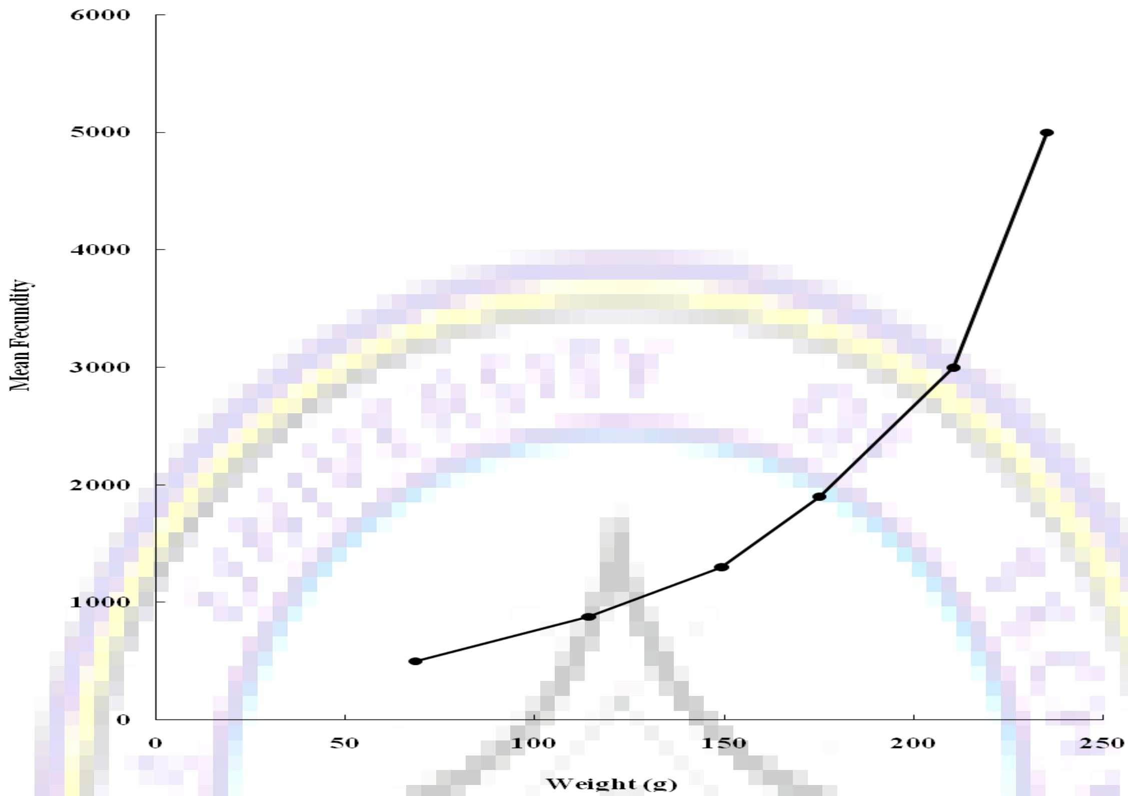



Figure 3: Mean fecundity and weight of *Parachanna obscura*

**Water quality of concrete tanks**

Table 4 shows the mean physico - chemical parameters of water in the concrete tanks used for the study. There were no significant differences ($p>0.05$) in the parameters measured. Highest pH was recorded in tank 3 (7.47) and lowest in tank 2 (7.30). Conductivity was highest in tank 1 (539.29µS/cm) and lowest in tank 3 (492.71µS/cm). Total alkalinity with highest value of 77.00 mg/l was recorded in tank 1 while the lowest was in tank 2 (72.71 mg/l). Total hardness was highest in tank 1 (111.43 mg/l) and lowest in tank 3 (107.57). $Co_2$ also follow the same trend of highest in tank 1 (3.17 mg/l) and lowest in tank 3 (3.08 mg/l). Dissolved oxygen was highest in tank 2 (7.37 mg/l) and lowest in tank 3 (7.13 mg/l)

**Table 4: Mean water quality of concrete tanks**

| Parameter | Tank 1 | Tank 2 | Tank 3 |
|---|---|---|---|
| **pH** | $7.45 \pm 0.81^a$ | $7.30 \pm 0.73^a$ | $7.47 \pm 0.59^a$ |
| **Conductivity (µS/cm)** | $539.29 \pm 111.42^a$ | $510.29 \pm 88.74^a$ | $492.71 \pm 56.72^a$ |
| **Total Alkalinity (mg/l)** | $77.00 \pm 12.95^a$ | $72.71 \pm 11.73^a$ | $74.86 \pm 12.31^a$ |
| **Total Hardness (ml/l)** | $111.43 \pm 11.98^a$ | $108.14 \pm 12.97^a$ | $107.57 \pm 21.90^a$ |
| **$Co_2$ (mg/l)** | $3.17 \pm 0.75^a$ | $3.15 \pm 0.63^a$ | $3.08 \pm 0.71^a$ |
| **Dissolved Oxygen (mg/l)** | $7.34 \pm 0.66^a$ | $7.37 \pm 0.51^a$ | $7.13 \pm 0.81^a$ |

Values in the same row with different superscript letters are significantly different ($p<0.05$) from each other

## DISCUSSION

### Sizes (length and weight) of *Parachanna obscura*

Fish size in any given water body entails the stock composition. There were variations in the sizes of *P. obscura* with standard length of 11.00 cm - 23.30 cm of mean 16.59. Konan *et al*. (2017) reported standard length of 16.20cm - 42.80cm and Osho and Usman (2019) reported mean standard length of 21.64 cm, which are greater than the findings of this study. Likewise, the weight was. Obasohan *et al*. (2012) did report mean of 106.4g, Osho and Usman (2019) with mean weight of 156.92 g, which is higher than 60.51 g recorded in this study. This implies that the sizes are small compared to the findings of these authors. This could be due to location difference, season or time of the year and nature of the environment amongst others. There were variations also in the sizes of *P. obscura* in the tanks, where tank 1 with the highest total length (mean = 22.52 cm) and weight (mean = 89.74g) differ significantly ($p>0.05$) from other tanks. This implies that different sizes were collected and used for this study. Additionally, it is always a common observation in water bodies that fish species differ in length and weight.

### Fecundity and Gonad Development of *Parachanna obscura* in relation to Size

Fecundity is very important in fisheries because it determines the reproductive viability or potentials of fish species. *P. obscura* exhibited wide variations in number of eggs across months with range 500 - 5,000, the highest number was November (5,000) and lowest in June (500). Olurin and Savage (2011) reported a range of 1,711 to 4,000 eggs for *P. obscura* weighing between 161.94 and 380.78 g from the Oshun River, Southwest Nigeria in August 2006 to February 2007. This trend across months or variations could be due to gonad development, environmental changes and availability of food or level of maturity of fish available during the period.

*Parachanna obscura* also showed variations in the number of eggs, with larger samples producing more eggs than smaller ones. This implies that fish with the highest weight recorded the highest number of eggs. This is similar to the findings of Osho and Usman (2019) that reported larger samples of *P. obscura* to have produced more eggs than the smaller ones, although highest number of eggs was not found in the largest fish and the lowest number of eggs was not found in the smallest fish. Different species of fish according to Murua *et al*. (2003) present a lot of differences in their reproductive potential. Also, variations in fecundity depend on the reproductive characteristics of species, environmental condition changes such as food availability, temperature, predation intensity and habitat amongst others. Similarly, Mekkawy and Hassan (2011) associated changes in fecundity with age, sex, size weight, gonad weight and locality. This could be the reason for such observation.

Gonad development in terms of size and maturity observed during this study is related to fish size. In other words, as the fish increase in size so also the gonad size. This is to allow more space for the gonads to be accommodated. This is in line with the findings of Chatzifotis *et al*. (2004) *cited in* Kareem *et al*., 2019) that reported a greater portion of the fish body is reserved for gonad accommodation. The total length and weight of 25.20 cm and 153.00g respectively observed at stage IV, total length and weight of 28.50 cm and 249.09 g at stage V indicated the stage at which the fish is matured. Odo *et al*. (2012) reported 24.70 cm as length at first maturity for both sexes while Kareem *et al*. (2019) reported mean lengths of 26.50 cm and 25.40 cm of male and female. This slight variation could be due the nature of the environment, availability of food amongst others.

**Water quality of the experimental concrete tanks**

The water quality parameters were not significantly different ($p>0.05$) from each other throughout the experimental period. The pH known as hydrogen ion concentration is an important property that determines the quality of water. Boyd (1990) reported optimum pH for fish to fall between 6.5 and 9.0. Also, pH range of 6.5 - 8.2 is suitable for aquatic life according to Murdock *et al*. (2002). The values reported for the tanks, which is alkaline fall within the recommended values for fish production. Dissolved oxygen is also an important parameter because it regulates metabolic process of aquatic communities and could be taken as an indicator of water conditions for their potential. The values recorded in the concrete tanks were greater than 4mg/l - 5mg/l according to Bellingham (2012) is suitable for sustaining fish and other aquatic life. Nevertheless, fish species have different dissolved oxygen requirements (Boyd, 1990). Dissolved oxygen less than 2 mg/l kills fish. Therefore, the values recorded in the tanks could sustain fish life. Total hardness is an important parameter of water quality. It is attributed to the presence of alkaline earths ions in water. Soft water contained 75 mg/l hardness, moderately hard at 75-150 mg/l), hard water at 150-300 mg/l and very hard water at 300 mg/l). The values recorded during this study implies that the water in the concrete tanks are moderately hard, which is also good for fish production. Likewise, conductivity, carbon (IV) oxide and alkalinity recorded in the tanks did not have any negative effects on the fish

## CONCLUSION AND RECOMMENDATIONS

The study elucidated some aspects of biology and survival of snake head *Parachanna obscura* in concrete tanks as a way to initiate its culture in captivity. There were various sizes of *P. obscura*, which significantly differ ($p>0.05$) in the concrete tanks. Mean fecundity of *P. obscura* increased across months with peak in November. There is relationship between weight and fecundity because *P. obscura* with highest weight had highest fecundity. Water quality parameters measured were within the acceptable limit for fish production. Other aspects of the biology of *P. obscura*, such as food and feeding habit, age and growth should be carried out. Stocking density of the *P. obscura* need to be critically studied. Trials need to be carried out in bigger concrete tanks and even earthen ponds. There is need to investigate into the right feed for *P. obscura.*

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# EVALUATION OF BODY MASS INDEX AND OXIDATIVE STRESS RESPONSES IN PERIPARTURIENT NIGERIAN SHEEP DURING COLD-DRY SEASON

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## ABSTRACT
The study investigated body mass index and oxidative stress responses by periparturient Yankasa, Uda, and Balami to the cold-dry (harmattan) season. Twenty-one ewes consisting of seven ewes for each breed were used. The body mass index (BMI), Oxidative stress biomarkers of malondialdehyde (MDA), superoxide dismutase (SOD), catalase, and glutathione peroxidase, were determined at prepartum weeks 2 and 1, and postpartum weeks 1 and 2. The lowest BMI was obtained in Yankasa ewes (2.83 ± 0.09) compared to Uda and Balami ewes (4.16 ± 0.41 and 4.05 ± 0.35, respectively). Concentrations of MDA at prepartum (67.44 ± 5.17 IU/mL vs 46.36 ± 2.53 IU/mL) and postpartum (70.50 ± 4.67 IU/mL vs 38.32 ± 3.97 IU/mL) periods in Yankasa ewes were higher ($P < 0.05$) than those of Balami ewes. The least ($P < 0.05$) SOD activity was recorded in Yankasa ewes (6.63 ± 0.03 IU/mL) compared to Uda and Balami ewes during prepartum week 1 (6.89 ± 0.05 IU/mL and 6.90 ± 0.05 IU/mL, respectively). In conclusion, Yankasa ewes had the least energy reserve as indicated by BMI compared to Uda and Balami ewes, the highest oxidative stress occurred in Yankasa ewes as evidenced by the higher MDA concentration and lowest SOD and catalase activities, indicating that they were stressed during the cold-dry season compared to other breeds.
**Keywords**: Body mass index, Cold-dry, Oxidative stress, Periparturient, Breed of sheep,

## INTRODUCTION
Nigerian sheep undergo a crucial physiological phase during the periparturient period, which can be further strained by the thermally challenging cold-dry season. This period is marked by significant hormonal and metabolic changes that affect the sheep's energy reserves and oxidative status. Body mass index (BMI) has been adapted as a useful indirect measure of fat reserves in domestic animals (Liu *et al*., 2019) and correlates closely with energy stores in sheep, making it a valuable predictor of energy reserves in mature Pelibuey ewes. Additionally, studies have linked BMI to hormone levels associated with energy and reproductive activity in goats (Tesema *et al*., 2023). Evaluating oxidative stress is essential in assessing the health and productivity of

ruminants as complementary tools in the evaluation of the nutritional and metabolic status of the animals (Yaqub *et al.,* 2021). Oxidative stress, arising from an imbalance between reactive oxygen species (ROS) production and antioxidants, contributes to reproductive and metabolic disorders in livestock. During the periparturient period, increased metabolic demands combined with thermal environmental stressors, such as cold and dry conditions, may further intensify oxidative stress in sheep (Ighodaro and Akinloye, 2018). Oxidative stress occurs during the periparturient period and cold-dry season can negatively impact Nigerian sheep. While much research on tropical livestock welfare has focused on heat stress, that of cold stress has been poorly investigated. Evaluating sheep during the periparturient period in the cold-dry season can reveal insights into the capacity of their antioxidant defence systems to cope with combined periparturient and cold stress.

## MATERIALS AND METHODS

### Experimental Site and Ethical Approval

This experiment was approved by the Animal Use and Welfare Committee at Ahmadu Bello University, Zaria, Nigeria, with approval number ABUCAUC/2023/081. The experiment was carried out at the Small Ruminant Research Unit of the National Animal Production Research Institute, Ahmadu Bello University, Shika-Zaria. The research site is located at 11˚ 12′ N and 7˚ 33′ E in Nigeria's Northern Guinea Savannah. Ewes were housed in ventilated pens with natural 12-hour light- 12-hour dark cycles.

### Experimental Animals, Design, and Management

This research was carried out between December 2021 to February 2022, during the cold-dry (harmattan) season. Twenty-one healthy ewes, consisting of 7 Yankasa, 7 Uda, and 7 Balami ewes were used for the study. Each aged between 2 to 3 years with a mean average body weight of 40.821 ± 2.419 kg. The ewes were grazed on natural pasture during the day and were supplemented with *Digitaria smutsii* hay and a concentrate mix (20% ground maize, 30% cotton seed cake, 40% wheat offal, 5% bone meal, and 5% table salt) at 3% of their body weight daily. They had unlimited access to water.

### Determination of Body Mass Index (BMI)

The morphometric parameters of abdominal circumference, withers' height, and body length were measured in each ewe using a tailor tape (Iqbal *et al.,* 2014). The morphometric parameters were used to determine the body mass index (BMI) according to the formula described by Tanaka *et al*. (2003);

Body mass index (BMI) = Body weight (kg)/{Withers height (m)/Body length (m) x 10}

### Blood Sample Collection

Five millilitres of blood was collected weekly via jugular venipuncture during the periparturient period. Blood was stored in plain test tubes, centrifuged at 3,000 x g for 10 minutes to obtain serum, and stored at -20°C for analysis. Serum samples were processed in the Department of Veterinary Physiology, Ahmadu Bello University, Zaria.

### Determination of Oxidative Stress Biomarkers

Oxidative stress biomarkers of Malondialdehyde, Superoxide dismutase, Glutathione Peroxidase, and Catalase were assayed from the serum samples (Abebi 1974; Ohkawa *et al*., 1979).

## RESULTS

### Changes in meteorological parameters during the study period

The highest mean ambient temperature (AT) occurred in the evening, with a temperature-humidity index (THI) also peaking during this time compared to the morning (AT: 28.50 ± 0.76 °C vs. 17.33 ± 0.33 °C; THI: 60.37 ± 0.67 vs. 48.18 ± 0.63). Although relative humidity (RH) was slightly lower in the evening compared to the morning, (Figure 1).

### Changes in malondialdehyde and antioxidant enzymes in Periparturient Nigerian Ewes

The highest mean (± SEM) MDA concentration was recorded in Yankasa ewes at prepartum week 2, which was significantly higher compared to Balami ewes (67.44 ± 5.17 µmol/mL vs. 46.36 ± 2.53 µmol/mL). Similarly, Yankasa ewes showed significantly higher MDA concentrations at postpartum week 2 than Uda and Balami ewes (70.5 ± 4.67 µmol/mL vs. 59.26 ± 4.70 µmol/mL vs. 38.32 ± 3.97 µmol/mL, $P < 0.001$). (Table 1). Balami ewes displayed the highest mean catalase activity in the prepartum week 1, while Uda ewes recorded the lowest in postpartum week 1. Yankasa and Uda ewes exhibited a gradual reduction in mean catalase activity from prepartum week 2 through to postpartum week 2. (Table 2). The highest mean SOD activity (± SEM) was observed in Balami ewes during postpartum week 2, while the lowest levels were seen in Yankasa ewes at postpartum week 1. The lowest SOD values across all periparturient stages were observed in Yankasa ewes, with significant differences ($P < 0.001$) at prepartum week 1 compared to Uda and Balami ewes (Table 3).

## DISCUSSION

Balami and Uda ewes had a significantly higher body mass index (BMI) than Yankasa ewes, suggesting that Balami and Uda ewes maintain greater energy reserves, potentially better supporting the demands of gestation compared to Yankasa ewes. The gradual BMI decline up to postpartum week 1 in Balami and Uda ewes reflects the high metabolic requirements of this reproductive phase, particularly during gestation and lactation (Swali and Wathes, 2007; Tekin *et al.*, 2023). However, Yankasa Ewes's BMI continued to decline up to postpartum week 2, which suggests they may be at a higher risk for postpartum metabolic diseases like pregnancy toxaemia if nutritional support is inadequate. The highest concentrations of malondialdehyde (MDA), a marker of oxidative stress, occurred in Yankasa and Balami ewes at prepartum week 2, while Uda ewes showed a decrease from prepartum week 1 to week 2. Elevated MDA levels in late pregnancy may reflect a depletion of non-enzymatic antioxidants (Mohebbi-Fani *et al.*, 2012). In line with Bernabucci *et al*. (2005) and Bouwstra *et al*. (2008), higher MDA levels during prepartum likely indicate increased lipid peroxidation linked to fetal development and the onset of lactation.

In this study, superoxide dismutase (SOD) activity was lowest in Yankasa ewes in prepartum week 1 compared to Balami and Uda ewes, with Yankasa ewes also displaying lower overall catalase activity. This decline in antioxidants may reflect either genetic differences or an increased energy requirement in Yankasa ewes. Higher energy mobilisation correlates with elevated reactive oxygen species (ROS) production, thus depleting antioxidants as they are used to counteract free radicals.

Antioxidants like SOD, catalase, and glutathione peroxidase (GPx) defend tissues against free radicals, transforming superoxide ions into less harmful molecules (Aurousseau *et al*., 2006). In this study, catalase and GPx activities were lowest in prepartum week 1in all the breeds. The decrease in activities of the two antioxidant enzymes and rise in MDA concentration during this period could be an outcome of a rise in radical scavenging activity by the endogenous antioxidant enzymes. This rise, apparently, resulted from a combined effect of ROS generation by pregnancy and cold stress, during the study period.

## CONCLUSION

Yankasa ewes had the least energy reserve as indicated by BMI compared to Uda and Balami ewes, the highest oxidative stress occurred in Yankasa ewes as evidenced by the higher MDA concentration and lowest SOD and catalase activities, indicating that they were stressed during the cold-dry season compared to other breeds. Alleviating stress and energy augmentation measures should be adopted to reduce negative effects of oxidative stress in Yankasa ewes during the cold-dry season.

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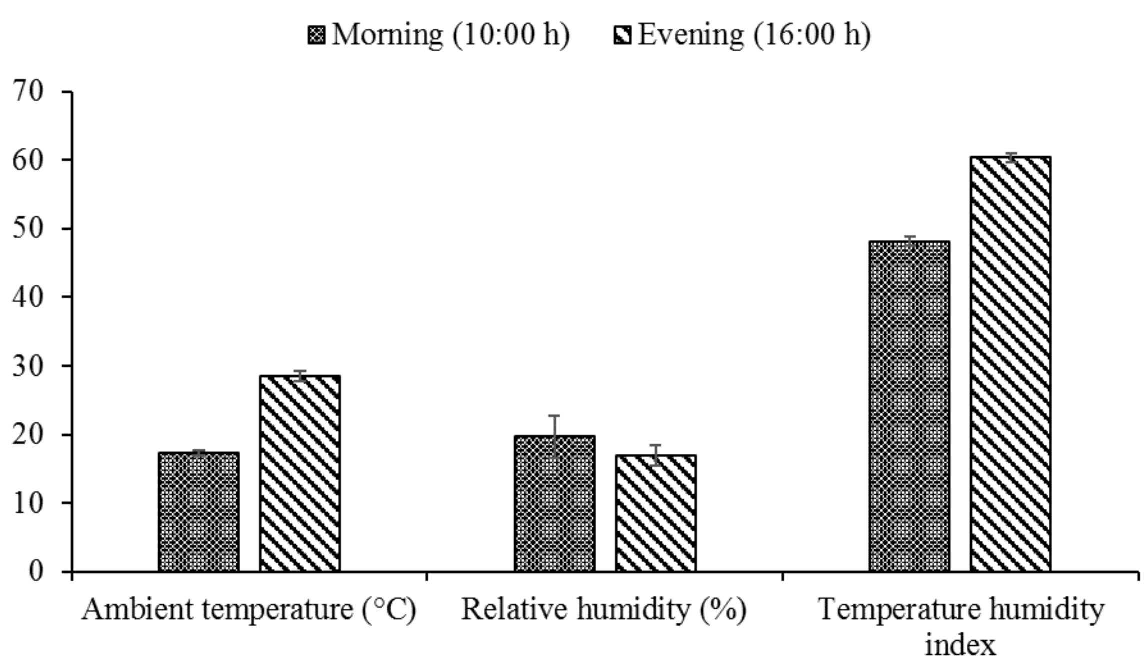


Bars with different superscript letters (a, b) are significantly ($P < 0.0001$) different.

**Figure. 1** Fluctuations in thermal environmental parameters in the morning and late afternoon hours

**Table 1: Mean (±SEM) malondialdehyde concentration (µmol/mL) in periparturient Nigerian sheep during the cold-dry season**

| Periparturient period | Yankasa | Uda | Balami |
|---|---|---|---|
| **Prepartum:** | | | |
| Week 2 | 67.44 ± 5.17[a] (48.49 - 85.33) | 51.98 ± 2.07[a] (41.74 - 58.02) | 46.36 ± 2.53[b] (35.47 - 54.7) |
| Week 1 | 48.57 ± 6.74 (23.41 - 80.43) | 57.20 ± 7.83 (22.44 - 82.13) | 38.55 ± 5.61 (25.86 71.11) |
| Mean | 58.01 ± 6.00 (23.41 – 85.33) | 54.59 ± 4.95 (22.44 – 82.13) | 42.46 ± 4.07 (25.86 – 71.11) |
| **Postpartum:** | | | |
| Week 1 | 52.92 ± 7.84 (18.96 - 83.15) | 61.93 ± 6.01 (39.89 - 85.71) | 40.48 ± 5.58 (21.25 - 60.50) |
| Week 2 | 70.50 ± 4.67[a] (52.95 - 85.49) | 59.26 ± 4.70[a] (40.49 - 74.41) | 38.32 ± 3.97[b] (22.96 - 53.46) |
| Mean | 61.71 ± 6.26 (18.96 – 85.49) | 60.60 ± 5.36 (39.89 – 85.71) | 39.40 ± 4.80 (21.25 – 60.50) |

ab: Mean with different superscript letters between columns are significantly different (P < 0.05)

**Table 2: Mean (±SEM) catalase (IU/mL) activity in periparturient Nigerian sheep during the cold-dry season**

| Periparturient period | Yankasa | Uda | Balami |
|---|---|---|---|
| **Prepartum:** | | | |
| Week 2 | 17.77 ± 2.28 (12.20 - 27.32) | 21.74 ± 4.22 (8.71 - 35.37) | 17.91 ± 2.35 (12.07 - 30.98) |
| Week 1 | 14.50 ± 0.72 (12.44 - 18.54) | 19.86 ± 2.15 (11.95 - 26.34) | 23.96 ± 4.10 (5.61 - 36.61) |
| Mean | 16.14 ± 1.50 (12.20 – 27.32) | 20.80 ± 3.19 (8.71 – 35.37) | 20.94 ± 3.30 (5.61 – 36.61) |
| **Postpartum:** | | | |
| Week 1 | 14.18 ± 1.58 (10.49 - 22.20) | 12.71 ± 3.26 (7.32 - 31.95) | 17.14 ± 3.58 (7.07 - 36.10) |
| Week 2 | 14.70 ± 1.16 (10.24 - 20.49) | 13.52 ± 1.25 (8.78 - 18.54) | 20.63 ± 2.96 (14.39 - 32.44) |
| Mean | 14.44 ± 1.37 (10.21 – 22.20) | 13.12 ± 2.26 (7.32 – 31.95) | 18.89 ± 3.27 (7.07 – 36.10) |

**Table 3: Mean (±SEM) Superoxide dismutase (IU/L) activity in periparturient Nigerian sheep during the cold-dry season**

| Periparturient period | Yankasa | Uda | Balami |
|---|---|---|---|
| **Prepartum:** | | | |
| Week 2 | 6.64 ± 0.07 (6.36 - 6.97) | 6.76 ± 0.23 (5.45 - 7.20) | 6.72 ± 0.11 (6.29 - 7.12) |
| Week 1 | 6.63 ± 0.03[a] (6.52 - 6.74) | 6.89 ± 0.05[b] (6.74 - 7.05) | 6.90 ± 0.05[b] (6.74 - 7.12) |
| Mean | 6.64 ± 0.05 (6.36 – 6.97) | 6.82 ± 0.14 (5.45 – 7.20) | 6.81 ± 0.08 (6.29 – 7.12) |
| **Postpartum:** | | | |
| Week 1 | 6.61 ± 0.07 (6.21 - 6.82) | 6.70 ± 0.07 (6.44 - 6.89) | 6.80 ± 0.07 (6.52 - 7.05) |
| Week 2 | 6.62 ± 0.16 (5.83 – 7.12) | 6.52 ± 0.11 (6.06 - 6.82) | 7.81 ± 1.13 (6.36 - 14.55) |
| Mean | 6.62 ± 0.12 (5.83 – 7.12) | 6.61 ± 0.09 (6.06 – 6.89) | 7.31 ± 0.60 (6.52 – 14.55) |

ab: Mean with different superscript letters between columns are significantly different ($p<0.05$)

**Table 4: Mean (±SEM) glutathione peroxidase (IU/mL) activity in periparturient Nigerian sheep during the cold-dry season**

| Periparturient period | Yankasa | Uda | Balami |
|---|---|---|---|
| **Prepartum:** | | | |
| Week 2 | 0.28 ± 0.06 (0.10 - 0.53) | 0.16 ± 0.03 (0.08 - 0.31) | 0.29 ± 0.05 (0.12 - 0.50) |
| Week 1 | 0.24 ± 0.04 (0.10 - 0.42) | 0.22 ± 0.03 (0.13 - 0.34) | 0.19 ± 0.03 (0.12 - 0.34) |
| Maen | 0.26 ± 0.05 (0.10 – 0.53) | 0.10 ± 0.03 (0.08 – 0.34) | 0.24 ± 0.04 (0.12 – 0.50) |
| **Postpartum:** | | | |
| Week 1 | 0.36 ± 0.07 (0.12 - 0.64) | 0.32 ± 0.08 (0.09 - 0.52) | 0.19 ± 0.03 (0.09 - 0.34) |
| Week 2 | 0.29 ± 0.05 (0.15 - 0.56) | 0.22 ± 0.06 (0.10 - 0.50) | 0.29 ± 0.06 (0.09 - 0.45) |

| | | | |
|---|---|---|---|
| Mean | 0.33 ± 0.06 (0.12 – 0.64) | 0.27 ± 0.07 (0.10 – 0.52) | 0.24 ± 0.05 (0.09 – 0.45) |

# HARNESSING PHYTOBIOTICS TO COMBAT ANTIMICROBIAL RESISTANCE IN NIGERIAN POULTRY PRODUCTION: A REVIEW

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## ABSTRACT
Local poultry production in Nigeria, a key contributor to food security and economic growth, faces serious food safety challenges due to inadequate biosecurity, high antimicrobial usage (AMU), and antimicrobial resistance (AMR). Despite the sector's crucial role in supplying poultry meat and eggs, overuse of antibiotics in small-scale poultry farms, often without veterinary guidance, has driven the rise of AMR, threatening public health through the transmission of resistant bacteria. This review highlights AMR in Nigerian poultry, noting high AMU, particularly of critical antimicrobials, among farmers with low awareness of proper usage. As an alternative, plant-based solutions, such as phytobiotics, are explored for their antimicrobial, growth-promoting, and immune-boosting effects in poultry. Indigenous Nigerian plants—including neem (*Azadirachta indica*), moringa (*Moringa oleifera*), aloe vera (*Aloe barbadensis*), lemongrass (*Cymbopogon citratus*), scent leaf (*Ocimum gratissimum*), bitter leaf (*Vernonia amygdalina*), and papaya (*Carica papaya*) demonstrate promising antibacterial effects, making them potential substitutes for antibiotics in local poultry systems. Integrating these sustainable alternatives can mitigate AMR, enhancing food safety and supporting public health in Nigeria's poultry sector.
**Keywords:** Poultry production, antimicrobial resistance (AMR), Phytobiotics, Food safety, Antibiotics alternatives.

## OVERVIEW OF FOOD SAFETY CHALLENGES IN LOCAL POULTRY PRODUCTION
Poultry farming is a significant sector in Nigeria, contributing to food security, employment, and economic growth. Local poultry production, particularly in household or small-scale settings, plays a vital role in food security and economic stability in many communities. However, it presents significant food safety challenges that can impact both producers and consumers. These challenges arise from various factors, including biosecurity practices, pathogen management, and consumer handling practices. With an estimated 180 million birds, Nigeria produces

about 300,000 metric tonnes of poultry meat and 650,000 metric tonnes of eggs annually, 30 % of which are produced by local poultry farms, with many engaged in small-scale operations. This involvement represents approximately 42% of the country's population participating in various aspects of poultry production. Approximately 85% of poultry farmers operate on a small scale, with 44% of chickens raised in extensive (backyard) systems (*Poultry Production in Nigeria*, CSIRO.au, 2017) and Nnodim, 2021). The overuse of antibiotics in Nigerian poultry farming is widespread, often employed for growth promotion, disease prevention, and treatment without proper veterinary guidance. A study indicated that about 80% of farmers used antibiotics without laboratory diagnoses or prescriptions (Saraiva *et al*., 2021)

**Antibiotic Use and Antimicrobial Resistance in Nigerian Poultry Farming**

High antimicrobial usage (AMU) has been documented across various poultry farms in Nigeria, with reports showing that farms used critically important antimicrobials at alarming rates. For example, broiler farms were found to have significantly higher AMU compared to layer farms due to practices aimed at promoting growth and feed efficiency (Azizi *et al*., 2024)

Key issues contributing to antimicrobial resistance (AMR) include farmers' lack of awareness about responsible antimicrobial use (AMU), inadequate biosecurity practices that heighten disease risk, and easy access to antibiotics without veterinary prescriptions, leading to misuse. The study by Alhaji *et al*. (2018) on antimicrobial use (AMU) and antimicrobial resistance (AMR) in North-central Nigeria revealed critical gaps in awareness and practices among 384 poultry farmers. Only 46.4% of commercial poultry farmers and 6.8% of local bird keepers recognized under-dosing antimicrobials as misuse, while 48% of farmers and 93% of keepers set dosages arbitrarily. Antimicrobial use (AMU) was common for therapeutic, preventive, and growth purposes, with 88.5% of small-scale farms categorized as high-risk for AMR due to frequent AMU without veterinary input, while 92.1% of local bird flocks posed minimal risk due to rare antimicrobial use. Factors like inadequate regulation and poor financial status influenced misuse. In another study by Bamidele *et al*., (2022) on antibiotic resistance (AR) in Nigerian smallholder poultry found high AR levels, especially in *Salmonella* (57.5%) and *E. coli* (34.2%). Antibiotic use raised bacterial prevalence with 30% of isolates showing multi-drug resistance.

**Public Health Implications of AMR in Poultry Farming**

The transmission of AMR bacteria from poultry products to humans through consumption represents a significant public health threat. The WHO has identified AMR as one of the top ten global public health threats facing humanity today (Tang *et al*., 2023). In Nigeria, the increasing prevalence of antibiotic-resistant infections complicates treatment options for both animal and human health conditions, leading to higher healthcare costs and increased morbidity.

**Phytobiotics as Alternatives to Antibiotics in Poultry Farming**

As the demand for sustainable agricultural practices increases, there is a growing interest in exploring plant-based solutions as alternatives to conventional antibiotics. Phytobiotics, also known as phytogenics or botanicals, are natural products derived from plants that possess bioactive properties beneficial for animal health. These include essential oils, herbs, and other plant extracts that can enhance growth performance, improve feed efficiency, and boost immunity in poultry. The exploration of plant-based solutions such as phytobiotics offers a promising avenue for reducing AMR emergence in poultry farming (Reddy *et al*., 2022). By improving growth performance, boosting immunity, and enhancing overall health without relying on antibiotics, these natural alternatives align with the global push for sustainable agricultural practices. Continued research into effective formulations, regulatory acceptance, and farmer education will be vital for integrating these solutions into mainstream poultry production systems, ultimately contributing to safer food systems and improved public health outcomes.

Exploring Nigerian indigenous plants as natural antibiotics and immune boosters in poultry farming can reduce antibiotic use, combat antimicrobial resistance, and enhance food safety and public health.

**Table 1: Nigerian Indigenous Plant and their studied antibiotic Potential and Effectiveness**

| **Plants** | **Antimicrobial Effects** | **Mode of Administration** | **Poultry Disease studied on** | **Authors (Original Studies)** |
|---|---|---|---|---|
| Neem leaves *(Azadirachta indica*) | Antibacterial, (proven to be effective against gentamycin) Antiviral and Anti-body production effects Neem improved growth and reduced bacteria with lowest mortality shown in the neem group treatments. | Feed Additives, Administered through drinking water | Newcastle disease, Avian Influenza (Bird Flu), Coccidiosis, Infectious Bursal Disease, Salmonellosis | Ali *et al*. (2021), Aiyedun *et al*. (2020), Akhter and Sarker. (2019), Beg *et al*. (2019), Zahid *et al*. (2013**)** |
| Moringa *(Moringa oleifera)* | Antibacterial, Growth-Promoting, Antioxidant, And Immune-Boosting effects | Feed additive | New Castle disease, Coccidiosis, | Olorungbohunmi, (2022), Tolba *et al.* (2022**)**, Allam *et al.* (2016), Ola-Fadunsin and Ademola (2013) |
| Aloe Vera *(Aloe barbadensis)* | Antibacterial, Hypocholesterolemic effects and Immune boosting effects | Administered through drinking water | Avian Influenza (Bird Flu), Newcastle Disease Coccidiosis. | Ebanga *et al*. (2024**)**, Hassan *et al*. (2024**)**, Quaye *et al*. (2023**)**, Kumari (2016**)** |
| Lemon Grass *(Cymbopogon citratus)* | Antibacterial, Growth-Promoting, Antioxidant, And Immune-Boosting effects | Administered through drinking water and as feed additive | Salmonellosis | Tiwari *et al.* (2018), Peichel *et al*. (2019), Yasir *et al.* (2020) |
| African Basil *(Ocimum gratissimum)* | Antibacterial effects, Immune boosting effects and Growth promoting effects | Administered through drinking water | Salmonellosis, Clostridium | Ouattara-Soro *et al.* (2023), Akpan *et al.* (2019) |
| Bitter leaf (*Vernonia amygdalina*) | Antimicrobial effects, Growth promoting effect, Improved feed conversion ratio. | Administered through drinking water and Feed additive | Salmonellosis, Coccidiosis | Ebanga *et al*. (2024**)**, Mafimidiwo *et al*. (2024**)**, Mandey *et al*. (2022), Banjoko *et al*. (2018**)** |
| Paw Paw Leaves (*Carica papaya)* | Antibacterial effects, Growth promoting effects | Feed additive/Dietary feed supplement | Coccidiosis, Eschericia coli | Hema *et al*. (2015), Omidiwura, (2017), Banjoko *et al*. (2020) |

**Author's Categorization**

**Conclusion and Recommendation**

Nigeria's local poultry production, particularly the widespread and often unsupervised use of antibiotics, contributes to the growing problem of antimicrobial resistance (AMR). Overuse of antibiotics in small-scale farms poses serious risks to both animal and human health, as resistant strains can be transmitted through poultry products. Furthermore, inadequate biosecurity practices, lack of farmer education, and insufficient regulation exacerbate these issues. However, plant-based alternatives like phytobiotics, derived from indigenous plants offer promising solutions. These plants have shown antimicrobial properties that can improve poultry health, immunity, and growth while reducing the need for antibiotics, aligning with the global push for sustainable, antibiotic-free farming practices.
The review recommends promoting research into the efficacy of phytobiotics and encouraging their integration into poultry farming systems. Farmer education programs are crucial to raise awareness about the dangers of antibiotic misuse and the benefits of plant-based alternatives. Additionally, strengthening regulations on antibiotic use, enhancing AMR surveillance, and fostering collaboration among researchers, policymakers, and the poultry industry are essential steps. Adopting these strategies will help reduce AMR in poultry farming, improve food safety, and support more sustainable agricultural practices, ultimately contributing to better public health outcomes and a safer food supply chain in Nigeria.

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# INFLUENCE OF DIETARY SUPPLEMENTATION OF ZINC AND SELENIUM NANOPARTICLES ON SENSORY ATTRIBUTE AND SELECTED MEAT QUALITY CHARACTERISTICS OF BROILER CHICKENS

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## ABSTRACT
The study was conducted to evaluate the effect of zinc and selenium nanoparticles supplementation on meat quality characteristics of broiler chickens. A total of 320 day-old Arbor acre broiler chicks were randomly allotted to sixteen treatments consisting of four replicates with five birds per replicate in a 4 × 4 factorial arrangements in a completely randomized design for 7 weeks. The zinc and selenium nanoparticles were produced by the biosynthetic method. The broiler chicks were reared on deep litter and fed basal diets supplemented with four levels of nano zinc (20, 30, 40 and 50 mg/kg NZn) and four levels of nano selenium (0.10, 0.15, 0.20 and 0.25 mg/kg NSe), respectively. Feed and water were provided ad libitum. On day 49, Two birds were randomly selected from each replicate, euthanized and dressed for evaluation of the carcass traits. All data generated were subjected to a two-way analysis of variance using the general linear model procedures of the Statistical Package for Social Science (SPSS). Results indicated that meat juiciness, aroma, tenderness and overall acceptability, as well as drip-loss, cooking loss and meat pH at 24 hours were enhanced without compromising the health status of the birds.

**Key words:** Nano Zinc, Supplementation, carcass characteristics, meat quality and Broiler chickens

## INTRODUCTION
Trace elements like zinc and selenium are essential nutrients in the production of broiler chickens for high meat quality and productivity (Haiam *et al*., 2020). Zinc (Zn) is necessary for proper physiology of the animal body, it plays crucial roles as co-factor of more than 300

enzymes, structural and regulatory functions in antioxidant and immune system, nucleic acid synthesis, cell proliferation, protein synthesis, protein and carbohydrate metabolism, and enzymatic activities in the living system (Fayiz *et al*., 2021). National Research Council (NRC,1994) recommended 30 mg of Zn/Kg and 0.15 mg of Se/Kg for broiler chickens respectively. This might not be adequate to support maximum performance as reported by Du *et al*. (2007). In addition, Glutathione peroxidase is a Se-dependent enzyme involved in the antioxidant system; it is the main enzyme which helps to control free radical formation via the reduction of hydrogen peroxide and lipid peroxide to water and the corresponding alcohol (Fayiz *et al*., 2021). Recently, with the emerging of nanotechnology, zinc and selenium nanoparticles can be incorporated in nano form as feed supplements to improve the efficiency of trace minerals in broiler chickens (Geetha *et al*., 2020). The nano-sized particles have higher potential than the conventional particles with very high surface area to volume ratio, which enables nanoparticles to be effective in very small amounts, making them absorbable more quickly than inorganic and organic minerals (Sawosz *et al*., 2009). The aim of this study was to evaluate influence of dietary supplementation of zinc and selenium nanoparticles on meat quality characteristics of broiler chickens.

## MATERIALS AND METHODS

### Experimental site

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm of the Department of Animal Production, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger State, Nigeria.

### Source of materials

Maize and soybean were purchased from Gidan Matasa and Step by Step Agro store, Western bypass, Minna. Zinc nitrate $Zn(NO_3)$ and Sodium hydroxide (NaOH), were bought from Pan lac laboratory equipment and chemicals store, Keteren gwari, Minna. The Africa scent leave (*Ocimun gratissimum*) used to produce the nano particles was sourced from olericulture garden Federal University of Technology, Minna. All other reagents and equipment used were obtained from the Step 'B' drug and vaccine discovery Laboratory, Bosso campus of the university. The green synthesis of nano zinc and selenium was carried out at the above laboratory in line with the methods described by Jay and Shafkat (2018).

The experimental diet (Table 1) was formulated in line with the nutrients requirement recommended for broiler chickens (NRC, 1994).

### Experimental animals, management and design

The three hundred and twenty (320) Arbor acre broiler chicks used for the study were sourced from Yammfy Farm hatchery, Ilemona, Kwara state. They were randomly distributed into sixteen treatments of four replicates with five birds per replicate in a factorial arrangement (4 x 4) using the completely randomized design. The birds were fed a common diet, they were reared on deep litter and all management's practices suggested for broiler chickens production were strictly observed.

### Data collection and analysis

Data collected on meat quality characteristics of broiler chickens were subjected to two-way analysis of variance using the Statistical Package for Social Science (SPSS Version 16.0). Significant means variations were separated using Duncan multiple range test at $P<0.05$.

Table 1: Ingredients composition of the experimental diet (as fed)

| Ingredient | % |
|---|---|
| Maize | 55.00 |
| Soybean cake | 26.00 |
| Fish meal | 3.00 |
| Wheat offal | 11.00 |
| Palm oil | 1.00 |
| Limestone powder | 1.00 |
| Bone meal | 2.00 |
| Salt | 0.25 |
| Lysine | 0.25 |
| Methionine | 0.25 |
| *Premix | 0.25 |
| **Total weight** | **100.00** |
| Calculated analysis | |
| Crude protein | 20.00 |
| Crude fibre | 5.53 |
| Ether extract | 5.55 |
| Ca | 1.11 |
| Avail P | 0.58 |
| ME (Kcal/Kg) | 3000.00 |

*0.25 % Premix supplied per Kg of diet: Vit. A, 2.5iu; Vit D3, 0.5iu; Vit E, 0.0057mg; Vit. K, 0.0005mg; Vit, B1, 0.00045mg; Vit B2, 0,0013mg; pantothenic acid, 0.0018mg; Vit. B12, 0.000005mg; Folic acid, 0.00018mg; Biotin, 0.000015mg; Choline chloride, 0.075mg; Cobalt, 0.00005mg; Copper, 0.00075mg; Iodine, 0.00025mg; Iron, 0.0025mg; Manganese, 0.01mg; Selenium, 0.00005mg; Zinc, 0.0075mg; Antioxidant, 0.00031mg

**RESULTS AND DISCUSSION**

Table 2: shows the results of the effect of dietary zinc and selenium nanoparticles on meat sensory properties of broiler chickens. The results indicated that aroma, tenderness and overall acceptability were significantly (P<0.05) affected supplementation with nano zinc, while nano selenium (NSe) supplementation did not significantly (P>0.05) affect all the sensory attributes except juiciness (P>0.05). There was interaction effect however, on colour and flavor of the meat. This effect may be due to the ability of Zn in inhibiting mitochondrial respiration and in decreasing the production of free radicals by acting as an antioxidant, thus facilitating the maintenance of meat sensory traits (Powell *et al*., 2000). The values obtained for the meat sensory traits are in agreement with Selim *et al*. (2014) who noted that addition of 50 mg/Kg nano zinc in broiler chickens' diet had beneficial effects on meat aroma, tenderness and overall acceptability. Dietary selenium nanoparticle improved the juiciness of breast and thigh meat across the treatment groups. This might imply that lower levels of NSe are more responsible for antioxidant activity and its active in reducing the production of Reactive Oxygen Species (ROS) in the body that are capable of impairing the quality of muscle fibre. The results of this study is partially in line with the observation of Zhou and Wang (2011) who reported that the breast meat juiciness of Guangxi Yellow chicken was enhanced when fed diet supplemented with nano selenium.

**Table 2: Effect of nano zinc and selenium enriched diets on meat sensory properties of broiler chickens**

| Factors | Colour | Flavour | Juiciness | Aroma | Tenderness | Overall acceptability |
|---|---|---|---|---|---|---|
| Nano Zinc(mg/Kg) | | | | | | |
| 20 | 7.31 | 6.37 | 7.25 | $7.37^{b}$ | $7.43^{a}$ | $7.62^{ab}$ |
| 30 | 6.50 | 6.75 | 6.62 | $7.50^{ab}$ | $6.68^{b}$ | $7.81^{ab}$ |
| 40 | 6.50 | 6.87 | 7.18 | $7.75^{ab}$ | $7.50^{a}$ | $8.00^{a}$ |
| 50 | 7.25 | 7.12 | 7.18 | $8.00^{a}$ | $7.68^{a}$ | $7.37^{b}$ |
| SEM | 0.28 | 0.33 | 0.22 | 0.17 | 0.22 | 0.19 |
| Nano Selenium (mg/Kg) | | | | | | |
| 0.10 | 7.00 | 6.56 | $7.37^{a}$ | 7.62 | 7.18 | 7.93 |
| 0.15 | 6.81 | 6.56 | $7.25^{a}$ | 7.56 | 7.31 | 7.62 |
| 0.20 | 6.63 | 7.25 | $7.25^{a}$ | 7.56 | 7.50 | 7.37 |
| 0.25 | 7.13 | 6.75 | $6.37^{b}$ | 7.87 | 7.31 | 7.87 |
| SEM | 0.28 | 0.33 | 0.22 | 0.17 | 0.22 | 0.19 |
| P-values | | | | | | |
| Main effects and interaction | | | | | | |
| NZn | 0.07 | 0.47 | 0.18 | 0.03 | 0.01 | 0.04 |
| NSe | 0.63 | 0.43 | 0.01 | 0.55 | 0.80 | 0.16 |
| NZn x NSe | 0.08 | 0.54 | 0.04 | 0.03 | 0.02 | 0.04 |

abc = means in the same column carrying different superscript differs significantly ($P<0.05$), SEM = standard error of mean, P –value = probability levels, mg = milligram and kg = kilograms, NZn = Nano Zinc and NSe = Nano Selenium.

Table 3: Effect of nano zinc and selenium enriched diets on pH, drip loss and cooking loss of broiler chickens' meat

| Factors | pH at 24 hours | pH at 48 hours | Drip loss (%) | Cooking loss (%) |
|---|---|---|---|---|
| Nano Zinc (mg/Kg) | | | | |
| 20 | 6.10 | 6.12 | 1.02 | $18.56^{a}$ |
| 30 | 5.71 | 5.90 | 1.07 | $16.31^{b}$ |
| 40 | 5.79 | 5.95 | 1.12 | $18.56^{a}$ |
| 50 | 5.73 | 5.70 | 1.30 | $16.15^{b}$ |
| SEM | 1.11 | 0.16 | 0.12 | 0.91 |
| Nano Selenium (mg/Kg) | | | | |
| 0.10 | $5.79^{ab}$ | 5.74 | $0.86^{b}$ | $16.45^{b}$ |
| 0.15 | $5.75^{ab}$ | 5.90 | $1.42^{a}$ | $18.09^{a}$ |
| 0.20 | $6.07^{a}$ | 6.07 | $1.17^{ab}$ | $16.80^{b}$ |
| 0.25 | $5.72^{b}$ | 5.96 | $1.06^{ab}$ | $17.71^{ab}$ |
| SEM | 1.11 | 0.16 | 0.12 | 0.91 |
| P-values | | | | |
| Main effects and interaction | | | | |
| sNZn | 0.06 | 0.35 | 0.47 | 0.04 |
| NSe | 0.04 | 0.53 | 0.03 | 0.01 |
| NZn x NSe | 0.04 | 0.93 | 0.01 | 0.01 |

abc = means in the same column carrying different superscript differs significantly ($P<0.05$).
SEM = standard error of mean, P –value = probability levels, mg = milligram and kg = kilograms, % = percentage, NZn = Nano Zinc ad NSe = Nano Selenium.

Table 4.10 shows the effect of dietary nano zinc and selenium enriched diets on the pH, drip loss and cooking loss of broiler chickens' meat. The results of nano zinc (NZn) revealed no significant (P>0.05) influence amongst the parameters measured except cooking loss across the treatments. The results of the cooking loss indicated that meat from birds on 20 and 40 NZn mg/kg supplemented diets had higher (P>0.05) values than those fed 30 and 50 NZn mg/kg supplemented diets. The findings of nano selenium (NSe) showed that meat pH at 24 hours, drip loss and cooking loss were significantly (P<0.05) affected. The supplementation of broiler chickens' diets with dietary nano selenium significantly enhanced meat pH at 24 hours, drip loss and the cooking loss. The values obtained in this study for meat pH at 24 hours were within the normal range of meat pH Values recommended for the highest meat quality products (Cai *et al*., 2012). This could be due to the biological role of nano selenium in protecting living cells against reactive oxygen species by acting as an antioxidant. The present results are in agreement with those of Boiago *et al*. (2014) who revealed that the use of organic sources of Se significantly improved the meat pH of broilers chickens.

**CONCLUSION AND RECOMMENDATIONS**

Based on the results obtained from the present study, dietary supplementation of up to 50 mg/Kg NZn and 0.25 mg/Kg NSe influenced meat juiciness, aroma, tenderness and overall acceptability, also as meat pH at 24 hours, drip loss and cooking loss without compromising the health status of the birds. Therefore, farmers can supplement Arbor acre broiler chickens' diets with up to 40 mg/Kg NZn and 0. 20 mg/Kg NSe for improved meat sensory attributes and quality parameters (pH, drip loss and cooking loss).

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# AMINO ACIDS PROFILE OF *CLARIAS GARIEPINUS* FROM THREE WATER BODIES IN NIGER STATE, NIGERIA

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**ABSTRACT**
The amino acids profile of *Clarias gariepinus* species collected from three water bodies in Niger State, Nigeria, was carried out using SNPs growth-related gene forward primer GH for the genotyping of the DNA, which was then sequenced and translated to amino acids. The sequence products were downloaded, aligned and translated to amino acids by bioedit software 7.2 and each of amino acid was counted, and the frequency was calculated by excel. The essential amino acids of leucine and arginine are the most abundant and the least abundant amino acids are tryptophan, lysine and histidine while in non-essential amino acids, serine and proline are the most abundant and the least abundant amino acid is tyrosine. The less abundant amino acids can be fed orally when this species is being raise in the hatchery.
**Keywords**: SNPs DNA marker, sequencing, Amino acids and growth gene

## INTRODUCTION
Catfish species especially *Clarias gariepinus* (African catfish), is of great economic importance as it is the most cultured catfish in Africa and the third most cultured catfish species in the world (Garibaldi, 1996; Fagbenro *et al*., 2013). Single nucleotide polymorphisms (SNPs) are polymorphisms due to single nucleotide substitutions or single nucleotide insertions or deletions (Okumu and Çiftci, 2003). Amino acids are the basic units of protein, that is, they combined to form protein, this protein is the main organic material in fish tissue and 65-75% total dry weight of fish is made up of protein and fish obtain amino acids from protein consume and use excess amino acids as an energy source (Millamena, 2002). Amino acids play significant role in fish growth and therefore, this research investigate amino acids composition in this valuable species.

## MATERIALS AND METHODS
Experimental fish collection:
Ten (10) samples of *Clarias gariepinus* was collected from Lapai/Agaie dam, Shiroro dam and Tagwai dam in Niger state, Nigeria with the help of local fishermen, for each sample that was used for the experiment, the caudal fin was cut, put in the Eppendorf tube containing 90% absolute ethanol and stored in a refrigerator until used.

### Isolation and Purity of Genomic DNA:
The genomic DNA was isolated using Quick-DNA™ miniprep plus kit protocol, revised 2021 (www.zymoresearch.com) by following the instruction manual version 1.3.2. with little modification for all the samples. Purity of the genomic DNA isolated was checked by measuring the ratio of absorbance at 260 to absorbance at 280nm to be 1.8-2.0 using Nano-drop spectrophotometer. The genotyping was carried out using growth-related gene SNPs primers (GH, Sense: AGAGCAACGGATGAGTAAC, Anti-sense: TGAAGCAAGACAGCAGAC,

Af416488.1) downloaded from GenBank (https://www.ncbi.nlm.nih.gov). The SNPs genotyping was also performed in a touch down thermal cycler (Applied Bio systems, USA) programmed in two cycles, 9 cycle and 35 cycles. sequencing was carried out using the protocol for BigDye terminator v 3.1 cycle sequence kit in a 96 well plates in an automated sequencing machine (ABI 3500). This was carried out at the Bioscience laboratory of International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria. The sequence products were downloaded, aligned and translate to amino acids using BioEdit 7.2 software and then, the frequency of each amino acid was calculated using excel spreadsheet.

## RESULTS

Translation of DNA sequence of *C. gariepinus* to amino acid:

The translation of DNA sequence of *C. gariepinus* to amino acid by growth related gene SNPs forward primer GH are shown in Figures 1, 2, 3, 4, 5 and 6.

>Cg1-GH-F

1 GTC CTA TCG CTA GGG TCT GGT AGA ATC CTC TTA GGT CGT AAT GAA 45
1 Val Leu Ser Leu Gly Ser Gly Arg Ile Leu Leu Gly Arg Asn Glu 15

46 GAC TCG TGC TAT CTC CAT CAG ATA TGA TTT GTT TAA ATG AAT GTG 90
16 Asp Ser Cys Tyr Leu His Gln Ile End Phe Val End Met Asn Val 30

91 CCA TCG ATT ATT TCC TGA TAA CCG CAC GTT CTG TTT GAT TTC TTA 135
31 Pro Ser Ile Ile Ser End End Pro His Val Leu Phe Asp Phe Leu 45

136 CTT TGG ATC CAA TAG GGA TGT GTG GAT GGA CAA ACC AGC CTG GAC 180
46 Leu Trp Ile Gln End Gly Cys Val Asp Gly Gln Thr Ser Leu Asp 60

181 GAG AAT GAC GCA TTT GCT CCG CCC TTC GAG GAT TTC TAC CAG ACC 225
61 Glu Asn Asp Ala Phe Ala Pro Pro Phe Glu Asp Phe Tyr Gln Thr 75

226 CTG AGC GAG GGG AAC TTG AGG AAG AGC TTC CGT CTG CTA AAA TTG 270
76 Leu Ser Glu Gly Asn Leu Arg Lys Ser Phe Arg Leu Leu Lys Leu 90

271 CTT AA- 276
91 Leu XXX 92

**Figure 1: Translation of DNA Sequence of *C. gariepinus* (Agaie/Lapai Dam Sample One) to Amino Acid by SNPs Forward Primer GH**

>Cg2-GH-F

1 TTC CCG TCG CTC AGG GTC TGG GTG TGT TCA TTT ACA TCA ATA ATG 45
1 Phe Pro Ser Leu Arg Val Trp Val Cys Ser Phe Thr Ser Ile Met 15

46 TAG AAC TCG TGC TAT CTC CAT CAG ATA TGA TTT GTT TAA ATG AAT 90
16 End Asn Ser Cys Tyr Leu His Gln Ile End Phe Val End Met Asn 30
91 GTG CCA TCG ATT ATT TCC CAA TAA CCG CAC GTT CTG TTT GAT TTC 135
31 Val Pro Ser Ile Ile Ser Gln End Pro His Val Leu Phe Asp Phe 45

136 TTA CTT TGG GTC CAA TAG GGA TGT GTG GAT GGA CAA ACC AGC CTG 180
46 Leu Leu Trp Val Gln End Gly Cys Val Asp Gly Gln Thr Ser Leu 60

181 GAC GAG AAT GAC GCA TTT GCT CCG CCC TTC GAG GAT TTC TAC CAG 225
61 Asp Glu Asn Asp Ala Phe Ala Pro Pro Phe Glu Asp Phe Tyr Gln 75

226 ACC CTG AGC GAG GGG AAC TTG AGG AAG AGC TTC CGT CTA CTT AAT 270
76 Thr Leu Ser Glu Gly Asn Leu Arg Lys Ser Phe Arg Leu Leu Asn 90

271 TGC TTC A-- 279
91 Cys Phe XXX 93

**Figure 2: Translation of DNA Sequence of *C. gariepinus* (Agaie/Lapai Dam Sample Two) to Amino Acid by SNPs Forward Primer GH**

>Cg3-GH-F

1 TTC CCC TCG CTA GGG TCT GGT GTG TAT CCA CTT ACT CGT AAT GTA 45
1 Phe Pro Ser Leu Gly Ser Gly Val Tyr Pro Leu Thr Arg Asn Val 15

46 GAA CTC GTG CTA TCT CCA TCA GAT ATG ATT TGT TTA AAT GAA TGT 90
16 Glu Leu Val Leu Ser Pro Ser Asp Met Ile Cys Leu Asn Glu Cys 30

91 GCC ATC GAT TAT TTC CCA ATA ACC GCA CGT TCT GTT TGA TTT CTT 135
31 Ala Ile Asp Tyr Phe Pro Ile Thr Ala Arg Ser Val End Phe Leu 45

136 ACT TTG GGT CCA ATA GGG ATG TGT GGA TGG ACA AAC CAG CCT GGA 180
46 Thr Leu Gly Pro Ile Gly Met Cys Gly Trp Thr Asn Gln Pro Gly 60

181 CGA GAA TGA CGC ATT TGC TCC GCC CTT CGA GGA TTT CTA CCA GAC 225
61 Arg Glu End Arg Ile Cys Ser Ala Leu Arg Gly Phe Leu Pro Asp 75

226 CCT GAG CGA GGG GAA CTT GAG GAA GAG CTT CCG TCA GCT ATC TTG 270
76 Pro Glu Arg Gly Glu Leu Glu Glu Glu Leu Pro Ser Ala Ile Leu 90

271 CTT AA- 276
91 Leu XXX 92

**Figure 3: Translation of DNA Sequence of *C. gariepinus* (Shiroro Dam Sample One) to Amino Acid by SNPs Forward Primer GH**

>Cg4-GH-F

1 TCC CCC TCG CAT AGG ATC TGG GAG TGT CTA TTA ACA TCA GTA ATG 45
1 Ser Pro Ser His Arg Ile Trp Glu Cys Leu Leu Thr Ser Val Met 15

46 AAG ATC TCG TGC TAT CTC CAT CAG ATA TGA TTT GTT TAA ATG AAT 90
16 Lys Ile Ser Cys Tyr Leu His Gln Ile End Phe Val End Met Asn 30
91 GTG CCA TCG ATT ATT TCC TGA TAA CCG CAC GTT CTG TTT GAT TTC 135
31 Val Pro Ser Ile Ile Ser End End Pro His Val Leu Phe Asp Phe 45

136 TTA CTT TGG GTC CAA TAG GGA TGT GTG GAT GGA CAA ACC AGC CTG 180

46 Leu Leu Trp Val Gln End Gly Cys Val Asp Gly Gln Thr Ser Leu 60

181 GAC GAG AAT GAC GCA TTT GCT CCG CCC TTC GAG GAT TTC TAC CAG 225
61 Asp Glu Asn Asp Ala Phe Ala Pro Pro Phe Glu Asp Phe Tyr Gln 75

226 ACC CTG AGC GAG GGG AAC TTG AGG AAG AGC TTC CGT CTA AAA AAC 270
76 Thr Leu Ser Glu Gly Asn Leu Arg Lys Ser Phe Arg Leu Lys Asn 90

271 TTG CTT CA- 279
91 Leu Leu XXX 93

**Figure 4: Translation of DNA Sequence of *C. gariepinus* (Shiroro Dam Sample Two) to Amino Acid by SNPs Forward Primer GH**

>Cg5-GH-F

1 GTC CCC TCG CTC AGG GTC TGG TAG AAA TCC TCG TAG GGC GTA GCA 45
1 Val Pro Ser Leu Arg Val Trp End Lys Ser Ser End Gly Val Ala 15

46 GAT GCG TCG TGC CGC TCG GCA GAT ATG ACT TGT TTA CAT GAA TGT 90
16 Asp Ala Ser Cys Arg Ser Ala Asp Met Thr Cys Leu His Glu Cys 30

91 GCG AAC GAT TAT TTC ACA TTA ACC GCA CGT TCT GTT TGA TTT CTT 135
31 Ala Asn Asp Tyr Phe Thr Leu Thr Ala Arg Ser Val End Phe Leu 45

136 ACT TTG GGT CCC ATA GGG ATG TGT GGA TGG ACA AAC CAG CCT GGA 180
46 Thr Leu Gly Pro Ile Gly Met Cys Gly Trp Thr Asn Gln Pro Gly 60

181 CGA GAA TGA CGC ATT TGC TCC GCC CTT CGA GGA TTT CTA CCA GAC 225
61 Arg Glu End Arg Ile Cys Ser Ala Leu Arg Gly Phe Leu Pro Asp 75

226 CCT GAG CGA GGG GAA CTT GAG GAA GAG CTT CCG TCT GCT GTC TTG 270
76 Pro Glu Arg Gly Glu Leu Glu Glu Glu Leu Pro Ser Ala Val Leu 90

271 CTT AA- 276
91 Leu XXX 92

**Figure 5: Translation of DNA Sequence of *C. gariepinus* (Tagwai Dam Sample One) to Amino Acid by SNPs Forward Primer GH**

>Cg6-GH-F

1 GAT CCG TCG CTA GGG TCT GGT AGA ATC CTC TTA GTC GTA GTG ATG 45
1 Asp Pro Ser Leu Gly Ser Gly Arg Ile Leu Leu Val Val Val Met 15
46 ACT CGT GCT ATC TCC ATC AGA TAT GAT TTG TTT AAA TGA ATG TGC 90
16 Thr Arg Ala Ile Ser Ile Arg Tyr Asp Leu Phe Lys End Met Cys 30

91 CAT CGA TTA TTT CCT GAT AAC CGC ACG TTC TGT TTG ATT TCT TAC 135
31 His Arg Leu Phe Pro Asp Asn Arg Thr Phe Cys Leu Ile Ser Tyr 45

136 TTT GGG TCC AAT AGG GAT GTG TGG ATG GAC AAA CCA GCC TGG ACG 180
46 Phe Gly Ser Asn Arg Asp Val Trp Met Asp Lys Pro Ala Trp Thr 60

181 AGA ATG ACG CAT TTG CTC CGC CCT TCG AGG ATT TCT ACC AGA CCC 225
61 Arg Met Thr His Leu Leu Arg Pro Ser Arg Ile Ser Thr Arg Pro 75

226 TGA GCG AGG GGA ACT TGA GGA AGA GCT TCC GTC TGC TGA CTT GCT 270
76 End Ala Arg Gly Thr End Gly Arg Ala Ser Val Cys End Leu Ala 90

271 TAA 273
91 End 91

**Figure 6: Translation of DNA Sequence of *C. gariepinus* (Tagwai Dam Sample Two) to Amino Acid by SNPs Forward Primer GH**

Frequency of amino acids in *C. gariepinus* by SNPs forward primer GH:

The frequency of amino acids in *C. gariepinus* from Agaie/Lapai dam, shiroro dam and Tagwai dam were generated from amino acid translated from the sequence of SNPs growth related gene forward primer (GH). The average frequency between the two samples and the total frequency from the three study sites were calculated as shown in Table 1.

**Table 1: The Frequency of Amino Acids in *C. gariepinus* Forward Primer GH**

| Essential amino acids | SNPs forward Primers GH | | | Total Frequency |
|---|---|---|---|---|
| | Agaie/Lapai dam | Shiroro dam | Tagwai dam | |
| Arginine | 3.0 | 4.5 | 9.5 | 17.0 |
| Histidine | 1.5 | 1.5 | 1.5 | 4.5 |
| Isoleucine | 4.0 | 5.5 | 3.5 | 13.0 |
| Leucine | 11.5 | 12.0 | 9.5 | 33.0 |
| Methionine | 1.5 | 2.0 | 3.0 | 6.5 |
| Lysine | 1.5 | 1.5 | 1.5 | 4.5 |
| Phenylamine | 7.0 | 4.0 | 3.5 | 14.5 |
| Threonine | 1.5 | 2.5 | 5.5 | 9.5 |
| Tryptophan | 1.0 | 1.5 | 2.0 | 4.5 |
| Valine | 5.0 | 5.0 | 5.0 | 15.0 |
| **Non-essential amino acids** | **SNPs forward Primers** | | | **Total Frequency** |
| | Agaie/lapai dam | Shiroro dam | Tagwai dam | |
| Alanine | 2.0 | 3.0 | 6.0 | 11.0 |
| Asparagine | 5.0 | 2.5 | 2.0 | 9.5 |
| Aspartic acid | 5.0 | 3.0 | 4.5 | 12.5 |
| Cysteine | 3.0 | 3.5 | 3.5 | 10.0 |
| Glutamic acid | 2.0 | 4.0 | 3.5 | 9.5 |
| Glutamine | 4.0 | 2.5 | 0.5 | 7.0 |
| Glycine | 4.0 | 4.5 | 6.0 | 14.5 |
| Proline | 4.5 | 7.0 | 5.0 | 16.5 |
| Serine | 7.0 | 8.0 | 8.0 | 23.0 |
| Tyrosine | 2.0 | 1.5 | 1.5 | 5.0 |

**DISCUSSION**

leucine is the most abundant essential acid, which agrees with the report by Krick *et al*. (2014), that, the most abundant amino acids in both Swissprot and TrEMBL databases is leucine, according to Li *et al*. (2011), the most abundant amino acid in high quality protein is leucine. The second most abundant essential amino acid is arginine, arginine influences nutrient metabolism, stimulates insulin release, is also involved in nonspecific immune responses, antioxidant responses and elevates disease resistance (Wang *et al*., 2021). While the least abundant essential amino acids are tryptophan, lysine, histidine and methionine, this might be because high energy is involved in synthesizing these amino acids. Akashi and Gojobori (2002) reported that, energy required for the syntheses of methionine and tryptophan are 446 ATPs and 892 ATPs respectively. In non-essential amino acids, serine and proline are the most abundant, this agrees with the report of (Wu, 2013), that proline and its metabolite (hydroxyproline) are most abundant, they constitute one-third of amino acids in the collagen proteins which comprise approximately 30% of body proteins. Serine is a precursor of many important cellular compound such as purines, pyrimidines, sphingolipids and folate which involves in syntheses of glycine, cysteine and tryptophan (Ahern *et al*., 2021), hence, its high abundance and the least abundant amino acid is tyrosine, as reported by Akashi and Gojobori (2002), that large amount of energy (350 ATPs) is required to synthesize tyrosine.

**CONCLUSION**

In conclusion, to enhance growth, when this species is being raise in the nursery, the less abundant amino acids should be added to their feed.

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# TOXICITY EFFECTS OF CRUDE SEED EXTRACTS OF DESERT DATE (*Balanite aegyptiaca)* ON CATFISH (*Clarias gariepinus)* JUVENILES

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**ABSTRACT**

This study investigates the toxicity effects of *Balanites aegyptiaca* crude seed extract on juveniles of *Clarias gariepinus*, as it affects the water quality and haematological parameters. The fresh fruits of *Balanites aegyptiaca* were collected from Jos, Nigeria, and processed to obtain a fine powder for analysis. Juvenile *Clarias gariepinus*, averaging 3g in weight and 9cm in length, were acclimatized to laboratory conditions for one week before exposure to varying concentrations (0.05, 0.10, 0.15, 0.20, and 0.25 g/L) of the extract. Water quality parameters such as temperature, pH, dissolved oxygen, and carbon dioxide were monitored daily throughout the experiment. Results indicated that while pH levels remained stable across treatments, significant variations in carbon dioxide levels were observed. Haematological assessments revealed a dose-dependent response in red blood cell counts and hemoglobin levels at lower concentrations, but a non-linear trend at higher concentrations. Overall, findings indicate that *Balanite aegyptiaca* extract can influence both water quality and fish health parameters.

**Keywords:** Water Quality, Haematological Indices, *Clarias gariepinus* Juveniles, Acute Concentrations, *Balanite aegyptiaca.*

## INTRODUCTION

All water pollution affects organism and plants that lives in these water bodies and in almost all cases (Chris Dinesen, 2022). The effect is damaging not only to the individual species and populations, but also to the natural biological communities, and that this occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful constituents (Agrawal et al., 2010). Many plant components have the potential effect to produce adverse effects on productivity of farm animals (Novak & Haslberger 2000). They have an array of chemicals noxious or toxic to fish and other animals including man, this chemicals diversity also includes many other compounds with medicinal values (Novak & Haslberger 2000).

Plants extracts have been used by man to collect fish in lentic and lotic waters. Indigenous tribes of South America have long used plants as piscicides (Power, Fuentes, & Harrison, 2008). According to Power et al. (2008) macerated material of plant origin is thrown into rivers, streams or shallow ponds, and then the fish which are stupefied float to the surface and can be collected. After analysing the phytochemicals, the plant material revealed the presence of active compounds such as rotenoids and saponins (Power et al., 2008).

The bark of *Balanite aegyptiaca* is used as a fish poison, but it is not poisonous to man (Heuze & Tran, 2012). The stem bark and the fruits are used in Morocco, Nigeria and Senegal as a laxative or purgative for colic and stomach aches (Nkunya, Weenen, & Bray, 2020). It is reported that the edible bitter-sweet pulp is used as food or confectionery, and laxative as well as for the treatment of constipation, the leaves are used to make soup by some tribes in Nigeria while in Chad the fresh twigs are burned to keep insect away (Nkunya et al., 2020). Therefore, this study seeks to evaluate the toxicity effects of aqueous crude seed extract of *Balanite aegypiaca* on *Clarias gariepinus* juveniles.

## MATERIALS AND METHODS

### Collection Area and Preparation of Toxicant

The fresh part (fruits) of the experimental plant was collected from Jos, Jos North Local Government Area of Plateau State North-central Nigeria. The *Balanites aegyptiaca* fruits was transported to Hydrobiology and Fisheries Research Laboratory of University of Jos, Nigeria where the seed was removed and dried under shed and pound using pestle and mortar and sieved with 0.5mm sieve into fine powder before taking the sample for phytochemicals and proximate analysis in the department of biochemistry University of Jos.

### Collection and Acclimation of Experimental Fish (*Clariasgariepinus*)Juveniles

Live and healthy, mixed sex Juveniles of *Clarias gariepinus* with an average weight of 3g and length of 9cm were purchased from a Private Fish Farm in Zarmaganda, Jos South, Plateau State and transported to Hydrobiology and Fisheries Research laboratory of University of Jos, Nigeria. Fish were transferred into six (6) plastic tanks each with 10L dechlorinated tap water and allowed to acclimatize to laboratory conditions for a period of one week. Fish were fed 3% body weight with commercial feed (Blue crown) twice daily. Three quarters of the water in the tank were siphoned out on daily basis to remove left over feed and faecal matter and replaced with fresh water. Mortality observed during acclimation period were replaced and allowed to stabilize to zero. Feeding stopped 24 hours prior to exposure to the bioassay media.

### Determination of Definitive Acute Concentrations of *B. aegyptiaca* Crude Seed Extract

Series of preliminary investigations was conducted to obtain the acute concentrations (Ayorinde, Audu, Ogundeko, & Ujah, 2020). Median lethal concentration that causes 50% mortality of exposed fish was determined and the five definitive tests concentrations of 0.05, 0.10, 0.15, 0.20, and 0.25g/L of *Balanite aegyptiaca* were obtained.

### Experimental Design

A total of twelve (12) transparent circular plastic tanks of 16 liters' capacity each with 10 liters of de-chlorinated tap water were used in a complete randomized block design. Each test tank was replicated and designated as A1-C2, E1-B2, C1-A2, D1-F2, B1-E2 and F1-D2. Each tank contained ten (10) mixed sex juveniles of *C. gariepinus*. Fish were sorted into cohort and distributed in batches of ten fish/per experimental tank with the control.

### Monitoring of Water Quality Parameters for Acute Toxicity

Water quality parameters of the tanks exposed to acute concentrations of *Balanite aegyptiaca* crude seed extract such as: Temperature (ºC), pH, Dissolved oxygen (g/L), and Free carbon (IV) oxide (g/L) were monitored daily, following the procedures described by APHA (2005).

**Haematological parameters of *Clarias gariepinus* juveniles exposed to Crude Seed extract of *Balanite aegyptiaca*.**

Haematological parameterswas carried out according to the method described by Maheswaran, Devapaul, Muralidharan Velmurugan, & Ignacimuthu (2008).

**Acute Bioasssay of Aqueous Crude Seed Extract of *Balanite aegyptiaca* on *Clarias gariepinus* juveniles**

The results of the acute bioassay on *Clarias gariepinus* using different concentrations (0.05, 0.10, 0.15, 0.20, and 0.25g/L) of aqueous crude seed extract from *Balanite aegyptiaca* over 96 hours are summarized in table 1 below. Mortality rates increased with higher concentrations: 100% at 0.25g/L, 80% at 0.20g/L, 60% at 0.15g/L, 40% at 0.10g/L, and 20% at 0.05g/L. No mortality was observed in the control tanks (0.00g/L).

Figure 1 elaborates the linear relationship between the probit mortality and the logarithm of concentration for *Clarias gariepinus* juveniles exposed to the aqueous crude seed extract of *Balanite aegyptiaca.* The calculated 96-hour $LC_{50}$ value for the extract on *Clarias gariepinus* juveniles is 0.111g/L, with upper and lower confidence limits of 0.080g/L and 0.153g/L, respectively

**Table 1: Acute Bioassay of *Clarias gariepinus* Juveniles Exposed to Aqueous Crude Seed Extract of *Balanite aegyptiaca***

| Conc. (g/L) | Log. Conc. | No of Fish | Mortality Time (Hours) | | | | | Percentage Mortality (%) | Probit Mortality |
|---|---|---|---|---|---|---|---|---|---|
| | | | 24hrs | 36hrs | 48hrs | 72hrs | 96hs | | |
| 0.25 | -0.6021 | 10 | 6 | 4 | - | - | - | 100 | 8.7190 |
| 0.20 | -0.6990 | 10 | 4 | 2 | 2 | - | - | 90 | 6.2816 |
| 0.15 | -0.8239 | 10 | - | 1 | 3 | 2 | - | 60 | 5.2533 |
| 0.10 | -1.0000 | 10 | - | 1 | 2 | 1 | - | 40 | 4.7467 |
| 0.05 | -1.3010 | 10 | - | - | 1 | - | 1 | 20 | 4.1584 |
| 0.00 | 0.00 | 10 | - | - | - | - | - | 0 | 0.0000 |

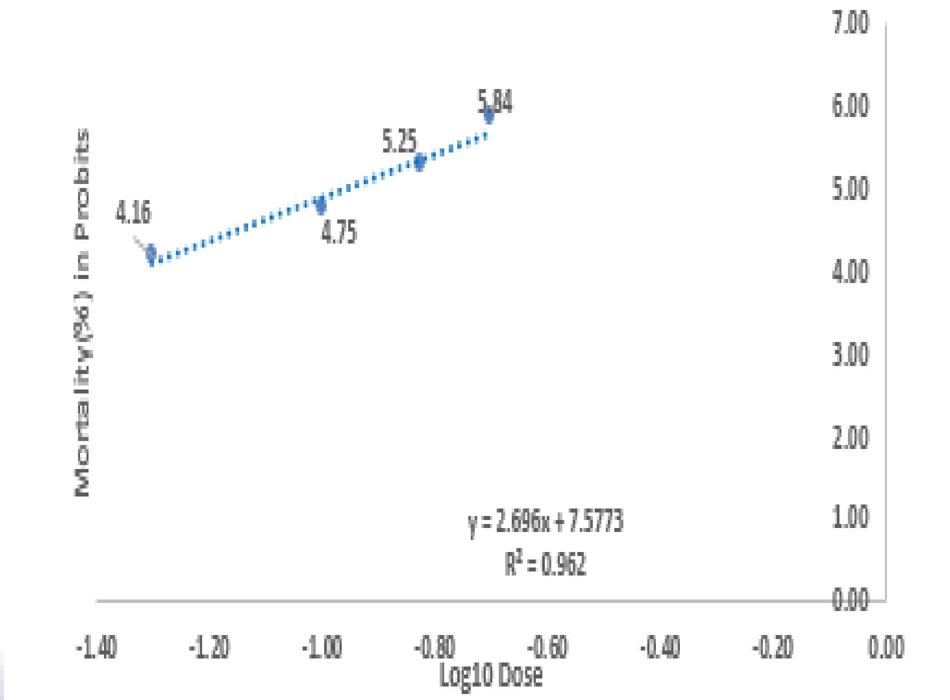


Figure 1: Graph of probit mortality against log concentrations

Table 2: Water Quality Parameters of Experimental Tanks During Acute Exposure of Aqueous Crude Seed Extract of *Balanite aegyptiaca* on *Clarias gariepinus* juveniles

| Parameters | A | B | C | D | E | Control | SEM | P-value |
|---|---|---|---|---|---|---|---|---|
| pH | 7.66 | 7.69 | 7.31 | 7.37 | 7.22 | 6.98 | 0.21 | 0.948 |
| CO2 | 56.00[a] | 43.75[b] | 27.25[d] | 23.00[e] | 33.25[c] | 32.75[c] | 2.67 | 0.000 |
| Temp. | 27.2 | 27 | 26.78 | 26.75 | 26.7 | 26.19 | 0.21 | 0.830 |
| Oxygen | 2.10[b] | 2.30[b] | 3.50[b] | 3.20[b] | 3.90[ab] | 5.40[a] | 0.33 | 0.018 |

[a, b] Means in the same row not sharing superscript are significantly different at $P<0.05$.
SEM = Standard error mean

**DISCUSSION**

The analysis of water quality at acute concentration shows that the pH levels across treatments indicate the water remains generally within the optimal range for most freshwater fish sp\ecies, which is typically between 6.5 and 8.5. Treatments 1 and 2 displayed the highest pH values, while Treatment 6 showed the lowest pH at 6.98. Despite the variation, the high p-value suggests no statistically significant difference among the treatments. Johnson et al. (2020) highlight that while fish can tolerate slight fluctuations in pH, significant deviations can lead to stress and impaired metabolic functions. Some species, such as salmonids, are particularly sensitive to acidic conditions, potentially experiencing higher mortality rates when exposed to pH levels below 6.5 (McDonald & Adams, 2018).

**Table 3: Mean Haematological Indices of *Clarias gariepinus* Juveniles Exposed to Acute Concentrations of Aqueous Crude Seed Extract of *Balanite aegyptiaca* for 96 Hours**

| CONC. (g/L) | 0 | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | P-values |
|---|---|---|---|---|---|---|---|
| WBC (µL) | 25.30±1.20 | 89.00±2.30 | 97.00±1.30 | 90.34±1.54 | 88.90±1.10 | 66.10±31.20 | 0.040 |
| LYM (%) | 23.52±1.27 | 17.56±1.86 | 47.66±24.65 | 19.31±0.10 | 20.81±0.74 | 23.67±5.30 | 0.420 |
| RBC ((µL) | 1.44±0.33 | 2.26±0.13 | 2.22±0.80 | 1.98±0.95 | 0.92±0.44 | 1.93±0.15 | 0.370 |
| HGB(g/L) | 86.00±8.00 | 189.00±1.00 | 160.50±12.50 | 148.00±99.00 | 64.50±0.05 | 119.00±32.00 | 0.410 |
| HCT(%) | 20.09±4.71 | 28.76±1.70 | 29.39±1.66 | 23.16±10.66 | 13.14±2.62 | 24.54±0.64 | 0.320 |
| MCV (fL) | 138.85±1.35 | 127.30±0.50 | 131.95±2.75 | 118.35±2.95 | 120.35±4.45 | 127.55±6.55 | 0.060 |
| MCH(pg) | 64.05±19.96 | 84.15±5.25 | 72.70±8.30 | 66.33±18.01 | 62.86±15.15 | 63.46±21.46 | 0.910 |
| MCHC(g/L | 462.50±148.50 | 661.00±44.00 | 552.00±166.00 | 564.00±166.00 | 518.00±107.00 | 490.00±143.00 | 0.880 |
| PLT (µL) | 36.50±3.50 | 141.50±27.50 | 90.00±7.00 | 170.50±27.50 | 169.50±39.50 | 221.50±139.50 | 0.430 |
| MPV (fL) | 12.33±0.09 | 11.93±0.30 | 12.13±0.36 | 11.38±1.67 | 10.37±0.05 | 11.00±1.14 | 0.610 |
| PDW (%) | 16.05±0.45 | 16.20±1.60 | 17.10v1.10 | 15.90±1.30 | 14.80±0.20 | 11.00±0.00 | 0.570 |

WBC=White blood cells
LYM= Lymphocytes
RBC= Redblood cells
HGB= Haemaglobin
HCT= haematocrit
MCV= Mean corpuscular volume
MCH= Mean corpuscular haemoglobin
MCHC= Mean corpuscular haemaglobin concentrations
PLT= platelets
MPV= mean platelets volume
PDW= platelets distribution width

$CO_2$ levels showed significant variation across treatments, with Treatment 1 having the highest $CO_2$ concentration at 56.00 mg/L, which is indicative of poor water quality and potentially detrimental to fish health. Lower $CO_2$ levels in Treatments 4, 5, and 6 are more favorable for fish. Elevated $CO_2$ levels are known to impair fish respiration and metabolic processes, leading to stress and altered behaviours (Thompson et al., 2020). Some fish species, like tilapia, have shown adaptability to higher $CO_2$ levels compared to more sensitive species, indicating variability in responses to increased $CO_2$ concentrations (Carter & Smith, 2021).

The temperature values across treatments were relatively stable and within a suitable range for many freshwater fish species. However, it shows no significant differences in temperature among the treatments. Optimal temperatures for many fish species fall between 20°C and 30°C, and studies have shown that temperature significantly affects fish growth and reproduction (Liu et al., 2022). Dissolved oxygen levels exhibited significant variation, with Treatment 1 (2.10 mg/L) indicating hypoxic conditions. Treatment 6 showed the highest level of 5.40 mg/L, which is more conducive to fish health. Studies have established that oxygen levels below 3 mg/L can cause stress and increased mortality rates in fish (Garcia et al., 2021). Different fish species exhibit varying tolerances to low oxygen levels; for example, catfish can survive in low oxygen conditions better than trout, which are more susceptible to hypoxia (Wang & Hu, 2020).

Haematological parameters are used in medical analysis of fish body function which is determined by the effect of the surrounding water (Ojutiku, Asuwaju, Kolo, Obande, &Agbelege, 2013), thus reveal the level of damage in fish. Fish exposed to toxicants can exhibit a variety of physiological responses, including blood disturbances (Osman, Koutb& Sayed, 2010; Thangam, Jayaprakash &Perumayee, 2014). The anisocytosis of red blood cells in this study indicates stress mediated release of blood cells by haematopoietic tissues (Al-Zaidan, 2017) and poikilocytosis implies destruction of blood cells due to the effects of the toxicant on the exposed fish (Ajima, Ogo, Audu, &Ugwoegbu, 2014) while normocytic and normochromic cells indicate that concentrations of the plant extract had no effect on the blood cells. Decrease in WBC and LYM recorded in this study opposed the findings of Adewoye, (2010), which reported an increase in WBC and LYM due to the fish's attempt to fight against the toxicant by producing more WBC and LYM to recover their health condition. The decrease in RBC as concentrations of the test material increase in this study is similar to the findings of Ajima et al. (2017) that RBC decreased after chronically treating C. gariepinus with urea fertilizer. It also agrees with the findings of Suely, Zabed, Ahmed, Mohamad, Nasiruddin, Sahu, & Ganesan (2015) after exposing Heteropneustesfossilis to concentrations of Terminalia arjuna. A significant decrease in RBC and HGB level after exposure to pesticides and other toxicants were reported by several investigators (Adewoye, 2010). The present study also corroborates the findings of Adedeyi & Odo (2017) who reported decline in HCT following elevation in concentration of selenium on C. gariepinus. Similar reduction had been reported by Thangam, et al. (2014) after exposing C. carpio to copper. In contrast with results of the present study, Riaz-ul-Haq, Javeed, Iram, Rasheed, Amjad, & Iqbal, (2018) have previously observed an increase in HCT (or PCV) of freshwater fish Channa punctatus exposed to endosulphan pesticide. The present study also agrees with the findings of Nnamdi, Benjamin, Abdulbashir, Kingsley, Tam-Miete, Opeyemi, & Micheal, (2020), which reported a significant decrease in the MCH and MCHC level of fishes exposed to sub-lethal concentrations of Abamectin and Fipronil. The observed decrease in these parameters could be due to bioaccumulation of the plant extract in the body (Dahunsi &Oransu, 2013) and the haemolytic properties of the toxicant owing to the presence of saponins (Francis, Kerem, Makkar, & Becker, 2006). The recorded mortality in this study could be due to stress induced by the aqueous crude seed extract of B. aegyptiaca on the immune system of C. gariepinus which might have slowed toxic progress and resulted in acute toxic response which agreed with the report of Adedeyi & Odo (2017).

**CONCLUSION**

The findings of this study indicated that the crude seed extract of *Balanite aegyptiaca* contains a variety of phytochemical components with distinct effects on fish physiology. These phytochemicals adversely impact water quality and fish organs, leading to changes in blood parameters and increased mortality among fish populations. Consequently, the crude seed extract of *Balanite aegyptiaca* could be considered an aquatic pollutant. Therefore, it is recommended that the indiscriminate use of this extract in aquatic environments is capable of affected non-targeted aquatic biota negatively, and as such should be discouraged. Moreover, the extract has to be cautiously applied in fish water environment.

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# EFFECT OF DIETARY INCLUSION LEVELS OF BLOOD MEAL ON PERFORMANCE OF GROWER PIGS

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## ABSTRACT

An experiment was conducted to investigate the effect of graded dietary levels of blood meal (BM) on the growth performance of growing pigs in 112 days. Twenty-four weaned pigs (Large white x Landrace) with an average body weight of 10.3±3kg were randomly assigned to four dietary treatments (D1, D2, D3, and D4) containing blood meal at 0, 2.7, 5.4, and 8.1% levels respectively. Each treatment was replicated thrice (2 weaned pigs per replicate) in a Completely Randomized Design. Results showed that the feed intake of grower pigs fed diets containing 2.7 and 5.4% BM was similar (p>0.05) and significantly higher than in other treatments. Final and daily weight gain (kg) (27.00±0) and 0.30±0) were significantly higher in piglets offered dietary treatment 4 (8.1% BM inclusion) than in other treatment groups. Feed conversion ratio and feed cost (₦/kg gain) were lower in piglets fed a diet of 2.7% BM inclusion. In conclusion, blood meal could be included in the diets of growing piglets at 2.7% to improve feed intake, feed conversion ratio, daily gain, and reduction in the cost of production.

**Key words:** Blood meal; feed intake; feed conversion, Piglets, production cost; weight gain

## INTRODUCTION

The increasing population growth, economic instability, high rate of inflation, climate change, and food security are national and global issues of governance. The problem of protein malnutrition in most developing countries where the level of animal protein intake represents only about one-tenth of that of the developed countries is real (FSC, 2015). A 2009 report by the International Food Policy Research Institute, anticipated that within the absence of resolute government motion, the availability of food inside the sub-Saharan African region will average 500 calories less per person in 2050, which indicates a 21% decline (CFSC, 2016). Despite the shortfall in protein intake and the imminent need to elevate productivity, the production of pigs in Nigeria has remained low (Osondu *et al.,* 2014). A study by Agunbiade *et al.* (2011) revealed that the neglect or slow growth of the swine industry can be attributed to acceptability and management issues. The management problems include disease outbreaks, poor feed efficiency, and high cost of feedstuffs. In developing countries like Nigeria and Kenya, conventional protein feedstuffs like soya bean, groundnut cake, and fish meal are scarce and expensive (Rekwot *et al*., 2012).

The alternative protein sources of animal origin include; feather meal, hair meal, meat and bone meal, tannery waste, skim milk powder, earthworms, maggots, crickets, locusts/grasshoppers, and blood meal (Rhule *et al*., 2007). Research interest has been directed towards the evaluation and use of alternative protein sources such as blood meal. Blood products have been observed to be effective protein sources that enhance growth rate and feed intake during the post-weaning phase of pigs. Notably, the nutritional problems associated with the use of BM as observed by George *et al.* (2001) and Cervantes-Pahm *et al.* (2010) were low-quality protein (due to its low digestibility and high levels of anti-nutritive factors) and its deficiency in essential amino acids (such as lysine, methionine, and threonine) respectively. George *et al*. (2001) reported the use of blood meal in place of soya bean meal at a 4% level for better feed consumption and daily gain while Fombad and Bryant (2004), recommended between 3.0 to 4.0% of blood meal inclusion levels in diets of grower pigs for improved performance. Therefore, this study was conducted to determine the effects of diets containing lower and higher inclusion levels of blood meal on the growth performance of grower pigs.

## MATERIALS AND METHODS

### Experimental site, collection, and processing of blood meal

The study was carried out at the piggery unit of the College of Agriculture and Animal Science, Mando, Kaduna (11º 10' N, 07º 38'E), located in the Northern Guinea savannah Zone of Nigeria. Kaduna has an elevation of 650m above sea level and an average rainfall of 1100mm from May to October with a mean relative humidity of 72%. The ambient temperature ranged from 15 to 36ºC (Garuba *et al*., 2012). Blood (40 litres) was collected from slaughtered cattle at the ZangoAbattoir, Tudun Wada, Kaduna, into a clean plastic container. The blood was subjected to heat treatment by boiling for 30 minutes in a clean metal drum. The blood meal was sun-dried for 72 hours according to the procedure described by Derouchey *et al*. (2002) and later stored in a clean air-tight plastic container for incorporation in the experimental diets.

### Experimental diets and management of animals

Twenty-four (24) crossbred (Large White x Hampshire) weaned piglets were procured from the College farm for the experiment. The piglets were randomly assigned to four experimental diets in a Complete Randomized Design (CRD). Each dietary group was replicated three times with two pigs per replicate. The feed intake and weight gain of the pigs were determined in an 8-week feeding trial by feeding diets incorporated with blood meal at graded levels of 0, 2.7, 5.4, and 8.1%, represented as Diet 1 (D1): Control (0%) without blood meal; Diet 2 (D2): Contained 2.7% blood meal; Diet 3 (D3): Contained 5.4% blood meal and Diet 4 (D4): Contained 8.1% blood meal. All the diets were iso-nitrogenous and iso-caloric and were formulated to contain 15% crude protein (CP). The gross composition of the experimental diets and calculated nutrient analysis is shown in Table 1.

The pigs were housed in twelve standard pens; each having well-ventilated open-sided walls with slated concrete floor measuring 165 x 180cm. The pens have concrete watering troughs measuring65 x 30 x 25cm and concrete feeding troughs measuring 48 x 30 x 20cm

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**Table 1: Gross composition of the experimental diets containing graded levels of bloodmeal**

| Ingredient (%) | Levels of blood meal (%) inclusion | | | |
|---|---|---|---|---|
| | D1 (0) | D2 (2.7) | D3 (5.4) | D4 (8.1) |
| Maize | 66.00 | 71.00 | 73.00 | 73.00 |
| Maize offal | 3.00 | 3.00 | 3.00 | 3.00 |
| Rice offal | 3.00 | 3.00 | 3.00 | 3.00 |
| Brewers dried grain | 3.00 | 5.00 | 5.00 | 5.00 |
| Blood meal | 0.00 | 2.70 | 5.40 | 8.10 |
| Groundnut cake | 18.00 | 5.00 | 10.00 | 2.00 |
| Fish meal (65%) | 1.00 | 1.00 | 1.00 | 1.00 |
| Bone meal | 1.00 | 1.00 | 1.00 | 1.00 |
| Limestone | 0.20 | 0.20 | 0.20 | 0.20 |
| Palm oil | 3.80 | 2.00 | 2.00 | 2.00 |
| Lysine | 0.20 | 0.20 | 0.20 | 0.20 |
| Methionine | 0.10 | 0.10 | 0.10 | 0.10 |
| Vitamin/mineral premix | 0.50 | 0.50 | 0.50 | 0.50 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 |
| Total | 100 | 100 | 100 | 100 |
| ***Calculated nutrients*** | | | | |
| Crude protein (%) | 15.78 | 15.46 | 15.52 | 15.98 |

| | | | | |
|---|---|---|---|---|
| ME (Kcal/kg) | 3195 | 3155 | 3085 | 3069 |
| Ether extract (%) | 4.67 | 4.23 | 3.85 | 3.57 |
| Crude fibre (%) | 4.30 | 4.49 | 4.39 | 4.29 |
| Calcium (%) | 5.50 | 5.50 | 5.50 | 4.60 |
| Phosphorus (%) | 7.30 | 8.50 | 10.10 | 11.90 |
| Lysine (%) | 0.53 | 0.60 | 1.05 | 1.17 |
| Met. + Cys. (%) | 5.20 | 4.90 | 5.60 | 5.90 |

Premix1 vitamin premix (Animal Care OptimixR) supplied per kg of feed: Vit. A 5,000 I.U; D3 3500 I.U; Vit. K 2.5mg; B1 2mg, B2 6mg; B6 4g; Niacin 40mgm; B12 0.02mg; Pantothenic acid 10mg; Folic acid 1mg; Biotin 88mg; Choline chloride 0.5gm; Anti-oxidant 0.125mg; Manganese 0.096gm; Iron 0.24gm; Copper 6x103mg; Iodine 1.4x103mg; Selenium 0.240mg; Cobalt 0.240mg; ME= Metabolisable energy

The pigs were quarantined for one week before the commencement of the experiment during which time they were de-wormed, and treated for ectoparasites using IVOMECTIN® injection (0.5 mls) and ear-notched for identification. All the pigs were fed experimental diets at 6% of their body weight and water *ad libitum*. The pigs were fed twice daily (8:00 am and 4:00 pm) throughout the experimental period. Feed refused was removed, dried, weighed, and recorded daily. Pigs were weighed at the beginning of the trial to determine the initial body weight and at weekly intervals for weight changes. The experiment lasted for 56 days. At the end of the experiment, average daily feed intake, average daily weight gain, feed conversion ratio, feed cost per kg weight gain, and mortality were calculated. The feed cost/kg weight gain was computed as the product of feed cost (per kg) and the feed conversion ratio.

**Statistical analysis**

Data were analyzed using the General Linear Model Procedure of Statistical Analysis software package. Treatment means were separated by Duncan's Multiple Range Tests (Duncan, 1995) of SAS (2002) at P<0.05.

## RESULTS

Table 2 shows the performance of grower pigs fed experimental diets containing varying inclusion levels of blood meal. The daily feed intake of pigs fed Diets 2 and 3 were similar (P>0.05) and significantly (P<0.05) higher than other treatments.

**Table 2: Effect of dietary levels of blood meal on growth performance of grower pigs**

| | Levels of blood meal (%) inclusion | | | | | |
|---|---|---|---|---|---|---|
| Parameters | D1 (0) | D2 (2.7) | D3 (5.4) | D4 (8.1) | SEM | P-Value |
| Initial weight (kg/pig) | 10.33 | 10.16 | 10.16 | 10.16 | 1.16 | 0.05 |
| Daily feed intake (kg/pig) | 1.12$^{c}$ | 1.25$^{a}$ | 1.23$^{a}$ | 1.21$^{b}$ | 0.01 | 0.05 |
| Final weight (kg/pig) | 26.16$^{a}$ | 20.16$^{c}$ | 22.83$^{b}$ | 27.00$^{a}$ | 1.18 | 0.05 |
| Weight gain (kg/pig) | 15.83$^{a}$ | 10.00$^{c}$ | 12.66$^{b}$ | 16.83$^{a}$ | 0.78 | 0.05 |
| Daily weight gain (kg/pig) | 0.28$^{a}$ | 0.13$^{c}$ | 0.22$^{b}$ | 0.30$^{a}$ | 0.01 | 0.05 |
| Feed conversion ratio | 4.00$^{b}$ | 3.50$^{a}$ | 5.45$^{c}$ | 4.04$^{b}$ | 0.34 | 0.05 |
| Feed cost (₦/kg weight gain) | 545.32$^{b}$ | 464.17$^{a}$ | 798.67$^{c}$ | 560.00$^{b}$ | 15.09 | 0.05 |

$^{abcd}$= Means within rows with different superscripts differ significantly (P<0.05)
SEM= Standard Error of Mean.

Daily weight gain (kg) of the pigs ranged from 0.13 to 0.30 kg across the treatments, with values being significantly higher in pigs fed Diet 4 (0.30kg) and lower in those fed Diet 2 (0.13 kg). The feed conversion ratio of pigs fed Diet 2(3.50) was lower and better compared to those on diets D1 (4.00), D3 (5.45) and D4 (4.04). Feed cost (₦/ kg weight gain) during the grower phase for pigs fed 0 and 8.1% BM diets were similar (P>0.05). The feed cost (N/ kg weight gain) of ₦798.67 for pigs fed 5.4% BM inclusion diet was significantly (P<0.05) higher than those on D1, D2, and D4 diets (₦464.17, ₦545.32 and ₦560.00) while those fed a 2.7% BM inclusion diet were lower compared to the of pigs fed D1, D3 and D4 diets. There was no mortality during the experimental period.

**DISCUSSION**

Reduced feed intake by the piglets fed the control diet (without blood meal inclusion) compared to other treatment groups was not expected. A major limitation of blood meal is the poor taste/palatability (Owen *et al*., 1995; Coffey *et al*., 2001; Hans, 2023) and its inclusion in the diets of monogastric might negatively impact feed intake. Reasons have been provided for what could have been responsible for the reduced daily feed intake recorded in the control diet according to Kim *et al*. (2017), blood meal's high protein and iron content may enhance diet palatability, encouraging pigs to consume a diet with BM over the control. They further assert that BM's high lysine content supports growth and feed intake. Kerr *et al*. (2015) infer that BM contains blood meal's high energy density and could support increased feed intake. They further assumed blood meal's protein and amino acid profile may stimulate hormonal responses (e.g., insulin-like growth factor-1) promoting feed intake. Also according to Cromwell (2009), the blood meal's particle size and texture might improve pellet quality, enhancing feed intake. The highest value of daily feed intake in piglets fed diet 2 (2.7% BM) is contrary to the findings of Hans *et al*. (2023) who reported the highest feed intake value in grower pigs at 6.0% BM inclusion in diet. The range of values for daily weight gain (0.13 to 0.30 kg) observed in this study was lower than the range of 509 to 524g reported by Chen *et al.* (2005) and Oscar *et al*. (2012) in the Large white x Landrace breed. It still fell below the range (290 to 347g) observed by Stein *et al*.(2023) when blood meal-incorporated diets were fed to grower pigs. The differences in the values could be attributed to differences in the processing methods, pig's breed used, blood collection time and probably drying methods employed (Derouchey *et al*., 2002; Cromwell, 2009).

The pigs fed an 8.1% blood meal diet had the highest average daily weight gain and attained the highest live weight than those on other diets. This indicates the superiority of the diet and suggests that the inclusion level of BM at 8.1% in the grower diet will enhance weight gain. The reason for the reduced gain in grower pigs fed 2.7% diet compared to those on 5.4 and 8.1% could be attributed to the increased nutrient density (essential amino acids, vitamins and minerals) potentially improving nutrient balance and invariably supporting growth (Kim *et al.,* 2017) However, the performance of pigs fed diet of 8.1% blood meal inclusion differed from the findings of Fombad and Bryant (2004), who recommended that 3.0 to 4.0% of blood meal inclusion improve the feed for better performance in grower pigs. The cost of feed per kg weight gain was lower in pigs fed diet 2 probably due to a slightly better feed conversion ratio.

**CONCLUSION AND RECOMMENDATIONS**

Findings from this study show that: The daily feed intake was similar with growing piglets on 2.7 and 5.4% BM diets and significantly highest compared to others while daily gains were observed to be significantly highest with pigs on 8.1 % BM which was similar to the control (0% BM). The feed conversion and feed cost N/kg weight gain were better and lower respectively for growing piglets on a 2.7% BM diet compared to piglets on other BM diets. There was no deleterious effect on the growth performance of growing pigs fed varying dietary inclusion levels of BM.

For improved growth performance the inclusion of blood meal at 8.10 % in the diet of growing pigs is recommended.

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# NUTRIENT UTILIZATION OF HYBRID AFRICAN CATFISH (*Heteroclarias*) FINGERLINGS FED DIFFERENT INSECTS MEAL

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## ABSTRACT

This study investigated the inclusion of *Zonocerus variegatus* meal (ZVM) and *Cirina butyrospermi* meal (CBM) as partial fishmeal replacements in the practical diets of hybrid African catfish (*Heteroclarias*) fingerlings for 70 days. The study was conducted at the Old Teaching and Research Farm of the Water Resources, Aquaculture and Fisheries Technology, Federal University of Technology Minna. Seven (7) isonitrogenous diets (40 % crude protein) were formulated with varying inclusion levels (0 – 45 %) of ZVM and CBM. The diets were designated as A1 (0 % inclusion: Control), A2 (15 % ZVM0, A3 (30 % ZVM), A4 (45 % ZVM), A5 (15 % CBM), A6 (30 % CBM) and A7 (45 % CBM). Proximate (crude protein, ether extract, moisture, ash, fibre; NFE calculated by difference) and mineral (sodium, potassium by flame photometry; phosphorus by spectrophotometry; calcium, magnesium by EDTA titration) compositions of feed ingredients, formulated diets, and fish carcasses were analysed using standard laboratory techniques. Fish blood samples were collected in a sample bottle via caudal fin bleeding at the beginning and end of the feeding trial. The collected blood samples were taken to the laboratory and analysed for packed cell volume, haemoglobin, red blood cell and platelet count. The results showed that ZVM and CBM inclusion did not negatively affect the physiological response of the fingerlings, as the haematological parameters remained within normal ranges. Significant differences ($p<0.05$) in fish whole-body proximate and mineral content were observed across treatments. This study further demonstrates the potential of ZVM and CBM as sustainable protein sources in *Heteroclarias* fingerling diets, with ZVM showing optimal growth performance at a 15 % inclusion level.

**Keywords:** Aquaculture, *Heteroclarias*, Insect, Meal, Nutrient, Utilization

## INTRODUCTION

The rapid expansion of aquaculture in Nigeria has established it as the second-largest producer in Africa with a leading role in African catfish production (Ogunji and Wuertz, 2023). The development of this sector (aquaculture) became necessary because of the increased pressure on the globally available fisheries stocks (due to noxious fishing methods) and the growing human population which became clear that the capture fisheries have either reached their upper limit or near collapse (Omeje *et al*., 2020). Increased fish production in sub-Saharan Africa is partly attributable to advancements in understanding species-specific nutritional requirements across life stages, improved feed formulation and management, and the adoption of high-density tank farming techniques (Hecht, 2013). Adequate feed intake is crucial for maximizing growth and profitability in aquaculture (Sun *et al*., 2016). The reliability of fishmeal as a protein source in aquaculture is due to its superior nutritional quality, encompassing high palatability, digestibility, attractability, a balanced amino acid profile and other growth factors that satisfy the dietary needs of aquatic organisms (Jannathulla *et al*., 2019; Luthada-Raswiswi *et al*., 2021). While the abundance, affordability, and relatively consistent nutrient composition of plant protein sources have generated interest in aquaculture, their application remains limited by factors such as low digestibility, imbalanced essential amino acid profiles and the presence of antinutritional compounds (Jannathulla *et al*., 2019). Numerous studies have investigated the partial or complete replacement of fishmeal with alternative animal protein sources in aquaculture feeds (Ayinla *et al*., 1994; Fasakin *et al*., 2003; Sogbesan *et al*., 2005; Ndako *et al*., 2019; Oliva-Teles *et al*., 2022).

The polyphagous insect (*Zonocerus variegatus*), a significant pest of food crops across West and Central Africa (Chiffaud and Mestre, 1990; Kekeunou and Tamesse, 2016), exhibits a broad dietary range encompassing numerous plant species, including various cultivated crops and rich in nutrient (Oke *et al*., 2013; Famutimi and Adewale, 2021). Human consumption of *Z. variegatus* as a means of biocontrol has been reported by Idowu and Modder (1996); Ademolu *et al*. (2010). The limited utilization of *Zonocerus variegatus* in animal feed, as noted by Bake *et al*. (2021), is attributable to their low lipid concentration and high chitin content. The Saturniidae species *Cirina butyrospermi* larvae, which feed on *Vitellaria paradoxa* leaves harvested during the rainy season (Payne *et al*., 2020), are a nutritionally rich source of essential vitamins and fatty acids (Yapo *et al*., 2017). These insects possess high nutritional value, providing essential amino acids, vitamins, and fatty acids that can supplement or partially replace conventional, and often more expensive, protein sources like fishmeal (Anankware *et al*., 2021). This substitution could improve feed efficiency and reduce production costs while potentially enhancing fish growth and overall health (Hossain *et al*., 2024). Furthermore, insect meals could contribute to sustainable aquaculture practices by reducing reliance on wild-caught fish for feed production (Singh *et al*., 2023). Aquaculture in Nigeria predominantly involves *Heterobranchus longifilis*, *Heterobranchus bidorsalis*, *Clarias gariepinus*, and *Clarias anguillaris* (Ayinla and Nwadukwe, 1992; Adewumi, 2014). The intergeneric hybrid "*Heteroclarias*," produced by crossing *Heterobranchus* (male) and *Clarias* (female) species, is highly valued for its rapid growth, disease resistance, and feed efficiency (Aluko, 1999; Adewumi, 2014). This study was therefore conducted to assess the effects of varying dietary inclusions of ZVM and CBM on the growth performance of *Heteroclarias* fingerlings.

## MATERIALS AND METHODS

### Study Area

This study was conducted at the Water Resources, Aquaculture and Fisheries Technology (WAFT) Department, Old Teaching and Research Farm, Bosso Campus, Federal University of Technology (FUT) Minna, Niger State, Nigeria (9°40'N, 6°30'E). Located within the Southern Guinea Savanna agroecological zone, the area experiences a bimodal rainfall pattern with a wet season (April-October) and a dry season from November – March (Ibrahim *et al*., 2018).

### Experimental Ingredients

Fishmeal (FM), dried *Zonocerus variegatus* meal (ZVM), soybean meal (SBM), maize meal (MM), starch, vegetable oil and a vitamin/mineral premix were obtained from Kure Ultra-Modern Market, Bosso Local Government Area, Niger State. The soybean was slightly toasted. *Cirina butyrospermi* meal (CBM) was procured from Kutigi Market, Lavun Local Government Area, Niger State. All ingredients underwent individual processing, winnowing, milling, sieving and packed in an airtight polyethene bag until needed. The ingredients were analysed for proximate and mineral compositions (Table 1).

### Diet Formulation

Seven (7) iso-nitrogenous (40 % crude protein) diets were formulated for *Heteroclarias* fingerlings using linear programming (Microsoft Excel) with varying inclusion levels of insects' meal and designated as A1 (0 %: Control), A2 (15 % ZVM), A3 (30 % ZVM), A4 (45 % ZVM), A5 (15 % CBM), A6 (30 % CBM) and A7 (45 % CBM). Feed ingredients were precisely weighed using a weighing (Golden Mettler 2000L: Model) balance. A moist dough was created by homogenizing the ingredients in a plastic bowl with added steam for gelatinization. This dough was then pelletized (2 mm diameter) using a manual pelletizer and oven-dried at 80°C for 40 minutes (Table 2).

**Experimental Fish**

The hybrid African catfish (*Heteroclarias*) fingerlings were obtained from a reputable fish farm in New Bussa, Niger State, and transported in an open plastic container to the experimental site. Upon arrival, they were acclimatized in an outdoor nursery tank (150 cm × 150 cm × 75 cm) for two weeks before the experiment commenced. They were fed a conditioning diet (vital fish feed) twice daily.

**Experimental Conditions**

The experiment was conducted using plastic aquaria (45 cm × 30 cm × 24 cm). Following initial weighing to determine the mean weight (2.28 – 2.29 g), ten (10) fingerlings were stocked per aquarium at the commencement of the trial. The fingerlings were fed to satiation three times daily, with uneaten feed and faecal matter siphoned from aquaria each morning using a 7.5 mm diameter rubber hose. Sampling was done every two weeks. The fish were removed from each aquarium using a hand net and weighed using a sensitive weighing balance (Model: 2000L Golden Mettler). The water samples were collected bi-weekly and transported to the WAFT Department laboratory for analysis (Table 7) of dissolved oxygen (DO), temperature (T), pH, biological oxygen demand (BOD), alkalinity (ALK), water hardness (WH), and electrical conductivity (EC).

**Biochemical Analysis**

The samples of feed ingredients, formulated diets (Table 3) and fish carcasses (Table 6) were taken to the WAFT laboratory for analysis of proximate and mineral compositions. The proximate analysis (crude protein, ether extract, moisture, ash, and fibre content) was conducted according to AOAC (2000) methods. Nitrogen-free extract (NFE) was calculated by difference: 100 – (crude protein + ether extract + moisture + ash + fibre). For mineral analysis, 2 g samples were weighed (Atom-110C balance) in a crucible and ash (M110 muffle furnace at 500 °C for 4 hours), followed by acid digestion (10 ml HCl). The resulting solution was filtered (50 ml volumetric flask), and analysed for sodium (Na) and potassium (K) using flame photometry (Jenway FF-200), phosphorus (P) using spectrophotometry (Jenway 741501), calcium (Ca) via EDTA titration (10 % KOH, casein indicator), and magnesium (Mg) via EDTA titration (ammonia buffer, Eriochrome black T indicator)

**Biological Evaluation**

The nutrient utilization (Table 4) parameters were calculated using the formulae:

iv. Weight gain (WG) = Final weight (Wf) – Initial weight (Wi) of the fish.
v. Specific growth rate (SGR) = ln Wf – ln Wi/T × 100, where: ln Wf = logarithm of the final weight, ln Wi = logarithm of the initial weight, and T = experimental duration.
vi. Feed conversion ratio (FCR) = weight of feed fed (dry weight)/weight gain of fish (wet weight).
vii. Average daily gain (ADG) = mean final body weight – mean initial body weight/number of days of the experiment.
viii. Survival rate (SR) = Nf/Ni × 100, where: Nf = number of alive at the end of the experiment, Ni = number stocked at the beginning of the experiment.
ix. Protein retention (PR) = protein gain/protein fed × 100
x. Protein efficiency ratio (PER) = weight gain/protein fed × 100.
xi. Apparent net protein utilization (ANPU) = carcass protein gain (g)/protein fed (g) × 100.
xii. Protein retention efficiency (PRE) = Protein retained/Protein consumed.

**Haematological Indices**

The fish blood samples (Table 5) were collected from each treatment group by bleeding the fish from the caudal fin using a dissecting blade at the beginning and end of the feeding trial as described by Vijayan and Moon (1992); and Stoskoph (1993). The collected blood samples were immediately placed into plastic tubes containing ethylene diamine tetra-acetic acid (EDTA) as an anticoagulant and transported to the Veterinary Hospital laboratory (Niger State Ministry of Livestock and Fisheries Minna) for analysis. The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated using the formulae described in Adamu and Solomon (2015). MCV (fl) = PCV/RBC × 10; MCH (pg) = Hb/RBC × 10 and MCHC (g/dl) = Hb/PCV × 100

**Data Analysis**

The collected data were analysed using one-way analysis of variance (ANOVA) with the aid of a statistical package for the social sciences (SPSS) version 27. Treatment means were compared using Duncan's Multiple Range Test (DMRT). Statistical significance was set at 5 % ($p<0.05$).

## RESULTS AND DISCUSSION

The result in Table 1 revealed that ZVM has a crude protein (46.31 %) and lipid content (14.14 %) while CBM has 39.38 % and 18.41 % respectively. Bake *et al*. (2021) reported a crude protein of 44.22 % and 4.15 % lipid for ZVM. Emmanuel *et al*. (2023) reported 18.13 % crude protein and 2.03 % lipid for CBM. The variations may be attributed to different environments, processing methods and seasons. The nutritional suitability of any feed ingredient for aquaculture can be assessed by quantifying its proximate composition, specifically moisture content, crude protein, lipid content, and ash content (Sogbesan and Ugwumba, 2008). Fish growth rates exhibit a strong correlation with the digestibility of nutrients in their diet. Therefore, accurate assessment of a novel feed ingredient requires discerning its effects on fish feed intake from its effects on nutrient digestibility and utilization, a process complicated by inherent variability in nutrient utilization among fish species (Glencross *et al*., 2007). The weight obtained from this study revealed that fish fed A2 had the highest weight gain (26.08 g) and differed significantly ($p<0.05$) from the fish fed A1 (17.02 g: control diet). However, it does not differ significantly ($p>0.05$) from the fish fed A3, A4, A5, A6 and A7. This suggests that ZVM and CBM inclusion at all levels tested did not negatively affect the growth rate. It also demonstrated that 45 % ZVM and CBM inclusions improved growth rate and nutrient utilization compared to the control diet. Consequently, fish fed the experimental diets showed similar growth patterns (Figure 1) and nutrient utilization. The FCR ranged between 1.28 – 1.96 while PR ranged between 30.16 – 33.17 and were not significantly different. There were significant differences among the treatment means in PER, though the fish-fed A2 had the highest value (0.65) while the fish-fed A1 had the lowest value (0.42). This result is similar to that reported by Alegbeleye *et al*. (2012) and Anvo *et al*. (2017).

The haematological parameters measured in this study are consistent with the physiological ranges reported for clariid catfish in various studies (Akinrotimi *et al*., 2011; Eyiwunmi *et al*., 2018; Abdel-Hay *et al*., 2021). The PCV ranged between 14.00 – 31.33 % and higher compared to the initial (13.67 %). Decreased blood PCV often indicates dietary toxins that impair blood formation (Tiamiyu *et al*., 2019). The results (Table 6) of whole-body protein vary significantly among the treatment means. The crude protein ranged between 50.84 – 62.61 %. The ether extract increased with higher inclusion levels of ZVM and CBM. This could be attributed to the high lipid content of the insect's meal. Fish lipid content exhibits inter- and intra-specific variation, influenced by temperature, salinity, season, fish size and age, habitat, life stage and dietary compositions especially whether a species is herbivorous, omnivorous or carnivorous (Saito *et al*., 1999; Hossain, 2011).

The mineral compositions of the fish's whole body vary significantly ($p<0.05$) among the treatment means and across the tested parameters. The fish fed A5 had the highest sodium content (0.56 k/kg), A2 had the highest calcium content (0.54 g/kg) and A3 had the highest magnesium content (0.44 g/kg). The result from this study did not corroborate with the findings of Toko *et al*. (2008) while investigating the mineral status of African catfish (*Clarias gariepinus*) fed diets containing graded levels of soybean or cottonseed meals. The variations may be attributed to different experimental fish, diets and environments. Pravina *et al*. (2013) reported that calcium plays a vital role in numerous physiological processes, including muscle contraction, oocyte activation, bone and tooth mineralization, blood coagulation, nerve impulse transmission, cardiac function and intracellular fluid balance. Mineral deficiencies in fish led to skeletal deformities, immunosuppression and anaemia (Shefat, 2018). The water quality variables (Table 7) measured were all within the acceptable range of fish culture as reported by Bake *et al*. (2021). This is evident as high survival rates were recorded across the experimental fish.

## CONCLUSION

In conclusion, proper processing of feed ingredients increases their nutrient compositions. The growth performance and low mortality rates observed in this study demonstrate the suitability of ZVM and CBM as ingredients in *Heteroclarias* fingerlings diets. Furthermore, the absence of adverse physiological effects on the experimental fish suggests that the inclusion of these ingredients (up to 45 %) does not compromise fish health or development. However, for optimal weight gain, ZVM could be included in the diet of *Heteroclarias* fingerlings at 15 %.

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**Table 1: Proximate and Mineral Compositions of the Major Feed Ingredients**

| **Ingredients** | **Proximate Compositions (%)** | | | | |
|---|---|---|---|---|---|
| | **FM** | **ZVM** | **CBM** | **MM** | **SBM** |
| Crude protein | 56.88 | 46.31 | 39.38 | 9.62 | 43.01 |
| Ether extract | 12.98 | 14.14 | 18.41 | 6.71 | 21.39 |
| Crude fibre | 0.00 | 19.65 | 7.00 | 2.55 | 6.22 |
| Ash content | 13.37 | 5.89 | 6.69 | 1.54 | 5.36 |
| Moisture content | 10.43 | 12.40 | 13.64 | 9.05 | 3.73 |
| Nitrogen free extract | 6.34 | 1.61 | 14.88 | 70.53 | 20.29 |
| | **Mineral Compositions (g/kg)** | | | | |
| Sodium | 1.52 | 1.42 | 1.30 | 0.09 | 0.06 |
| Potassium | 8.56 | 5.46 | 0.54 | 0.83 | 1.76 |
| Phosphorus | 0.21 | 0.12 | 0.13 | 0.06 | 0.09 |
| Calcium | 1.88 | 1.29 | 1.36 | 1.26 | 0.21 |
| Magnesium | 0.77 | 0.44 | 0.70 | 0.43 | 0.51 |

**Table 2: Compositions of the Experimental Diets**

| **Ingredients/Treatments** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** |
|---|---|---|---|---|---|---|---|
| *Cirina butyrospermi* meal | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 30.00 | 45.00 |
| *Zonocerus variegatus* meal | 0.00 | 15.00 | 30.00 | 45.00 | 0.00 | 0.00 | 0.00 |
| Maize meal | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 7.00 |
| Fishmeal | 64.76 | 54.37 | 43.98 | 33.59 | 57.38 | 49.90 | 38.00 |
| Soybean meal | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Starch | 12.32 | 9.17 | 6.02 | 1.41 | 6.98 | 0.00 | 0.00 |
| Vegetable oil | 2.92 | 1.46 | 0.00 | 0.00 | 0.64 | 0.10 | 0.00 |
| Vitamin/mineral premix | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Energy kcal/100 g | 271.76 | 271.79 | 271.83 | 284.54 | 264.62 | 272.59 | 279.96 |

**Table 3: Proximate and Mineral Compositions of the Experimental Diets**

| Treatments/ Parameters | Proximate Compositions (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A1 | A2 | A3 | A4 | A5 | A6 | A7 |
| Crude protein | 39.21 | 39.78 | 39.18 | 38.89 | 39.43 | 40.03 | 38.22 |
| Ether extract | 10.97 | 10.95 | 10.19 | 11.31 | 7.37 | 12.19 | 7.40 |
| Crude fibre | 2.52 | 3.32 | 3.86 | 4.32 | 2.84 | 2.58 | 4.04 |
| Ash content | 11.06 | 13.77 | 13.31 | 13.44 | 13.76 | 13.91 | 14.18 |
| Moisture content | 6.88 | 4.91 | 6.82 | 4.74 | 6.77 | 5.86 | 6.67 |
| Nitrogen free extract | 29.36 | 27.27 | 26.64 | 27.30 | 29.83 | 25.43 | 29.49 |
| | **Mineral Compositions (g/kg)** | | | | | | |
| Sodium | 0.48 | 0.38 | 0.45 | 0.67 | 0.58 | 0.57 | 0.45 |
| Potassium | 1.02 | 1.04 | 1.24 | 1.61 | 0.90 | 1.21 | 1.07 |
| Phosphorus | 0.11 | 0.14 | 0.14 | 0.16 | 0.09 | 0.10 | 0.11 |
| Calcium | 0.29 | 0.20 | 0.25 | 0.24 | 0.26 | 0.27 | 0.23 |
| Magnesium | 0.52 | 0.34 | 0.46 | 0.53 | 0.44 | 0.45 | 0.38 |

**Table 4: Nutrient Utilization of the Experimental Fish Fed the Diets for 70 Days**

| Parameters/ Treatments | A1 | A2 | A3 | A4 | A5 | A6 | A7 | ±SE |
|---|---|---|---|---|---|---|---|---|
| IW(g) | 2.29 | 2.29 | 2.29 | 2.2 | 2.29 | 2.29 | 2.28 | 0.00 |
| FW (g) | $19.31^{b}$ | $28.37^{a}$ | $22.87^{ab}$ | $23.70^{ab}$ | $23.95^{ab}$ | $26.38^{ab}$ | $23.25^{ab}$ | 0.96 |
| WG (g) | $17.02^{b}$ | $26.08^{a}$ | $20.58^{ab}$ | $21.42^{ab}$ | $21.67^{ab}$ | $24.09^{ab}$ | $20.97^{ab}$ | 0.96 |
| SGR (%) | $3.04^{b}$ | $3.58^{a}$ | $3.28^{ab}$ | $3.34^{ab}$ | $3.30^{ab}$ | $3.48^{ab}$ | $3.32^{ab}$ | 0.06 |
| FCR | $1.96^{a}$ | $1.28^{a}$ | $1.55^{a}$ | $1.47^{a}$ | $1.60^{a}$ | $1.33^{a}$ | $1.55^{a}$ | 0.08 |
| ADG (g) | $0.24^{b}$ | $0.37^{a}$ | $0.29^{ab}$ | $0.31^{ab}$ | $0.31^{ab}$ | $0.34^{ab}$ | $0.30^{ab}$ | 0.01 |
| SR (%) | $83.33^{ab}$ | $70.00^{b}$ | $83.33^{ab}$ | $86.67^{a}$ | $83.33^{ab}$ | $76.67^{ab}$ | $86.67^{a}$ | 1.86 |
| PR (%) | $33.17^{a}$ | $32.50^{a}$ | $31.78^{a}$ | $31.48^{a}$ | $30.16^{a}$ | $31.47^{a}$ | $32.53^{a}$ | 0.42 |
| PER | $0.42^{b}$ | $0.65^{a}$ | $0.52^{ab}$ | $0.54^{ab}$ | $0.54^{ab}$ | $0.60^{ab}$ | $0.53^{ab}$ | 0.02 |
| ANPU | $21.45^{b}$ | $29.97^{a}$ | $23.37^{b}$ | $8.94^{de}$ | $17.39^{bc}$ | $5.56^{e}$ | $13.19^{cd}$ | 1.87 |
| PRE | $4.41^{ab}$ | $4.82^{a}$ | $4.67^{ab}$ | $4.17^{ab}$ | $4.80^{a}$ | $4.04^{b}$ | $4.19^{ab}$ | 0.10 |

Values in the same row with different superscripts are significantly different ($p<0.05$) from each other

IW = Initial weight, FW = Final weight, WG = Weight gain, SGR = Specific growth rate, FCR = Feed conversion ratio, PI = Protein intake, ADG = Average daily gain, %SR = Percentage survival rate, PR = Protein retention, PER = Protein efficiency ratio, ANPU = Apparent net protein utilization, PRE = Protein retention efficiency

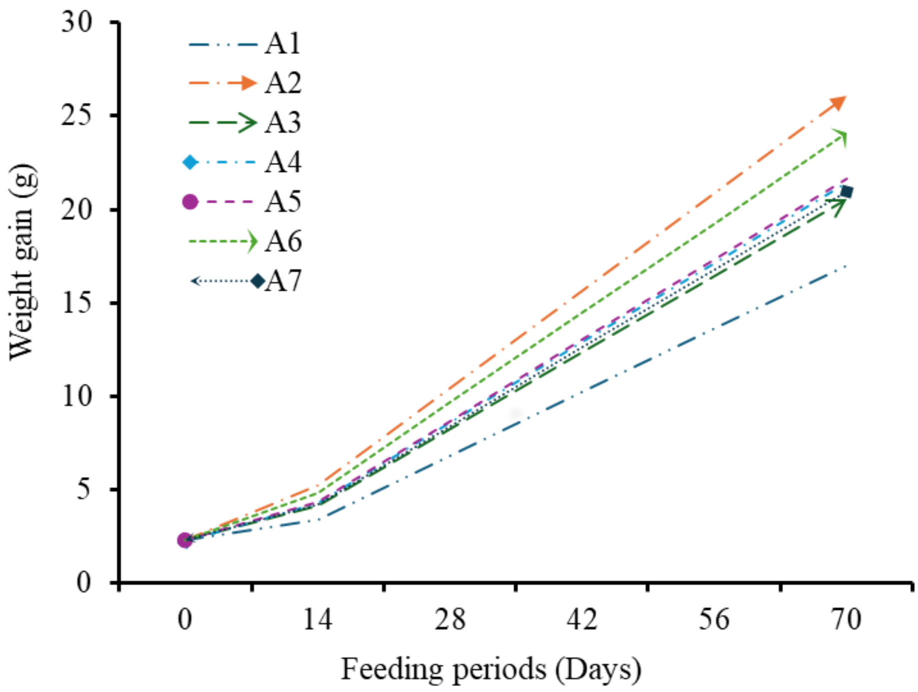


**Figure 1:** **Growth Response Curve of *Heteroclarias* Fingerlings Fed Experimental Diets for 70 Days**

**Table 5:** **Haematological Indices of the Experimental Fish Fed the Diets for 70 Days**

| Parameters/ Treatments | PCV (%) | Hb (g/dl) | RBC (×10^9/l) | WBC (×10^9/l) | PLC (×10^9/l) | MCV (fl) | MCH (pg) | MCHC (%) |
|---|---|---|---|---|---|---|---|---|
| Initial | 13.67 | 4.56 | 2.28 | 0.28 | 102.67 | 60.03 | 20.01 | 33.34 |
| A1 | 17.67$^{b}$ | 5.89$^{b}$ | 2.95$^{b}$ | 0.95$^{b}$ | 116.33$^{c}$ | 59.96$^{a}$ | 19.98$^{a}$ | 33.32$^{a}$ |
| A2 | 14.67$^{b}$ | 4.89$^{b}$ | 2.44$^{b}$ | 0.44$^{b}$ | 115.00$^{c}$ | 60.02$^{a}$ | 20.01$^{a}$ | 33.34$^{a}$ |
| A3 | 31.33$^{a}$ | 10.44$^{a}$ | 5.22$^{a}$ | 3.22$^{a}$ | 231.00$^{a}$ | 59.98$^{a}$ | 19.99$^{a}$ | 33.33$^{a}$ |
| A4 | 15.00$^{b}$ | 5.00$^{b}$ | 2.50$^{b}$ | 0.83$^{b}$ | 112.33$^{c}$ | 59.97$^{a}$ | 19.98$^{a}$ | 33.32$^{a}$ |
| A5 | 17.00$^{b}$ | 5.67$^{b}$ | 2.83$^{b}$ | 0.83$^{b}$ | 116.00$^{c}$ | 59.99$^{a}$ | 20.00$^{a}$ | 33.33$^{a}$ |
| A6 | 14.00$^{b}$ | 4.66$^{b}$ | 2.34$^{b}$ | 0.34$^{b}$ | 125.00$^{c}$ | 59.92$^{a}$ | 19.95$^{a}$ | 33.31$^{a}$ |
| A7 | 28.00$^{a}$ | 9.33$^{a}$ | 4.67$^{a}$ | 2.67$^{a}$ | 197.67$^{b}$ | 60.00$^{a}$ | 20.00$^{a}$ | 33.33$^{a}$ |
| ±SE | 1.42 | 0.47 | 0.24 | 0.23 | 9.56 | 0.01 | 0.01 | 0.00 |

Values in the same column with different superscripts are significantly different ($p<0.05$) from each other

PCV = Packed cell volume, Hb = Haemoglobin, RBC = Red blood cell, WBC = White blood cell, PLC = Platelet count, MCV = Mean corpuscular haemoglobin volume, MCH = Mean corpuscular haemoglobin, MCHC = Mean corpuscular haemoglobin concentration

**Table 6:** **Proximate and Mineral (Carcass) Compositions of the Experimental Fish Fed the Diets for 70 Days**

| Parameters/ Treatments | Proximate Compositions (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | A1 | A2 | A3 | A4 | A5 | A6 | A7 | ±SE |
| Protein | 48.18 | 58.52$^{b}$ | 62.61$^{a}$ | 59.40$^{b}$ | 52.46$^{e}$ | 56.55$^{c}$ | 50.84$^{e}$ | 54.50$^{d}$ | 0.96 |
| Ether extract | 9.16 | 10.37$^{c}$ | 8.81$^{d}$ | 11.02$^{bc}$ | 11.30$^{bc}$ | 10.23$^{c}$ | 11.69$^{b}$ | 14.44$^{a}$ | 0.36 |
| Ash content | 18.18 | 16.91$^{a}$ | 14.69$^{ab}$ | 15.41$^{ab}$ | 14.36$^{ab}$ | 15.40$^{ab}$ | 15.57$^{ab}$ | 12.82$^{b}$ | 0.42 |
| Crude fibre | 7.25 | 5.72$^{d}$ | 5.45$^{d}$ | 6.03$^{d}$ | 8.26$^{b}$ | 6.16$^{d}$ | 9.32$^{a}$ | 7.18$^{c}$ | 0.28 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Moisture content | 6.15 | 5.28$^{ab}$ | 4.93$^{b}$ | 5.73$^{ab}$ | 5.49$^{ab}$ | 5.47$^{ab}$ | 5.92$^{a}$ | 5.83$^{ab}$ | 0.11 |
| Nitrogen free extract | 11.09 | 3.20$^{bc}$ | 3.51$^{bc}$ | 2.40$^{c}$ | 8.12$^{a}$ | 6.20$^{ab}$ | 6.67$^{ab}$ | 5.23$^{abc}$ | 0.66 |
| **Mineral Compositions (g/kg)** | | | | | | | | | |
| Sodium | 0.44 | 0.48$^{c}$ | 0.46$^{cd}$ | 0.54$^{a}$ | 0.49$^{bc}$ | 0.56$^{a}$ | 0.54$^{a}$ | 0.52$^{ab}$ | 0.01 |
| Potassium | 1.06 | 1.28$^{bc}$ | 1.70$^{a}$ | 1.27$^{bc}$ | 1.61$^{a}$ | 1.25$^{c}$ | 1.37$^{b}$ | 1.62$^{a}$ | 0.04 |
| Phosphorus | 0.11 | 0.11$^{ab}$ | 0.12$^{a}$ | 0.10$^{b}$ | 0.11$^{ab}$ | 0.11$^{a}$ | 0.12$^{a}$ | 0.11$^{ab}$ | 0.00 |
| Calcium | 0.42 | 0.39$^{bcd}$ | 0.54$^{a}$ | 0.32$^{cd}$ | 0.31$^{d}$ | 0.29$^{d}$ | 0.47$^{ab}$ | 0.35$^{cd}$ | 0.02 |
| Magnesium | 0.19 | 0.40$^{a}$ | 0.17$^{c}$ | 0.44$^{a}$ | 0.13$^{c}$ | 0.21$^{bc}$ | 0.27$^{b}$ | 0.13$^{c}$ | 0.02 |

Values in the same row with different superscripts are significantly different ($p<0.05$) from each other.

**Table 7: Water Quality Parameters Monitored for 70 Days**

| Parameters/ Treatments | T (°C) | pH | DO (mg/l) | BOD (mg/l) | ALK (mg/l) | WH (mg/l) | EC (µs/cm) |
|---|---|---|---|---|---|---|---|
| Initial | 26.90 | 7.27 | 5.67 | 3.07 | 68.67 | 103.33 | 501.00 |
| A1 | 26.80$^{a}$ | 6.88$^{ab}$ | 6.30$^{a}$ | 4.53$^{a}$ | 75.33$^{b}$ | 113.67$^{b}$ | 558.00$^{b}$ |
| A2 | 27.50$^{a}$ | 6.82$^{ab}$ | 5.97$^{a}$ | 4.03$^{a}$ | 76.00$^{b}$ | 124.00$^{ab}$ | 564.00$^{b}$ |
| A3 | 27.50$^{a}$ | 6.82$^{ab}$ | 6.07$^{a}$ | 4.40$^{a}$ | 79.33$^{ab}$ | 126.00$^{ab}$ | 594.00$^{ab}$ |
| A4 | 27.40$^{a}$ | 6.88$^{ab}$ | 5.97$^{a}$ | 4.10$^{a}$ | 80.00$^{ab}$ | 120.33$^{ab}$ | 600.00$^{ab}$ |
| A5 | 26.80$^{a}$ | 6.68$^{b}$ | 5.97$^{a}$ | 4.13$^{a}$ | 72.00$^{b}$ | 115.00$^{ab}$ | 528.00$^{b}$ |
| A6 | 27.20$^{a}$ | 7.02$^{a}$ | 5.73$^{a}$ | 4.03$^{a}$ | 86.00$^{a}$ | 131.67$^{a}$ | 654.00$^{a}$ |
| A7 | 27.10$^{a}$ | 6.87$^{ab}$ | 6.70$^{a}$ | 4.00$^{a}$ | 75.33$^{b}$ | 120.33$^{ab}$ | 558.00$^{b}$ |
| ±SE | 0.06 | 0.05 | 0.13 | 0.14 | 1.34 | 2.22 | 11.99 |

Values in the same column with different superscripts are significantly different ($p<0.05$) from each other.

T = Temperature, DO = Dissolved oxygen, BOD = Biological oxygen demand, ALK = Alkalinity, WH = Water hardness, EC = Electrical conductivity

# DEFATTED RHINOCEROS BEETLE LARVAE: A POTENTIAL FISHMEAL ALTERNATIVE FOR SUSTAINABLE AQUA-FEEDS

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## ABSTRACT

This study evaluated defatted rhinoceros beetle larvae (*Oryctes rhinoceros*) as a sustainable alternative protein source for aquaculture feed. Abundant in Nigeria, rhinoceros beetle larvae (RBL) initially contain 49.3% crude protein and 21.73% crude fat. Through defatting, the crude protein content increased to 52.1%, while crude fat was reduced to 13.6%, creating a nutrient profile more suitable as a fishmeal substitute. Defatted RBL also provides essential amino acids, such as lysine (6.1 mg/g) and methionine (1.8 mg/g), that could support fish growth and health. Anti-nutritional factors, including tannins and phytates were within safe limits, promoting efficient digestion and nutrient utilization. *In-vitro* digestibility tests revealed an 88% digestibility rate for defatted RBL, closely matching fishmeal's 90% digestibility. These findings highlight the potential of defatted RBL as a nutritionally rich, digestible, and environmentally friendly protein source that could reduce reliance on traditional fishmeal in aquaculture and promoting sustainable fish farming.

**Key words:** Rhinoceros Beetle, Protein, Aqua-feed, Fishmeal

## INTRODUCTION

Aquaculture stands out as one of the fastest-growing food production sectors, with its expansion fueled by the global demand for affordable, high-quality protein sources. Fishmeal, derived from wild-caught fish, has traditionally been the main protein source in aquaculture feeds due to its balanced amino acid profile and digestibility. However, overreliance on fishmeal has led to several critical concerns: unsustainable fishing practices, environmental degradation, and price volatility. These issues underscore the urgent need for sustainable, cost-effective protein alternatives to ensure the industry's future viability (Naylor et al., 2021; Tacon & Metian, 2022). Globally, fishmeal prices have steadily risen due to overfishing and the depletion of wild fish stocks, which are predicted to decline by 10-15% by 2050 if current fishing trends continue (FAO, 2022). The environmental impact of fishmeal production also includes significant carbon emissions, adding to global climate change pressures (Parker et al., 2018). This trend is compounded by increased demand for aquaculture, as fish consumption rises with growing global populations and health-conscious consumers preferring fish as a lean protein source (World Bank, 2023). Given these pressures, researchers and feed producers are actively seeking alternative protein sources that are both sustainable and nutritionally comparable to fishmeal (Henry et al., 2015). Insect-based proteins, in particular, are gaining recognition as promising candidates for fish feed due to their nutrient profiles, lower environmental impact, and efficient production (van Huis, 2019).

Insects such as black soldier fly larvae and mealworms have been extensively studied as aquaculture feed ingredients, but recent research has identified rhinoceros beetle larvae (RBL) as an emerging high-protein alternative (Rumpold & Schlüter, 2013). RBLs are notable for their rapid growth rates, high protein content, and relatively low land and water resource requirements, making them an attractive option for aquaculture. Studies indicate that RBL has a protein content comparable to conventional fishmeal, with essential amino acids needed for fish growth and health

(Kumar et al., 2023). RBL's potential as a fishmeal replacement is also strengthened by the fact that they are less costly to rear compared to other insects, and their production can reduce waste through bioconversion (Barroso et al., 2017). This study aims to evaluate the potential of RBL meal as a fishmeal replacer in aquaculture. It focuses on the processing methods, nutritional composition, anti-nutritional factors, and digestibility of RBL meal. By comparing RBL's nutritional and functional properties with those of conventional fishmeal, this study contributes to ongoing efforts to develop sustainable, alternative protein sources for aquaculture.

## MATERIALS AND METHODS

### Sample Collection and Preparation

Rhinoceros beetle larvae were collected from natural habitats in Okitipupa, Ondo State, Nigeria. Upon collection, the larvae were transported to the laboratory and prepared for further processing. They were dried at 32°C for 72 hours using a laboratory dryer (Model: Germany FP 240).

### Oil Extraction/De-fattening Process

To increase the protein concentration and reduce fat content, an automatic oil extraction machine (Model: ZF-868) was used to defat the insect samples. The dried RBL meal was introduced into the oil press machine, which separated oil from the solid insect meal. The resulting defatted RBL meal was ground into a fine powder for use in feed formulation.

### Chemical Analysis and Nutritional Composition

The proximate composition of RBL, including moisture, crude protein, crude fat, ash, and crude fiber, was analyzed following the protocols established by the Association of Official Analytical Chemists (AOAC, 2015). Crude protein was determined using the Kjeldahl method, while crude fat content was measured using solvent extraction methods. The amino acid profile was analyzed by Ultra High-Performance Liquid Chromatography (UHPLC), and anti-nutritional factors such as tannins, phytates, and oxalates were quantified using established procedures by Onwuka (2005), Lolas and Markakis (1975), and Day and Underwood (1986) respectively.

### Statistical Analysis

All data were measured in triplicate. Data analysis was conducted using Microsoft Excel 2010 and SPSS version 20.0. A T-test with a 0.05 Type I error rate was applied to determine significant differences between groups.

## RESULTS

### Nutritional Profile of Processed RBL Meal

The defatted RBL meal had a high protein concentration of approximately 52.1% after processing, making it a suitable protein source for aqua-feed. The fat content decreased to less than 14% after oil extraction, enhancing the stability of the feed. (Table: 1).

**Table 1: Proximate composition of full-fat RBL, defatted RBL and DFM**

| Nutrient | Full-Fat RBL (%) | Defatted RBL (%) | DFM (%) |
|---|---|---|---|
| Moisture | 9.5 ± 0.1 | 11.8 ± 0.07 | 4.62 ± 0.04 |
| Crude Protein | 49.34 ± 0.2 | 52.10 ± 0.3 | 70.13 ± 0.18 |
| Crude Fat | 21.73 ± 0.13 | 13.60 ± 0.01 | 4.71 ± 0.04 |
| Total Ash | 5.29 ± 0.01 | 6.75 ± 0.00 | 4.39 ± 0.02 |
| Crude Fiber | 12.89 ± 0.08 | 11.49 ± 0.00 | 2.44 ± 0.09 |

Note: DFM = Danish fishmeal, RBL = Rhinoceros beetle larvae: Values are means ± standard deviation

**Amino Acid Profile**

RBL meal contains all essential amino acids, including lysine, methionine, and valine, which are important for fish health and development. The amino acid profile of RBL is comparable to fishmeal, making it a viable alternative. Fatty acid analysis revealed a balanced composition of saturated and unsaturated fatty acids, including linoleic acid and oleic acid, which are beneficial for fish metabolic health (Table: 2).

**Table 2. Amino acid profile of defatted RBL meal and DFM (mg/100g)**

| Essential Amino Acid | RBL Concentration (mg/100g) | DFM Concentration (mg/100g) | Nonessential Amino Acid | RBL Concentration (mg/100g) | DFM Concentration (mg/100g) |
|---|---|---|---|---|---|
| Arginine | 5.5 | 5.19 | Alanine | 2.18 | 5.49 |
| Lysine | 6.1 | 7.61 | Asparagine | N/A | N/A |
| Methionine | 1.82 | 3.88 | Aspartic acid | 1.83 | 7.85 |
| Valine | 5.5 | 4.21 | L-citrulline | N/A | N/A |
| Leucine | 1.86 | 6.42 | Ethanolamine | N/A | N/A |

Note: DFM = Danish fishmeal, RBL = Rhinoceros beetle larvae

**Anti-Nutritional Factors**

The presence of anti-nutritional factors in RBL, such as tannins, oxalates, and phytates, was evaluated. These factors were found to be within acceptable levels, reducing the risk of negative effects on fish digestion and nutrient absorption. The antioxidant content in RBL was moderate, potentially contributing to enhanced feed stability and fish immune response (Table: 3).

**Table 3: Anti-nutritional contents of RBL**

| Anti-Nutritional Factor | Content in RBL (mg/100g) | Acceptable Range for Fish Feed | References |
|---|---|---|---|
| Tannins | $298.15 \pm 0.22$ | < 500 mg/100g | Kumar et al., 2023; Barroso et al., 2017 |
| Phytic acid | $0.419 \pm 0.00$ | < 1 mg/100g | Henry et al., 2015 |
| Oxalic acid | $16.46 \pm 0.01$ | < 20 mg/100g | Rumpold & Schlüter, 2013 |

Note: DFM = Danish fishmeal, RBL = Rhinoceros beetle larvae: Values are means ± standard deviation

**Protein Digestibility**

In-vitro digestibility assays demonstrated high digestibility of RBL meal, reaching values of 88.78 ± 0.0 and comparable to traditional fishmeal (90.61 ± 0.35). This indicates that RBL protein is readily accessible and can be effectively utilized by fish, which is essential for growth performance and feed efficiency in aquaculture.

**DISCUSSION**

The suitability of Rhinoceros Beetle Larvae (RBL) as a fishmeal substitute reflects a promising shift towards sustainable and environmentally friendly protein sources in aquaculture. Fishmeal, while traditionally valuable for fish nutrition, has led to significant ecological challenges due to overfishing and unsustainable harvesting practices. Several studies have studied the protein content in insect meals, including Black Soldier Fly Larvae (BSFL) and mealworms, both of which are commonly used insect proteins in aquafeeds. Van Huis *et al.,* (2021) found that BSFL has a protein content ranging from 40-44%, similar to the 49.34% in defatted RBL observed in this study. The slightly higher protein in defatted RBL positions it competitively among insect meals, though it falls short of DFM's 70.13%. However, Belghit *et al.,* (2019) emphasize that the nutritional adequacy of insect meal depends on the target fish species and dietary formulation, and that inclusion levels can be adjusted to meet specific requirements. These findings suggest that while defatted RBL's protein content is lower than DFM, its digestibility and amino acid profile allow it to meet many of the nutritional needs in formulated diets.

Amino acids, particularly lysine and methionine, are essential for growth in aquaculture. A study by Henry *et al.,* (2015) reported that mealworm protein contains adequate levels of lysine and methionine, comparable to fishmeal, though at a slightly lower concentration. The current study revealed that defatted RBL contains essential amino acids, even at lower concentrations, and comparable with other insect meals like mealworms and BSFL, which have been used successfully in aquaculture diets. Studies such as Nogales-Mérida *et al.,* (2019) have further demonstrated that partial fishmeal replacement with insect meals like BSFL did not negatively impact fish growth in rainbow trout and African catfish, buttressing the fact that defatted RBL could perform similarly when carefully formulated. The presence of anti-nutritional factors in insect meals is often a point of concern. Henry *et al.,* (2015) mention that insects like mealworms and BSFL contain chitin, which can impact digestibility in monogastric species. However, studies have shown that moderate levels of chitin may actually support gut health by promoting beneficial microbiota (Jayanegara *et al.,* 2017). In the present study, anti-nutritional factors in defatted RBL are within safe limits suggesting that RBL's levels of tannins, oxalates, and phytates are unlikely to impact fish negatively if appropriately balanced in the diet.

The environmental sustainability of insect meals has been well documented. Halloran *et al.,* (2017) underscore that insect farming requires minimal land, water, and feed resources, contributing to sustainability in comparison to traditional fishmeal production, which relies on wild fish stocks. The findings of the current study support this, indicating that Defatted RBL offers not only a sustainable alternative to DFM but also an economically feasible option due to its low production costs and adaptability to local production systems. The scalability of insect meal production has been emphasized by Veldkamp *et al.,* (2022), who suggest that insects could meet the growing global protein demand for aquaculture, making RBL a strategic component in sustainable feed formulations.

## CONCLUSION

While DFM remains superior in terms of pure protein content and amino acid concentrations, defatted RBL meals offers viable alternatives for sustainable aquaculture. Studies suggest that insect meals, including RBL, can partially replace fishmeal without compromising fish health or growth performance, particularly when supplemented or combined with other protein sources. Furthermore, the environmental and economic advantages position insect-based diets as a critical component of future aquafeeds.

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# EFFECTS OF DIETARY INCLUSION OF ONION POWDER (*Allium cepa*) ON HAEMATOLOGICAL INDICES OF BROILER CHICKENS

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## ABSTRACT

This study was conducted to determine the effects of dietary inclusion of onion powder (*Allium cepa*) on haematological Indices of broiler chickens. One hundred and twenty (120) unsexed Arbor-acre day old broiler chicks were used for the study. In a completely randomized design chicks were allotted into four treatments: A, B, C, and D with thirty chicks in each. Each treatment was further subdivided into three replicates comprising ten chicks. The chicks were housed in deep litter pens, and fed onion powder (*Allium cepa*) diets incorporated at 0 % (control), 0.2 %, 0.4 %, and 0.6 %, respectively for eight weeks. The data obtained from this study were analyzed using general linear model of Minitab, 2017. The results obtained from the experiment showed White blood cell (WBC), red blood cell (RBC), haemoglobin (Hb), monocyte (MON), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) displayed variations across treatments but showed no statistically significant ($P>0.05$) differences. However, a significant difference ($P<0.05$) was observed in lymphocyte (LYM) levels, with values rising from 77.90 % at 0.0 % inclusion to 81.11 % at 0.6 %. The addition of onion powder in broiler diets had a significant effect on lymphocyte count. The result recommends that onion powder can be a viable natural additive to enhance immune function without compromising blood health.

**Keywords**: Haematological Indices, Broiler chickens, Onion Powder, Dietary Inclusion

## INTRODUCTION

Broiler chickens are essential source of animal protein worldwide, and the poultry industry plays a vital role in meeting the increasing demand for meat products (FAO, 2021). The search for safe, natural, and cost-effective dietary supplements has become an area of interest in the poultry sector to enhance growth performance, health, and productivity (Puvača *et al*., 2020). Recently, researchers have focused on plant-based additives as alternatives to synthetic growth promoters due to their potential health benefits and the growing consumer demand for naturally enhanced animal products (Jing *et al*., 2024). Among these plant-based additives, onion powder (*Allium cepa*) has garnered attention for its potential role in improving the health and productivity of broiler chickens (Malematja *et al*., 2023). Onion, a member of the Allium family, contains bioactive compounds like flavonoids, saponins, and organosulfur compounds, which exhibit antioxidant, antimicrobial, and immunomodulatory properties (Narashans *et al*., 2022). The use of onion powder as a dietary inclusion may contribute to enhanced immune function, improved blood parameters, and increased disease resistance in broilers, making it an area of significant research interest (Abdulkareem *et al*., 2023).

Haematological indices, including red blood cell count, white blood cell count, hemoglobin concentration, and packed cell volume, are vital indicators of health and physiological status in poultry (Onunkwo *et al*., 2022). These parameters are closely linked to the immune response, oxygen transport capacity, and overall well-being of chickens, and they provide insights into how dietary modifications impact poultry physiology (Oke *et al*., 2024). Studies have shown that phytogenic diet composition directly affects these haematological indices, influencing not only growth performance but also disease resistance and stress response (Marimuthu *et al*., 2020). An *et al*. (2015) reported that onion extract in broiler diets positively affected red blood cell count, hemoglobin levels, and hematocrit values, indicating improved health status. The flavonoid quercetin, abundantly found in onions, is believed to contribute to these effects due to its ability to stabilize cellular membranes and modulate immune function (Li *et al*, 2016). Onion powder has also shown potential as a natural antimicrobial agent, which may benefit broiler health by improving gut health and reducing pathogenic bacteria levels (Diya, 2017). The antimicrobial and immunomodulatory properties of onion could help reduce disease incidence and enhance feed efficiency, leading to a healthier flock and improved productivity (Hashemi and Davoodi, 2012). This study aims to examine the effects of dietary inclusion of onion powder on the haematological indices of broiler chickens. Previous research has shown positive results in enhancing immune function, growth performance, and gut health in poultry, but the specific impact on haematological parameters remains underexplored (Asghar *et al*., 2018).

## MATERIALS AND METHODS

### Experimental Location

The experiment was carried out at Ikot Etuk Udo community located in Abak local government area of Akwa Ibom State. Abak local government area is situated in the humid tropics of South-south Nigeria along latitude 4° 58' 56°N and longitude 7° 47' 21°E, providing a unique setting for the study. The area has an elevation of 226 feet, relative humidity of 60-90 %, an annual rainfall of 3500-5000mm, and an average monthly temperature of $24^0$C-$26^0$C (SLUS-AK, 1994).

### Preparation of the Experimental Diets

Fresh Red Globe bulbs (*Allium cepa*) were purchased from Itam market in Uyo, Akwa Ibom state, Nigeria. They were adequately cleaned, peeled, grated into small pieces, and air-dried in a well-ventilated room without direct sunlight exposure. The dried onion pieces were sorted out carefully and then pulverized into powder and stored in air tight bags before proximate analysis (Horwitz and Latimer, 2005).

### Housing

The poultry house had uniform flooring, feeders, and water distribution to ensure optimal living conditions for the birds. All proper biosecurity measures were observed as the poultry house and equipment were fumigated and disinfected using formalin and potassium permanganate. Feeders and drinkers were properly washed with clean water. Highly efficient moisture-absorbent bedding materials were provided and changed regularly.

### Experimental Design and Management of Birds

A total of 120 unsexed Abor acre day-old broiler chicks were obtained for the study. After brooding and necessary vaccination, a completely randomized design, was used to allocate the chicks into four treatments: A, B, C and D with thirty chicks in each. Each treatment was further subdivided into three replicates of ten chicks. The treatments were incorporated at A= 0 % (control), B= 0.4 %-B, C= 0.6 %, and D= 0.8 % of onion powder (*Allium cepa*). The experimental birds were housed in deep litter pens and managed with all necessary routine management and practices adhered to. Adequate feed and water were also supplied *ad-libitum*.

**Collection and analysis of Blood Samples**

At the end of the eighth week, birds were subjected to 12 hours of fasting before slaughtering and blood collection. Two birds per replicate were randomly selected from the three treatments. Twenty-four blood samples (2 ml each) were ethically collected from the birds via and put in ethylene diamine tetra-acetic acid (EDTA) treated bottles. The samples were quickly stored in an ice box, using ice packs, and transferred to the laboratory for hematological analysis within three hours post-sampling.

**RESULTS AND DISCUSSION**

This study examined the effects of dietary inclusion of onion powder (*Allium cepa*) at varying levels (0.0 %, 0.2 %, 0.4 %, and 0.6 %) on the haematological indices of broiler chickens. These indices included White Blood Cell Count (WBC), Red Blood Cell Count (RBC), Hemoglobin (Hb), Lymphocytes (LYM), Monocytes (MON), Packed Cell Volume (PCV), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC). The inclusion of onion powder resulted in specific changes in the haematological parameters of broilers, which may reflect its immunomodulatory and potential health benefits. The white blood cell counts slightly decreased as the onion powder inclusion level increased, with values ranging from 85.41 (0 % onion) to 83.08 (0.6 % onion). However, this reduction was not statistically significant (P>0.05), suggesting that the observed variation might be due to other factors rather than the diet alone. White blood cells are crucial in assessing the immune response, as it indicates the presence of infections or inflammations.

Red blood cell counts increased at 0.2 % and 0.4 % inclusion levels, with counts of 2.92 and 3.73 ×10^6/µl, respectively. At 0.6 % inclusion, the red blood cell count declined to 2.84, but the difference was not statistically significant (P>0.05). Red blood cell indicates oxygen transport efficiency in broilers, and increased red blood cell count can imply enhanced physiological performance. Previous studies suggested that quercetin, a major antioxidant in onions, could improve red blood cell count due to its protective effects on blood cells. This potential improvement in red blood cell with moderate onion inclusion aligns with these antioxidant benefits. Hemoglobin levels slightly increased with the inclusion of onion powder, from 10.13 g/dl at 0 % to 11.10 g/dl at 0.6 %, though not significantly (P>0.05). Higher hemoglobin concentrations improve the oxygen-carrying capacity of blood, which is essential for growth and metabolic efficiency. This trend aligns with the findings of Abd El-Hack *et al*. (2022), who suggested that natural additives like onion powder may enhance hemoglobin levels levels due to the increased bioavailability of minerals involved in hemoglobin synthesis.

A significant increase in lymphocyte percentages was observed with onion powder inclusion, rising from 77.90 % at 0 % to 81.11 % at 0.6 % (P<0.05). Lymphocytes play a vital role in immune responses and are indicators of the health status of broilers. However, this result is at variance with the report of (Kim *et al*., 2015). Monocyte levels decreased with increasing onion powder levels, from 6.17 % at 0 % to 4.91 % at 0.6 %, but the changes were not statistically significant (P>0.05). Monocytes are essential in the immune response, particularly in fighting infections (Kim *et al*., 2011). The reduction in monocytes may indicate an overall enhancement in immune function, possibly due to the antimicrobial effects of onion powder, which reduces the immune load on the birds (Hashemi and Davoodi, 2011).

Packed cell volume values showed no significant changes across the treatment groups (P>0.05), remaining relatively consistent. Packed cell volume is a measure of the proportion of blood volume occupied by red blood cells, and it serves as an indicator of hydration status and anemia in birds. Mean corpuscular volume, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentration values varied slightly but showed no significant differences across treatments (P>0.05). The stability of these indices across onion powder levels suggests that onion supplementation does not significantly (P>0.05) alter the morphology or hemoglobin content of red blood cells. Similar studies have found that Allium-derived products do not markedly impact these indices, indicating a safe profile for onion powder inclusion without hematological

disruptions. Mean corpuscular volume measures the average size of red blood cells, while MCH and MCHC indicate the average amount of hemoglobin per cell and the hemoglobin concentration within cells, respectively (Aditya *et al*., 2017).

Table 2 shows the proximate composition of Onion powder (*Allium cepa*). The results show that the experimental onion extract had moisture (85.17 %), ash (0.59 %), crude fibre (0.60 %), crude lipid (0.71 %), protein (1.84 %), carbohydrate (7.99 %). The carbohydrate content (7.99 %) contributes to the caloric value, while the relatively low levels of ash, crude fiber, and crude lipid underscore its suitability as a low-calorie feed additive. Pareek *et al*. (2017) recorded different moisture, carbohydrates, crude protein, and fats results. The results for ash obtained by Bhattacharjee *et al*. (2013) is lower than those obtained in the present study. The results obtained for moisture, crude protein, lipids, ash, carbohydrates, and crude fiber content were similar to that of the present research Malematja *et al*. (2023).

| **PARAMETERS** | **ONION (*ALLIUM CEPA*) POWDER INCLUSION LEVEL (%)** | | | | | **P-value** |
|---|---|---|---|---|---|---|
| | **0.0** | **0.2** | **0.4** | **0.6** | **SEM** | |
| WBC ($10^3$/µl) | 85.41 | 84.01 | 83.91 | 83.08 | 0.48 | 0.09 |
| RBC ($10^6$/ µl) | 2.71 | 2.92 | 3.73 | 2.84 | 0.23 | 0.52 |
| Hb (g/dl) | 10.13 | 11.00 | 10.57 | 11.10 | 0.22 | 0.71 |
| LYM (%) | $77.90^{c}$ | $78.13^{bc}$ | $80.91^{b}$ | $81.11^{a}$ | 0.95 | 0.03 |
| MON (%) | 6.17 | 5.14 | 5.11 | 4.91 | 0.28 | 0.17 |
| PCV (%) | 33.60 | 31.55 | 32.70 | 32.10 | 0.44 | 0.91 |
| MCV (fL) | 108.11 | 111.61 | 101.90 | 106.71 | 2.01 | 0.19 |
| MCH (pg) | 42.91 | 40.32 | 41.00 | 43.71 | 0.79 | 0.99 |
| MCHC (g/dl) | 29.00 | 31.91 | 30.61 | 30.81 | 0.60 | 0.44 |

Table 1: Haematological Indices of Broiler Chickens Fed Onion powder supplemented Diet

ab mean value in the column bearing different superscript are significantly different (p<0.05)

Note: WBC: White Blood Cell Count, RBC: Red Blood Cell Count, Hb: Haemoglobin, LYM: Lymphocytes, MON: Monocytes, PCV: Pack Cell Volume, MCV: Mean Corpuscular Volume, MCH: Mean Corpuscular Haemoglobin, MCHC: Mean Corpuscular Haemoglobin Concentration.

Table 2: Proximate Composition of Onion Powder (*Allium cepa*)

| Parameter | *Allium cepa* (%) |
|---|---|
| Moisture | 85.17 |
| Ash | 0.59 |
| Crude Fibre | 0.60 |
| Crude Lipid | 0.71 |
| Protein | 1.84 |
| Carbohydrate | 7.99 |

## CONCLUSION

The inclusion of onion powder in broiler diets had specific effects on hematological indices, most notably on lymphocyte count, without adversely affecting other parameters. These findings indicate that onion powder can be a viable natural additive to enhance immune function without compromising blood health. Further studies are recommended to evaluate the long-term impacts of higher inclusion levels and potential effects on other vital broiler health parameters.

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# EXPRESSION OF LIPOPROTEIN LIPASE GENE, MEAT QUALITY AND SENSORY PROFILING OF SOME CHICKEN BREEDS REARED UNDER INTENSIVE MANAGEMENT SYSTEM

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## ABSTRACT

This research evaluates the lipoprotein lipase gene expression, meat quality and sensory parameters in different breeds of Chickens in Southern Guinea Savana of Nigeria. A total of 300-day-old birds of mixed sexes were used in this study. One hundred each of the Fulani ecotype, Noiler and Broiler chicken birds were randomly allotted into three experimental treatments, with each treatment replicated into five containing twenty birds per replicate in a completely randomized design arrangement, with Fulani ecotype as Treatment 1, Noilers as Treatment 2 and Broiler chickens as Treatment 3. The birds were fed an experimental diet containing 21 % crude protein and 2900 Kcal ME/kg in a single-phase feeding regime for 22 weeks for T1 and T2 and 8 weeks for T3. Lipoprotein lipase gene expression, meat quality and sensory parameters of the different breeds of Chickens were determined. The breeds showed no significance ($p>0.005$) differences on the expression pattern of lipoprotein lipase gene of the three breeds of chicken. Lipoprotein lipase was highly upward regulated in Fulani ecotype chickens with a cycle threshold value of 2.61, while there was a downward regulation of the gene in the Noilers and Broilers with cycle threshold values of -0.97 and -1.64, respectively. The meat quality parameters revealed significant ($p<0.05$) differences on the cooking yield percentage, cooking loss percentage, water holding capacity percentage, drip loss percentage and pH percentage across the treatments. The sensory parameters of the breeds showed significant ($p<0.05$) differences on colour, flavour, tenderness, juiciness and general acceptability with the highest in T1 except in T4 that has the highest in tenderness. The findings highlight the nuanced interplay between genetic traits, meat processing methods, and consumer sensory perceptions, emphasizing the need for targeted breeding and processing strategies to optimize meat quality and market acceptability.

**Keywords:** Fulani ecotype chickens, Noiler chickens, Broiler chickens, Intensive management system, RNA extraction, cDNA synthesis

## INTRODUCTION

The quality of poultry meat is influenced by advancements in production, breeding practices, and genetic management (Veronica, 2024). As a primary source of animal protein, chicken plays a crucial role in global consumption, offering a nutritious, affordable, and accessible option for diverse economic groups (Wooming, 2015). Meeting the rising demand for chicken products necessitates targeted breeding objectives to enhance both the quality and quantity of production (Imran *et al.,* 2014; Mazzoni *et al.,* 2015). Commercial chicken breeds are characterized by rapid growth and high feed efficiency but often exhibit low disease resistance, excessive fat accumulation, and suboptimal organoleptic properties, which can deter farmers and investors (Debora *et al.,* 2017). Conversely, local chicken ecotypes are favoured for their superior disease resistance and organoleptic qualities, largely attributed to minimal fat deposition (Debora *et al*., 2017). However, these advantages are offset by their slower growth rates (Ajayi and Agaviezor, 2016).

Fat metabolism plays a pivotal role in growth and quality traits, with lipoprotein lipase (LPL) serving as a key enzyme in lipid breakdown and energy distribution (Andrade, 2018; Mead *et al*., 2002a). The liver is the primary site for lipogenesis in chickens, although genetic background, age, and adipose depot specificity influence lipid synthesis and deposition (Manso Filho *et al*., 2007; Cui *et al*., 2018). Understanding the genetic underpinnings of these metabolic processes is essential for developing marker-assisted selection strategies to optimize local chicken breeds. This study investigated the role of LPL as a candidate gene influencing meat quality, and sensory attributes in Nigerian indigenous chickens. Findings will contribute to genetic databases, providing a foundation for breeding programs designed to enhance the economic viability and consumer appeal of local chicken stocks.

## MATERIALS AND METHODS

### Experimental Location

The research was conducted at the Teaching and Research Farms, Bosso Campus, Department of Animal Production, Federal University of Technology, Minna (latitude 9° 35′ 0.80" N, longitude 6° 32′ 46.74" E). Laboratory works were conducted in the departmental laboratories of Animal Production and Biochemistry of the University, and the African Biosciences laboratory Ibadan. The mean annual rainfall of the study area varies from 1102.6 to 1361.7 mm. The vegetation is Southern guinea savannah, and it lies at an altitude of 147 m above sea level (Njoku *et al*., 2021).

### Experimental Materials

The indigenous birds used in the study include the Fulani ecotype, and Noiler chickens. Parent stock of the Fulani ecotype was sourced from nearby villages within Bosso Local Government Area of Niger State, Nigeria, and used to generate the chicks used for the study. The Noiler and Broiler chickens were procured from Amo hatchery, Ibadan. Maize, maize offal, and protein concentrate used in feed compounding were sourced from the open market and agro-mill shops. Drugs, and vaccines were sourced from an agro veterinary store within Minna metropolis. Feeders and watering trough, wood shavings, and wire mesh used in constructing the pens were all sourced from within Minna. Heat source for brooding the birds was via electric bulb, and charcoal pots.

### Experimental Diet and Design

A total of 300-day-old birds of mixed sexes were used in this study. One hundred each of the Fulani ecotype, Noiler and Broiler chicken birds were randomly allotted into three experimental treatments. Each treatment was replicated five times with twenty birds (20) per replicate in a completely randomized design (CRD). The birds were grouped into three treatments with Fulani ecotype as Treatment 1 ($T_1$), Noiler birds as Treatment 2 ($T_2$) and Broiler birds as Treatment 3 ($T_3$ as the control). The birds were fed an experimental diet formulated to contain 21 % crude protein and 2900 Kcal ME/kg (Table 1) in a single-phase feeding regime. Feed and water were served *ad libitum* throughout the experimental duration of 22 weeks for T1 and T2, while T3 was fed for 8 weeks.

**Table 1: Ingredient and Proximate composition of experimental diet**

| Ingredients | Percentage (%) |
|---|---|
| Maize | 55.32 |
| Maize offal | 05.00 |
| Concentrate | 39.68 |
| Total weight (kg) | 100.00 |
| Proximate analysis | |
| Crude Protein | 21 |

| | |
|---|---|
| Metabolisable Energy (Kcal/kg) | 2,900 |
| Moisture content | 4.2 |
| Crude fiber | 5.5 |
| Crude fat | 7.24 |
| Ash | 9 |
| Nitrogen free extract | 53.05 |

**Management of the Experimental Birds**

The birds were managed using a deep litter system. Before the arrival of the chicks, the pens were cleaned, disinfected/fumigated, and littered with wood shavings up to 5 cm deep. A charcoal fire maintained the temperature in the brooding house. Daily cleaning, Drug administration, and vaccination were carried out until the bird's attained maturity.

**Sample Collection and Handling**

A total of 9 fresh liver tissue samples were collected from three breeds of birds, three each from Fulani ecotype, Noiler and Broiler chickens. Five grams of the fresh liver samples were collected using a surgical knife and gently placed into a sterile Eppendorf tube and completely submerged with RNAlater (an aqueous, non-toxic tissue and cell storage reagent that stabilizes and protects cellular RNA intact) solution. The samples were properly labelled and transported in an icepack to African Biosciences Laboratory, JaaGee House, Ibadan-Ife expressway, Ibadan, Oyo state, Nigeria, within 24 hours of collection, where they were kept under -20 °C in a deep freezer for RNA extraction and Lipoprotein lipase gene expression studies.

**Lipoprotein lipase gene expression/Ct values determination**

The extracted Lipoprotein lipase was converted to their cDNA's using the FIREScript RT cDNA Synthesis KIT according to the procedure explained by Egena *et al.* (2023). The process involved using 1 ul of Reverse Transcriptase, 2 ul of 10x reaction buffer, 0.5 ul RNase Inhibitor (Ribogrip), 0.5ul of primers with a 5-uM concentration and 10ul of the RNA sample (at 50ng/µl). Nuclease-free water was used to balance the reaction volume to 20ul. The thermocycling conditions were as follows: Annealing at 25°C for 10 minutes, Reverse Transcription at 45°C for 30 minutes and Enzyme inactivation at 85°C for 5 minutes. The synthesized cDNAs were amplified using the My IQ single-color real-time cycler. TheqPCRmix used was Solis Biodyne 5x HOT FirePol qPCR supermix plus. The reaction was done in 25µl reactions consisting of 4 µl of the 5x HOTFirepolqPCR Mix, 0.4 µl each of the forward and reverse primers and a specific probe, which had a concentration of 250nM, 18.2 µl of Nuclease-free water and 2 µl cDNA template(100ng). The cycling conditions were as follows: Initial Activation at 95°C for 12 minutes, Denaturation at 95°C for 15 seconds, Annealing at 55 and 53°C for 20 seconds, and Elongation at 72°C for 20 seconds.

**RESULTS AND DISCURSION**

The results of the gene Expression/ relative fold change values determination of Lipoprotein lipase (LPL) genes in Different Breeds of Chickens are shown in Figures 1. These results provide insights into the potential impact of gene expression on fat content in meat. The results showed a highly upward regulation of the Lipoprotein lipase gene in Fulani ecotype chickens with a relative fold change value of 2.61, while there was a downward regulation of the gene in both the Noilers and Arbor acre Broiler chickens with a relative fold change value of -0.97 and -1.64, respectively. The high upward regulation of the gene in the Fulani ecotype is indicative of the presence of low-fat content in the meat from this species of chicken. More so, the downward regulation of the gene in Noiler and Broiler birds is suggestive of the presence of high-fat content in these breeds of chicken. However, as seen from the result of the gene expression, the fat content regulates fat concentration and, as such, more fatty meat.

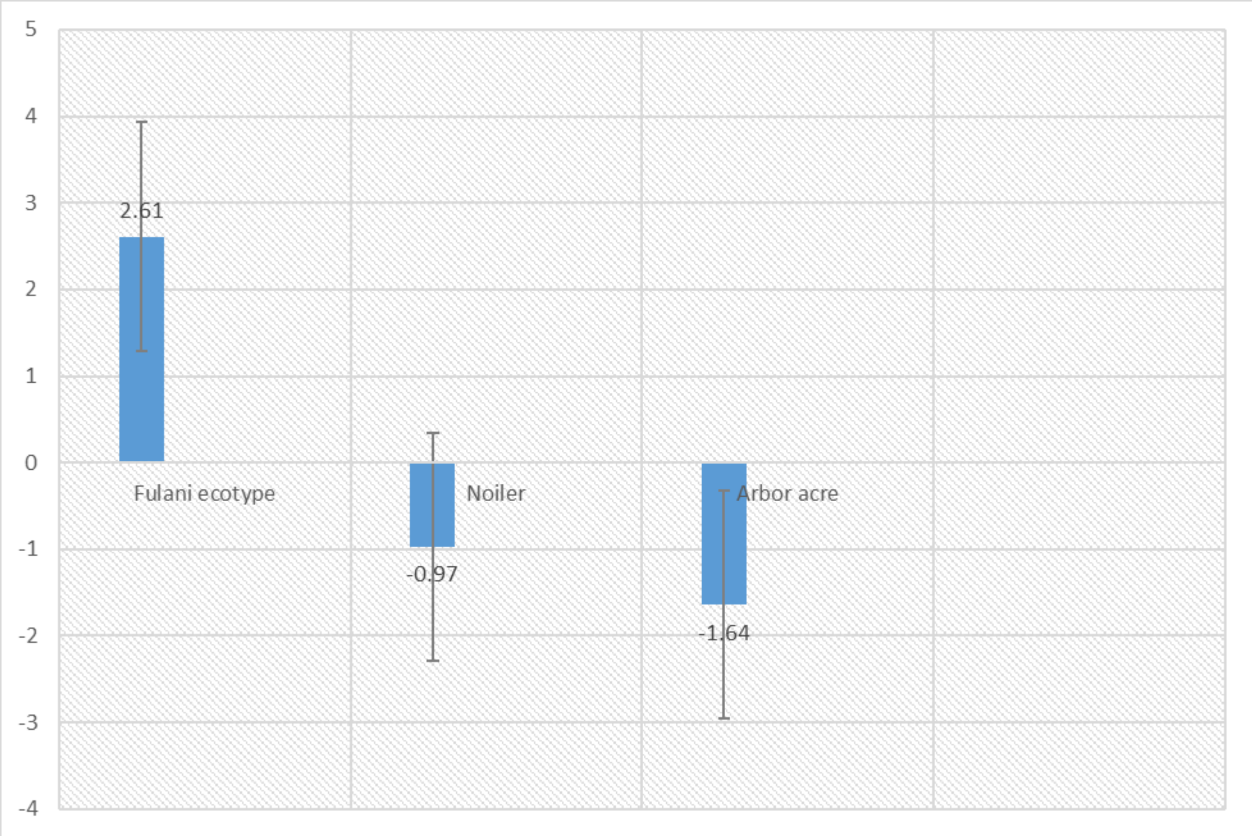


Figure 1: Expression pattern of lipoprotein lipase (LPL) gene of three breeds of chicken.

These results align with the report of Mead *et al.* (2002a), who reported that this gene has been known to play a critical role in regulating the breaking down of fat in the form of triglycerides, which could be more in the Arbor Acre Broiler chickens than in the Noiler birds as results showed a lower downward regulation of the gene in Broiler chickens than in the Noiler chickens. The higher the upward regulation, the more the activity of the gene in regulating fat concentration and, as such, more, leaner meat, while the lower the downward regulation.

The result of meat quality characteristics of selected poultry species in Nigeria presented in Table 1: The meat quality analysis demonstrated significant ($p<0.05$) variations across the treatments in key parameters, including cooking yield, cooking loss, water holding capacity, drip loss, and pH percentages. These findings suggest that the treatments had a measurable impact on the physical and chemical properties of the meat, which are critical indicators of its overall quality and consumer acceptability. Such variations can influence the juiciness, tenderness, and shelf life of the meat, underscoring the importance of these parameters in evaluating meat processing and breeding strategies (Veronica, 2024).

The results of Sensory properties of meat from selected poultry species in Nigeria is presented in Table 2: Significant ($p<0.05$) differences were observed in tenderness, juiciness and overall acceptability. Meat sensory properties mainly comprise meat colour, tenderness, juiciness, and flavour, which greatly influence consumer choice at the point of visual and in-mouth and or nose perception (Font-i-Furnols and Guerrero, 2014). The upward regulation of the LPL gene in the Fulani ecotype chicken is an indication of a better regulation of fatty acid released from lipoproteins, and increased mediation of the uptake and storage of triglycerides in adipocytes. This will translate to better marbling of the meat influencing its palatability. According to Smith and Carpenter (1974), fat could affect meat juiciness by augmenting the water holding capacity, through lubrication of the muscle fibres during cooking, via reducing the tenderness of the meat, and thus, the seeming sensation of juiciness, or by stimulating salivary flow during mastication. Since bettermarbled meat tends to be juicier, these could be the reasons for consumer's appreciation for meat from the Fulani ecotype chicken. One thing that is not too clear though is, how to reconcile this with the actual toughness of meat obtained from the Fulani ecotype chicken particularly when compared to meat from Arbor acre chicken which is more tender and fattier. Further study will be needed to elucidate this discrepancy.

**Table 1: Meat quality characteristics of selected poultry species in Nigeria**

| Parameters | T1 | T2 | T3 | SEM | P –value | L S |
|---|---|---|---|---|---|---|
| Cooking yield % | $73.00^{b}$ | $74.00^{b}$ | $68.00^{a}$ | 0.77 | 0.00 | * |
| Cooking loss % | $27.33^{b}$ | $26.00^{a}$ | $33.00^{c}$ | 0.86 | 0.00 | * |
| WHC % | $6.33^{a}$ | $6.00^{a}$ | $8.00^{b}$ | 0.26 | 0.00 | * |
| Drip loss % | $3.67^{b}$ | $3.00^{a}$ | $5.00^{d}$ | 0.22 | 0.00 | * |
| pH | 6.00 | 6.00 | 6.00 | 0.00 | 0.00 | * |

$^{abc}$: means denoted by different superscripts along the same row differ ($P<0.05$) significantly
*: significant ($P<0.05$); SEM: Standard Error of Mean; LS: Level of Significance
WHC: Water Holding Capacity; %: percentage
T1: Fulani Ecotype; T2: Noiler Chickens; T3: Broiler Chickens (Arbor acre)

**Table 2: Sensory properties of selected poultry species in Nigeria**

| Parameters | T1 | T2 | T3 | SEM | P-value | L S |
|---|---|---|---|---|---|---|
| Colour | 7.67 | 7.45 | 7.20 | 0.10 | 0.09 | NS |
| Flavour | 7.17 | 6.82 | 6.78 | 0.12 | 0.17 | NS |
| Tenderness | $7.20^{ab}$ | $7.02^{b}$ | $7.42^{a}$ | 0.12 | 0.05 | * |
| Juiciness | $7.75^{b}$ | $7.25^{ab}$ | $7.17^{ab}$ | 0.11 | 0.02 | * |
| Acceptability | $8.10^{a}$ | $7.50^{b}$ | $7.80^{ab}$ | 0.09 | 0.04 | * |

$^{abc}$: means denoted by different superscripts along the same row differ ($P<0.05$) significantly
*: significant ($p<0.05$); NS: Not significant ($P>0.05$); SEM: Standard Error of Mean
LS: Level of significance
T1: Fulani Ecotype; T2: Noiler Chickens; T3: Broiler Chickens (Arbor acre)

## CONCLUSION

The Expression pattern/Cycle threshold values of Lipoprotein lipase (LPL) gene have provided details on the inter-muscular and subcutaneous lipid regulatory capabilities of the different Breeds of Chickens in Nigeria. The analysis of meat quality revealed significant ($p<0.05$) variations in critical physical and sensory parameters, such as cooking yield, cooking loss, water holding capacity, drip loss, and pH. These differences underscore the substantial impact of the treatments on both the chemical and sensory qualities of the meat. Enhanced marbling, attributed to the regulation of the LPL gene in Fulani ecotype chickens, likely contributed to improved juiciness and flavour due to its effect on fat distribution. While the Fulani ecotype chicken showed promise in terms of marbling and consumer preference, the observed toughness compared to more tender and fattier Arbor Acre chicken indicates a need for further research. These findings highlight the nuanced interplay between genetic traits, meat processing methods, and consumer sensory perceptions, emphasizing the need for targeted breeding and processing strategies to optimize meat quality and market acceptability.

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# AQUEOUS JAMAICAN YELLOW PEPPER JUICE AND PERFORMANCE CHARACTERISTICS OF THREE STARTER BROILER CHICKENS

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## ABSTRACT

This study was conducted to evaluate the role of aqueous Jamaican yellow pepper juice on the performance characteristics of three breeds of starter broiler chickens. A total of 96 day old and unsexed birds, weighing 42.93, 33.77 and 33.10 kg for Ross 308, Cobb 500 and Arbor acre Plus respectively, were randomly assigned to four treatments, with replicated thrice and containing 8 birds in a completely randomized design arrangement. Treatment 1 (T1) served as the control group while treatments 2, 3, and 4 were Ross 308, Cobb 500, and Arbor Acre Plus birds, respectively. Growth performance indices (initial body weight, final body weight, mean weekly body weight gain, feed conversion ratio, mean weekly feed intake, mean weekly water intake, growth rate), and nutrient digestibility parameters were all evaluated; also, the cost benefit analysis of using the aqueous pepper juice. The results indicated that, only initial body weight and mean water intake differed ($p<0.05$) with T2 birds (Ross 308) consistently having higher values than birds in the other treatment groups. However, no significant ($p>0.05$) differences were observed in the final body weight, mean body weight gain, mean feed intake, and feed conversion ratio. Significant ($p<0.05$) differences were observed in all the parameters measured on nutrient digestibility, with T2 birds (Ross 3|||08) showing better digestibility for most of the nutrients, and T4 birds (Arbor acre Plus) having the least nutrient digestibility values. The cost of feeding per kg body weight gain also differed ($p<0.05$), with T3 birds (Cobb 500) returning the lowest cost, and T2 birds (Ross 308) having the highest. It was concluded that, further research should explore the use of different doses, or combination of pepper juices to determine the optimal level that could possibly impact feed efficiency and growth performance.

**Keywords:** Aqueous pepper juice, Jamaican yellow pepper, Ross 308, Cobb 500, Arbor acre Plus, Cost-benefit analysis.

## INTRODUCTION

Poultry, especially broiler chickens, has been considered as one of the fastest-growing sectors in agriculture worldwide. It is an economically enhancing sector because of its affinity to produce a delicious tasty meat and at a cheap cost (Li *et al*., 2021). However, an increasing human population, and a high demand for meat have created serious challenges for intensive animal rearing, including issues related to animal welfare and pollution of the environment. To minimize these problems, there is a growing interest in employing the use of natural alternative agents (probiotics, prebiotics, organic acids, essential oils), and products from spice plants like Jamaican pepper, sweet pepper, and red pepper derived from *Capsicum annuum* L as against the popular synthetic antibiotics in poultry production (El-Hack *et al.,*2022). Jamaican pepper (containing eugenol as a primary bioactive compound), has antimicrobial properties, maintaining a healthy balance of gut microflora, contribute to better gut health in broilers chickens, and reduces the risk of gastrointestinal infections which could otherwise impair nutrient absorption and overall growth performance; it also plays a role in modulating the immune system of broiler chickens by stimulating the production of antibodies, and making the birds more resistant to infections (Barreto *et al*., 2008; Brenes and Roura, 2010). Its flavour-enhancing properties may increase feed intake, leading to greater body weight gain (Saleh *et al*., 2018).

The use of natural additives such as Jamaican yellow pepper juice in poultry diets, has gained attention due to their potential health benefits and effects on growth performance. Pepper juice (from varieties such as *Capsicum annuum*) is of interest due to its bioactive compounds, including capsaicin, and other phytochemicals that may positively influence digestion, feed conversion, and growth. Therefore, it's important to clearly understand its precise effect on the growth performance of broiler chickens. The beneficial effect of aqueous pepper supplementation in broiler chickens such as Ross 308, Arbor acre Plus, and Cobb 500 had earlier been reported (Egena *et al*., 2023), and it was observed to have had positive effects on feed intake, nutrient digestibility, body weight gain, and feed conversion ratio. These improvements may be associated with the phytochemicals within, and especially capsaicin which could activate the release of digestive enzymes, thus giving efficiency to the digesta, and improving growth performance. However, scanty is the literature associated with the use of Jamaican yellow pepper (in whatever form) and its effect on broiler chicken's performance. The aim of the study therefore, is to evaluate the role of aqueous Jamaican yellow pepper juice on the performance characteristics of three breeds of starter broiler chickens.

## MATERIALS AND METHODS

This experiment was carried out at the Teaching and Research Farm of the Department of Animal Production, Federal University of Technology, Minna, Niger State, Nigeria. Minna is situated between latitude 9° 28' and 9° 37' N, and longitude $6^0$ 23' and $6^0$ 33' E, with an annual rainfall of 1000-1500 mm, and temperature between 38-42°C (Odegbenro and Ojoye, 2022). The fresh pepper juice used for the study was extracted using an extractor (Paloma PL-690 350W, Japan), and stored in a refrigerator at 4°C until when it was required for use. A total of 96 day old and unsexed birds, weighing 42.93, 33.77 and 33.10 kg for Ross 308, Cobb 500 and Arbor Acre Plus, respectively, were fed for 28 days with a commercial feed containing 22 % crude protein, 5 % crude fat, 5 % crude fibre, and 0.45 % available phosphorus. Treatment 1 was the control, treatment 2 had Ross 308 birds, treatment 3 had Cobb 500 birds, and treatment 4 had the Arbor Acre Plus birds. Each treatment was replicated into 3, with each replicate containing 8 birds in a completely randomized design arrangement.

Upon arrival, the birds were weighed to obtain their initial body weight, and given glucose and multivitamins for energy boost, and stress relief. The birds except those on the control were all served 6 ml of the aqueous Jamaican yellow pepper juice mixed with 94ml of water which was finished before fresh water was given *ad libitum* to all the birds for the period of twenty-eight (28) days. Heat was provided with the aid of charcoal stoves, and lighting was supplied throughout the experimental period to enhance illumination, and to aid eating at night. The birds were vaccinated against Newcastle and Gumboro diseases. Other routine management practices were observed throughout the trial.

Data was collected on feed intake, weekly body weight changes, feed conversion ratio, water intake, apparent nutrient digestibility, and cost benefit of giving the aqueous pepper juice. Apparent Nutrient Digestibility (AND) of dry matter, crude protein, crude fibre, ether extract, ash, and nitrogen free extract contents of the feed and feaces were determined using the procedures of AOAC (2005) with the formula;

$$\text{AND (\%)} = \frac{\text{Nutrient in feed consumed - Nutrient voided in faeces}}{\text{Nutrient in feed consumed}} \times 100$$

The cost of feeding per kg was calculated to evaluate the price of feeding each broiler chicken as follows;

Cost of feeding (₦)/ kg of feed = <u>Unit price of feed x Mean feed intake</u>

1000

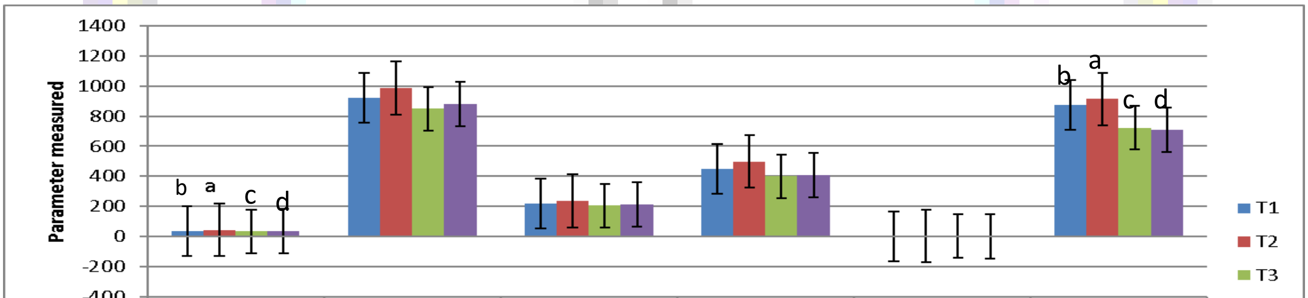
while the cost of feeding per kg body gain was calculate thus;

$$\text{Cost of feeding (₦)/ kg body weight gain} = \frac{\text{Cost of feeding/kg}}{\text{mean body weight gain}} \times 1000$$

Data collected were subjected to one-way analysis of variance using Analystat (an Android enabled statistical software).

## RESULTS

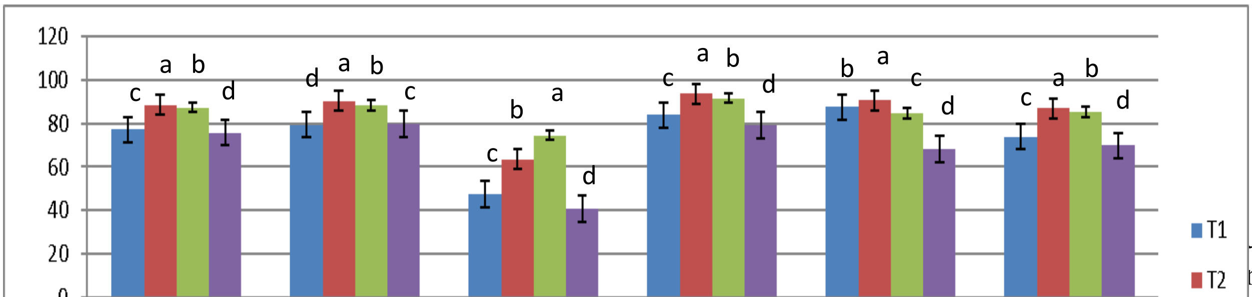
The results of the growth performance of broiler chickens served aqueous Jamaican yellow pepper juice are presented in Figure1. The results revealed that, among all the parameters measured, only the initial body weight and the mean water intake were significant ($p<0.05$), while the final body, mean body weight gain, mean feed intake, and feed conversion ratio were not significantly ($p>0.05$) affected. T2 birds had heavier initial body weight, followed by T1, T3, and the lowest was in T4. Mean water intake followed the same trend, with T2 birds drinking the most water, followed by T1,T3, and T4 in that order.




| | IBW | FBW | MBWG | MFI | FCR | MWI |
|---|---|---|---|---|---|---|
| T1 | 36.45 | 923.93 | 220.87 | 448.31 | 2.03 | 876.05 |
| T2 | 42.93 | 986.67 | 235.94 | 498.25 | 2.11 | 913.1 |
| T3 | 33.77 | 849.66 | 203.97 | 400.35 | 1.97 | 721.81 |
| T4 | 33.1 | 883.41 | 212.58 | 410.25 | 1.94 | 709.98 |

**Figure 1: Growth performance of three breeds of broiler chickens served aqueous Jamaican yellow pepper juice; T1 =control; T2 = Ross 308; T3 = Cobb 500; T4 = Arbor acre Plus**

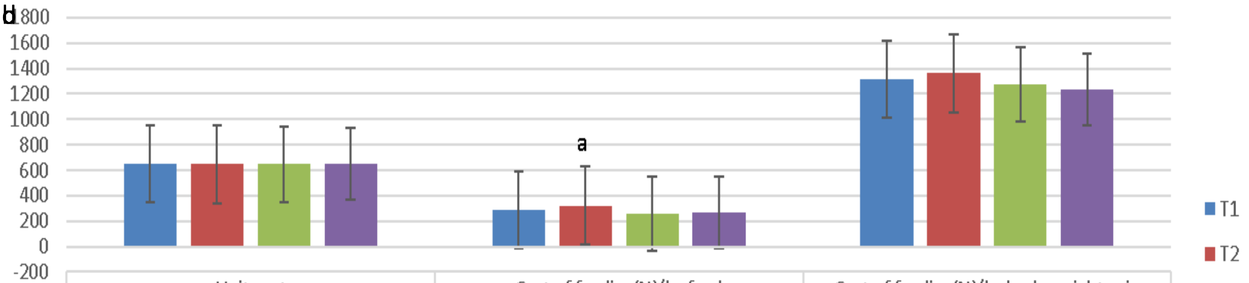
weight of these three breeds, is in contrast to the report of Kareem-Ibrahim *et al.* (2021), that the distribution of initial weight at hatching was not significant among these three breeds. The higher mean water intake observed in Ross 308 birds (T2) may be because the birds in this treatments tolerabled the level or concentration of aqueous Jamaican yellow pepper juice administered, and this may have improved hydration, enhanced feed intake, and improved digestive health, thus resulted in the higher body weight gain in birds. This agrees with McCreery (2015), that high water consumption helps to improve hydration, digestive health, and feed intake.




| | DM | CP | CF | Ash | EE | NFE |
|---|---|---|---|---|---|---|
| T1 | 77.32 | 79.49 | 47.44 | 84.03 | 87.59 | 73.92 |
| T2 | 88.54 | 90.42 | 63.62 | 93.65 | 90.72 | 87.03 |
| T3 | 87.38 | 88.18 | 74.6 | 91.67 | 84.54 | 85.18 |
| T4 | 75.72 | 79.92 | 40.8 | 79.3 | 68.13 | 69.88 |

**Figure 2: Apparent nutrient digestibility of three breeds of broiler chickens served aqueous Jamaican pepper juice at starter phase; T1=control; T1=Ross 308; T3=Cobb 500; T4=Arbor acre Plus**

Jamaican yellow pepper juice given. This result agrees with Egena *et al.* (2023), who reported that, the presence of capsicidins a component of red pepper could affects afferent nerve fibre and appetite




| | Unit cost | Cost of feeding(N)/kg feed | Cost of feeding(N)/kg body weight gain |
|---|---|---|---|
| T1 | 649 | 289.61 | 1313.45 |
| T2 | 649 | 321.87 | 1364.47 |
| T3 | 649 | 258.63 | 1274.91 |
| T4 | 649 | 265.02 | 1234.04 |

Figure 3: Cost benefit analysis of three breeds of broiler chickens served aqueous Jamaican pepper juice; T1 = control; T2 = Ross 308; T3 = Cobb 500; T4 = Arbor acre Plus

The cost benefit analysis showed that T2 birds had the highest cost of feeding/kg feed, and also the highest body weight gain across all parameters measured compared to birds in T3 group which, although the body weight gain and body weight gain per kg feed were not as high as T2 birds recorded the least cost of feeding/kg feed. This shows the need to put into consideration the choice of breed of broiler chickens, if additive, like Jamaican yellow pepper juice is to be given to broiler chickens. This is because, improved body weight gain per kg feed does not sometimes economically translate into lower cost of feeding.

## CONCLUSION

The use of aqueous Jamaican yellow pepper juice as an additive did not significantly improve the growth performance parameters of the three broiler chickens breeds except in the water intake. Treatment 2 birds (Ross 308) consistently performed nominally better across all the parameters measured. The apparent nutrient digestibility coefficients were all influenced across the three breeds of broiler chickens. The lowest cost of feeding/kg feed was observed in T3 birds (Cobb 500).

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# ASSESSMENT OF THE ANTIOXIDANT ACTIVITY OF BLACK PEPPER (*Pipper guineese*)

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**ABSTRACT**

The beneficial effects of black pepper plants on poultry health and growth performance likely may be due to their immune-stimulatory qualities which have also led to their widespread use. Among other spices, black pepper stands out for its strong antioxidant properties, which have garnered attention. The current study used 2, 2-diphenyl-1-picrylhydrazyl (DPPH) as a free radical and ascorbic acid as a benchmark to assess the antioxidant activity of black pepper. The DPPH inhibition activity was carried out using the standard method. The DPPH inhibition activity of the black pepper extract was observed to increase from 24.31% to 69.03% with increasing concentration of the black pepper extract from 0.2 to 1.0 mg/ml. The black pepper extract was noticed to have DPPH inhibition activity and exhibited a dose-dependent trend. The IC50 values for the black pepper and ascorbic acid were 0.725 and 0.320 respectively. Black pepper can serve as a natural alternative to conventional antioxidant feed additives.

**Keywords:** Black pepper, antioxidant, spices, ascorbic acid, herbs, plant.

## INTRODUCTION

There is a growing demand for safe and readily available natural antioxidants to replace synthetic ones. Natural plant products, including herbs, spices, and various plant-derived compounds, have been recognized as effective alternatives to antibiotics, growth promoters, and antibacterial agents, offering numerous health benefits (Al-Sagheer *et al.,* 2019; Abou-Elkhair *et al.,* 2020). *Piper guineense*, a perennial herbaceous plant from the family *Piperaceae* (Nzelu *et al.,* 2020), is predominantly found in tropical regions of Western and Central Africa, particularly in southern Nigeria (Ojiako *et al.,* 2018). Commonly referred to as West African Black Pepper, Benin Pepper, Guinea Pepper, or Ashanti Pepper in English, it is locally known as "masoro" in Hausa, "iyere" in Yoruba, and "uziza" in Igbo (Alagbe *et al.,* 2021). Its greenish-yellow flowers are spirally arranged, and its seeds are reddish-brown when ripe but turn black upon drying, taking on an oval shape (Alagbe *et al.,* 2021). The seeds of *Piper guineense* serve various purposes, including use as a spice, food preservative, herbal medicine, and fragrance in the cosmetic industry (Nwozo *et al.,* 2017). Therefore, the present research work was carried out to assess the antioxidant potential of black pepper and the possibility of its inclusion as a natural feed additive.

## MATERIALS AND METHODS

### Source of Experimental Test Material

Black pepper was sourced from Kure Ultra-Modern Market in Minna, Niger State. The sample was ground into powder using an electric blender.

### Preparation of Sample Extract

One gramme (1g) of the powdered black pepper was weighed into a conical flask. Subsequently, 100 ml of ethanol was added to the flask. The mixture was extracted for 40 minutes in a digital 4-hole water bath (Model: E-Track England) at 70°C. After cooling to room temperature, the extract was filtered using Whatman filter paper (No.1).

**Determination of Antioxidant Activity Using the Free Radical Scavenging Assay**

The antioxidant activity of black pepper was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay, following the method of Mukherjee *et al.* (2011) with minor modifications (using different sample extract concentrations 0.0, .0.2, 0.4, 0.6, 0.8 and 1.0 mg/ml). Ascorbic acid (vitamin C) served as the standard control antioxidant. A solution of DPPH was prepared at a concentration of 100 µM in methanol, adjusted to a final concentration of 0.03 µM. Serial dilutions were performed to calculate the IC50. In 96-well microplate total volume was 100 $\mu$l which was consisting of 90 $\mu$l of DPPH solution and 10 $\mu$l of the test solution. The contents were mixed and incubated for 30 minutes at 37°C. An ultraviolet spectrophotometer was used to determine the absorbance at 517 nm. Ascorbic acid was used as the standard antioxidant. All readings were taken in triplicate and the mean values were then recorded. A decrease in absorbance indicated increased radical scavenging activity and the percentage inhibition of each concentration was calculated using the formula:

$$\text{Percentage inhibition} = \frac{\text{Absorbance of control - Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

## RESULTS AND DISCUSSION

The DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay is a commonly employed technique to assess antioxidant activity. The values obtained from IC50 for the black pepper was 0.725 and 0.320 for the ascorbic acid. In this study, figure 1.0 shows the antioxidant of black pepper extract exhibited scavenging activity ranging from 24.31% to 69.03%, highlighting its potential as a valuable antioxidant source. The increased inhibition activity with higher extract concentrations (0.2 mg/ml to 1.0 mg/ml) as shown in figure 1.0, demonstrates a dose-dependent relationship. Similar trends have been noted in other studies, where the antioxidant properties of plant-based extracts were shown to positively correlate with concentration due to the presence of bioactive compounds such as phenols, flavonoids, and alkaloids (Kumar *et al*., 2018; Balasundram *et al*., 2006). This dose-dependent trend suggests that black pepper extract becomes more effective at higher concentrations, likely due to its richness in piperine—a key bioactive compound recognized for its antioxidant properties (Gorgani *et al*., 2017). When compared to the standard antioxidant ascorbic acid, which demonstrated inhibition ranging from 49.43% to 97.44% within the same concentration range, black pepper showed notable activity, though ascorbic acid remained more potent. These findings align with prior research highlighting black pepper's antioxidant potential, supporting its role in mitigating oxidative stress and related chronic diseases (Singh *et al.*, 2016). This underlines the therapeutic significance of black pepper extract, particularly in developing natural antioxidant products.

## CONCLUSION AND RECOMMENDATIONS

The findings from this study establish that black pepper extract exhibits significant antioxidant activity, as demonstrated through its DPPH free radical scavenging ability. The dose-dependent relationship observed suggests that higher concentrations of black pepper extract provide greater free radical inhibition, which can be attributed to its bioactive components, particularly piperine. Black pepper extract could be used in the formulation of dietary supplements aimed at combating oxidative stress, due to its potent bioactive properties. However, the level of inclusion in the dietary formulation will be determined with experimentation with animals. Additionally, black pepper extract can be explored as a natural additive in functional foods and beverages to enhance their antioxidant capacity.

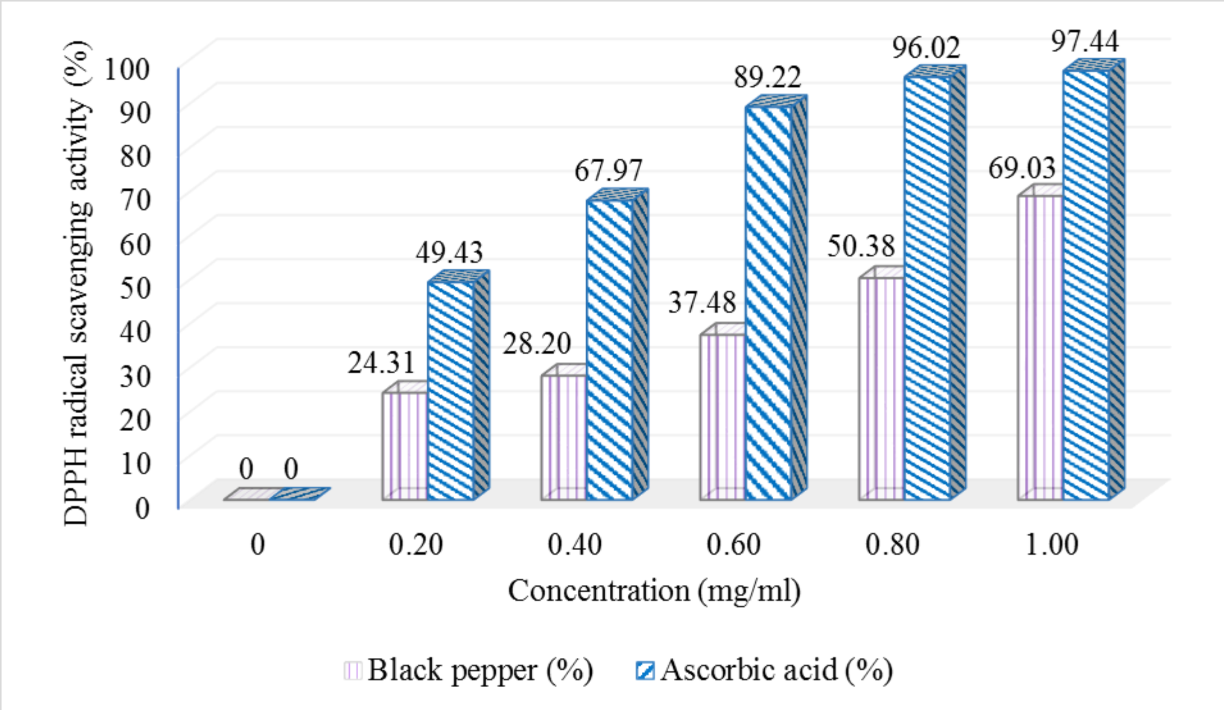


**Figure 1.0: Black pepper antioxidant activity**

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# EMERGING TECHNOLOGIES IN FISHERIES AND AQUACULTURE: A REVIEW

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## ABSTRACT
The growing global population is increasing the demand for protein sources, especially fish, putting pressure on both capture and culture fisheries. Overfishing, habitat destruction, and climate change further strain the sector, highlighting the need for advanced technologies in fisheries and aquaculture. Innovations such as Artificial Intelligence, Robotics, Drones, Sensors/Remote Sensing, IoT, and Blockchain offer promising solutions for improving sustainability, productivity, and efficiency. However, slow adoption due to high costs, lack of awareness, skill gaps, regulatory barriers, data quality issues, and ethical concerns remains a challenge. This review examines the application of these technologies in enhancing fish production, management, and conservation. The findings suggest that emerging technologies have significant potential to increase production, reduce environmental impacts, and promote sustainability in the sector. Future research should focus on developing affordable solutions, understanding consumer attitudes, addressing ethical concerns, improving data quality, and exploring new applications to fully leverage the potential of these technologies in fisheries and aquaculture.
**Keywords:** Fisheries, Aquaculture, Innovation, Sustainability, Emerging Technologies.

## INTRODUCTION
Since the mid-20th century, the integration of technology into our modern world began to accelerate significantly, making it become an integral part of our lives, shaping the way we live, work, and interact. As a result, almost all industries, including fisheries and aquaculture, have embraced the use of technology to enhance efficiency and productivity. Over the past years, the fisheries and aquaculture sector is experiencing significant increase in growth globally (FAO 2020). Aquaculture in particular, shows a significant increase in growth and produces more fish than capture fisheries (Farmery *et al.,* 2022; Rowan 2023). This is as a result of increased depletion in wild fish stock due to habitat loss, climate change, overfishing and other human activities. This necessitates the need for finding solutions to conserve fish stocks, at the same time meet the protein requirements of the ever-increasing human population (FAO 2020; The Fish Site 2024). Technology refers to the application of scientific knowledge to create tools, machines, and systems that improve efficiency, productivity, and quality of life. In simpler terms, technology is anything that helps us do things better or faster than we could without it (Britannica 2023). The aim of technology includes problem solving, innovation, efficiency and improvement. Ab-Rahman *et al*. (2017); Mustapha *et al*. (2021) noted that fisheries and aquaculture stands as a rapidly expanding industry that demands significant technological advancements to improve its practices. Emerging technologies are transforming and

revolutionizing the fisheries and aquaculture sector, offering innovative solutions to address pressing challenges such as overfishing, climate change, and food security (Ab-Rahman *et al*., 2017). This review explores recent advancements in various technologies, including artificial intelligence, robotics, machine learning, virtual reality (VR), 3D printing, drones, sensors/remote sensing, internet of things, blockchain and their potential applications in fisheries and aquaculture management, sustainability, and conservation.

## METHODOLOGY

This review employed a systematic approach to gather, analyze, and synthesize relevant literature on emerging technologies in fisheries and aquaculture.

**Literature Search and Data Collection**

A broad search was conducted using databases like Scopus, PubMed, and Google Scholar, alongside FAO reports. Keywords included emerging technologies, fisheries, aquaculture, AI, blockchain, IoT, and sustainability. Out of 150 screened publications (2016–2024), only those that focused on fisheries and aquaculture were included.

**Inclusion and Exclusion Criteria**

Studies centered on advanced technology applications in fisheries and aquaculture were included, while unrelated or generalized discussions were excluded.

**Critical Analysis and Classification**

Data was analysed to identify themes and categorize technologies based on applications like management, productivity, sustainability, and conservation.

**Comparative Evaluation**

Findings were benchmarked against international standards (e.g., FAO), highlighting challenges and gaps for future research.

**Limitations of the Review**

Reliance on secondary data may introduce biases, and socio-economic or policy factors were less emphasized.

**Emerging Technologies in Fisheries and Aquaculture**

**Artificial Intelligence**

Artificial Intelligence (AI) refers to the capability of computers or computer-controlled devices to perform tasks that mimic human intellectual processes, such as reasoning, learning, and problem-solving (Russell & Norvig, 2016). AI holds immense potential in fisheries and aquaculture, aiding decision-making by processing vast data quickly and accurately (Razman *et al*., 2020). It can predict fish stock abundance by analysing historical and environmental data, optimize feeding strategies through fish behaviour and growth analysis, and detect diseases using image analysis for early intervention. These applications promote sustainability, reduce waste, and enhance efficiency.AI can also automate labour-intensive tasks like harvesting, sorting, and processing fish, improving efficiency, reducing costs, and enhancing worker safety. For instance, AI-powered robots minimize injury risks and ensure product quality during processing and packaging (Liu *et al*., 2023). Additionally, AI improves feeding efficiency by adjusting feed delivery based on real-time data on fish size, growth rates, and environmental conditions, reducing waste and boosting feed conversion rates (Narsale *et al*., 2024). Moreover, AI enables continuous water quality monitoring, assessing parameters such as temperature, pH, and dissolved oxygen. This data can optimize water treatment processes, prevent harmful algal blooms, and automate corrective actions like adjusting water flow or adding treatment chemicals (Mustapha *et al*., 2021). Overall, AI enhances productivity, sustainability, and resource management in fisheries and aquaculture.

**Robotics**

Robotics, the engineering discipline focused on designing and operating robots, plays a transformative role in fisheries and aquaculture by automating labour-intensive tasks, enhancing efficiency, and reducing costs. Autonomous robots can clean ponds, remove debris, and prevent harmful substance buildup, improving environmental conditions (Duckett *et al*., 2018). They can also inspect and repair fishing nets, reducing downtime and boosting catch rates. In aquaculture, robots monitor fish behaviour, detect diseases, and deliver feed efficiently using cameras and sensors to track movements and identify stress or illness. Automated feeders optimize feed delivery, reducing waste and improving conversion rates (Liu *et al*., 2023). Advanced robotics can perform delicate tasks like injecting vaccines or extracting milt with ultrasound-guided needles, improving fish health and productivity. Additionally, robots inspect underwater fishing nets, remove damaged sections, and prevent fish escapes from enclosures, contributing to sustainable and secure operations (Duckett *et al*., 2018; Narsale *et al*., 2024).

**Drones**

Drones, or unmanned aerial vehicles (UAVs), equipped with high-resolution cameras and sensors, offer versatile and cost-effective solutions for aquaculture management. They enable aerial surveillance of fish farms, monitoring overall health, detecting issues like fish escapes, predator threats, and water quality problems (Ubina & Cheng, 2022). Some drones, fitted with waterproof cameras, perform underwater inspections of structures like cages and nets, helping identify damage such as tears or holes. Prompt repairs reduce losses and improve operational efficiency. Additionally, drones gather extensive data on water quality, fish behaviour, and environmental conditions. This data, combined with AI and cloud computing, provides actionable insights to optimize operations. AI can analyse drone footage to detect signs of fish disease or stress, while cloud computing facilitates the storage and processing of large datasets (Mustapha *et al*., 2021). Drones enhance efficiency, sustainability, and precision in aquaculture practices.

**Sensors/Remote Sensing**

Sensors and remote sensing technologies collect data without physical contact, offering valuable tools for fisheries and aquaculture. They monitor water quality parameters like temperature, pH, dissolved oxygen, and salinity, enabling real-time optimization of water treatment processes and prevention of harmful algal blooms (Liu *et al*., 2023; Ubina & Cheng, 2022). Sensors also track fish behaviour, such as feeding frequency and activity levels, to optimize feeding schedules and minimize waste. They measure fish metabolism and heart rates, providing insights into health and stress levels (Mustapha *et al*., 2021). These applications improve fish welfare, feed efficiency, and cost-effectiveness.

**Internet of Things**

Internet of Things (IoT) refers to a network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, and network connectivity. These devices can collect and exchange data, allowing for automation, remote monitoring, and improved efficiency. IoT devices can generate vast amounts of data related to various aspects of aquaculture, such as water quality, fish health, and environmental conditions. By connecting these devices and integrating the data into a centralized platform, stakeholders can gain valuable insights into the industry and make informed decisions. Moreover, Social media platforms can be used to engage with stakeholders and disseminate information (Dupont *et al*., 2018).

**Blockchain Technology**

Blockchain technology, a decentralized and secure digital ledger, offers transparency and immutability, making it valuable for fisheries and aquaculture. It enables secure data sharing and protects sensitive information while enhancing supply chain transparency (Narsale *et al*., 2024; Liu *et al*., 2023). Smart contracts automate payments, ensuring accurate and timely transactions while preventing fraud and illegal fishing. Blockchain provides full traceability across the value chain, verifying product sustainability and quality standards (Mustapha *et al*., 2021). Additionally, it tracks fish product movements, reducing food wastage and improving safety by ensuring proper handling and storage.

**Virtual Reality**

Virtual Reality (VR) is a computer-generated simulation of a 3D environment that users can interact with through devices like headsets or gloves, creating immersive experiences (Britannica, 2023). In fisheries and aquaculture, VR offers diverse applications, including simulating water conditions to study the effects of temperature, salinity, and nutrients on fish health and growth. It can also visualize underwater habitats to explore aquatic ecosystems and dynamics (Liu *et al*., 2023). VR enhances training for fisheries and aquaculture professionals, providing hands-on experiences in safe, controlled environments. It enables aquaculture workers to simulate scenarios like disease outbreaks or equipment failures, preparing them for real-world challenges. For students and professionals, VR creates interactive learning experiences, such as virtual field trips to aquatic habitats, enriching education in aquatic biology. Additionally, VR raises public awareness of fisheries and aquaculture issues through engaging simulations. It allows users to safely experience high-risk environments, like equipment failures or oil spills, teaching safety procedures and hazard management. VR can also simulate remote fishing grounds or aquaculture facilities, enabling risk assessment and strategic planning. Overall, VR serves as a versatile tool for education, training, and environmental exploration in fisheries and aquaculture.

**Table 1: Applications of emerging technologies in fisheries and aquaculture**

| Technology | Applications | Benefits | Source |
|---|---|---|---|
| Artificial Intelligence | Fish stock prediction, disease detection, feeding optimization | Reduced waste, improved efficiency | Russell & Norvig (2016) |
| Robotics | Pond cleaning, net inspection, precise vaccination | Reduced labour costs, enhanced productivity | Duckett *et al*. (2018) |
| Drones | Aerial and underwater farm monitoring | Early problem detection, operational efficiency | Ubina & Cheng (2022) |
| IoT | Real-time water quality monitoring, centralized data management | Improved decision-making, automation | Mustapha *et al*. (2021) |
| Blockchain Technology | Supply chain transparency, fraud prevention | Traceability, consumer trust | Narsale *et al*. (2024) |

**Limitations/Barriers in Adoption of Emerging Technologies in Fisheries and Aquaculture**

**High Initial Cost**

Implementing advanced technologies like AI, IoT, and drones requires significant investment in specialized equipment, software, and expertise. These costs are often prohibitive for small-scale fisheries and aquaculture, especially in developing regions with limited financial resources (Ubina & Cheng, 2022).

**Lack of Awareness**

Many stakeholders in the industry are unaware of the benefits and potential applications of these technologies. This knowledge gap can lead to resistance, with decision-makers hesitant to invest in tools they do not fully understand (Mustapha *et al*., 2021).

**Skill Gap**

Specialized skills are necessary to effectively operate and maintain these technologies. A lack of training among industry professionals limits their adoption and utility (Nirsale *et al*., 2024; The Fish Site, 2024).

**Regulatory Barriers**

Existing regulations often lag behind technological advancements, with areas like data privacy, environmental impact, and safety requiring updates to accommodate new innovations (Ubina & Cheng, 2022).

**Data Quality Issues**

Emerging technologies rely on accurate, reliable data, which can be challenging to obtain, particularly in remote or underdeveloped areas. Cybersecurity threats also pose risks to interconnected systems and sensitive data (Liu *et al*., 2022).

**Need for Robust Training Data**

AI and machine learning require extensive, high-quality training data, which can be costly and time-consuming to collect and process (Liu *et al*., 2023).

**Ethical Concerns**

Technologies raise ethical issues, including privacy violations, job displacement, and environmental impacts. Addressing these concerns is crucial for sustainable and responsible adoption (Ubina & Cheng, 2022).

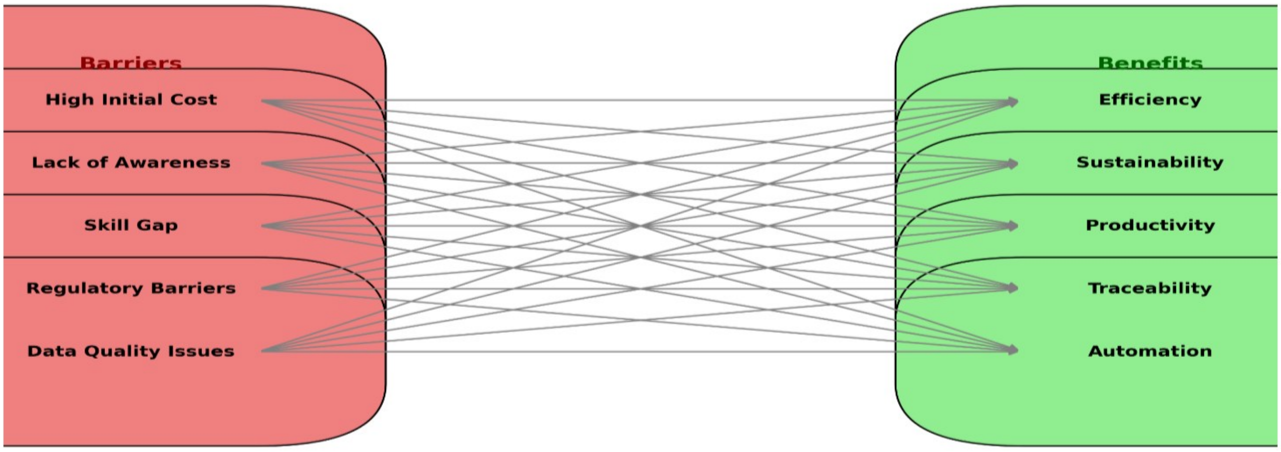


**Figure 1: Adoption barriers and benefits of emerging technologies in fisheries and aquaculture**

## CONCLUSION

Emerging technologies such as AI, robotics, VR, 3D printing, drones, sensors, IoT, and blockchain offer transformative opportunities to optimize fisheries and aquaculture. These innovations can enhance sustainability, efficiency, and profitability in the sector. However, challenges like high costs, data quality issues, skill gaps, consumer acceptance, and ethical concerns hinder widespread adoption. Addressing these barriers is crucial. Future research should focus on developing affordable, accessible solutions, tackling ethical issues, and expanding technology applications to unlock their full potential in revolutionizing fisheries and aquaculture practices.

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# PROXIMATE COMPOSITION AND PHYTOCHEMICAL CONSTITUENTS OF CACTUS PEAR PLANT EXTRACTS USING DIFFERENT SOLVENT

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## ABSTRACT
This study investigates the proximate composition and phytochemical constituents of cactus pear (*Opuntia ficus-indica*) extracts obtained using 100 % water (WE), 50: 50% methanol: water (MWE), 100 % methanol (ME) extraction solvents and fresh cladodes (FC). The proximate and phytochemical analysis revealed significant ($p<0.05$) difference in the samples. The water methanol (WME) extraction solvents samples had higher amount of crude fibre, ash at 3.76 % and 6.26 % while FC samples had the lowest at 2.17 and 4.01 % respectively. There was no significant ($p>0.05$) difference between the water methanol (WME) extraction solvents and, methanol (ME) extraction solvents in crude protein and crude fat. High moisture content of observed in the fresh cladodes at 82.42 %. The phytochemicals constituents indicated that methanol-extracted samples exhibited the highest concentration of total phenolic and flavonoid content, suggesting superior antioxidant activity in the extract compared to other samples. These results highlight the potential of cactus pear plant extract which could be of use as a valuable ingredient in the development of functional foods and nutraceuticals

**Keywords:** Cactus pearl (*Opuntia ficus-indica*), solvent, extract, phytochemicals,

## INTRODUCTION
The cactus pear (*Opuntia ficus-indica* L.) is the most economically significant plant in the Cactaceae family worldwide (Christiana *et al.,* 2018). Both the fruit and cladodes are eaten fresh, but they can also be cooked, dried, canned, or processed into concentrated juices, jams, or syrups. Furthermore, prickly pear has been utilized for phytoremediation, animal feed, biofuel production, and medicinal purposes (Mendoza *et al.,* 2018). In recent years, the utilization of *Opuntia* in functional food development has gained significant attention (Dick *et al.,* 2020). The rising demand for healthy and convenient foods has contributed to the expansion of this relatively new area within the food industry (Oniszczuk *et al.,* 2020). This growing interest in functional foods has prompted the exploration of *Opuntia* cladodes as potential ingredients in novel functional food products.

Phytochemicals in plants contains bioactive substances possessing positive or negative effect depending on the dose, nature of the compound and its bioavailability (Walia *et al.,* 2019). The pear cactus (*Opuntia ficus-indica*), is a rich source of antioxidants such as flavonoids, phenolic acids, and betalains. These compounds have demonstrated the ability to neutralize free radicals, thus protecting cells and DNA from oxidative stress and damage. The consumption of these antioxidants has been associated with a reduced risk of type 2 diabetes and other chronic diseases, including cancer, cardiovascular disorders, and neurodegenerative conditions (Azer *et al.,* 2019). Incorporating *Opuntia* mucilage and cladode flour into cookies, bread, cake, and gluten-free crackers has shown increased total phenolic acid content, antioxidant activity, and sensory acceptance compared to control products (Dick *et al.,* 2020).

Cacti are remarkable plants that have developed unique adaptations to thrive in arid environments, enabling them to survive in conditions characterized by limited water availability. This study aims to investigate the health benefits of cacti found in Minna with a particular focus on the proximate composition and the phytochemical constituents of cactus pear plant extracts utilizing different extraction. By analyzing these phytochemical constituents and their potential applications, this research aspires to unlock the full benefits of these extraordinary plants and promote their sustainable use.

## MATERIALS AND METHODS

### Source of raw material

Fresh cladodes of *Opuntia Ficus indica* were obtained from Murtala Park Garden Minna, Niger state. All samples were washed with clean water, separated into portions, and stored at 4°C prior to processing.

### Preparation of cladode powder extract

Fresh cladodes were selected and the leaf spines carefully removed. The cladodes were then washed in a running water to eliminate any contaminants or other foreign matters. The washed cladodes were then subjected to size reduction using a cutter to enhance their surface area. Thereafter 500g of cladodes was weighed and 100 mL of solvent was added in a blender (Kenwood BLP31.A0 WH) and this was allowed to blend for 15 min at operating speed of 6 to achieve a uniform mixture and followed by filtering (100 µm sieve), this was followed by centrifuging at 1800-3500 rpm and drying in an air draft oven (50 ºC, 3 h) to obtain the extract. The solvents used for the extraction were 100 % water (WE), 50: 50% methanol: water (MWE), and 100 % methanol (ME). Fresh cladodes were also analyzed (FC).

### Proximate and Phytochemical Analyses

The proximate properties of cactus cladodes extracts which include the moisture, crude fat, crude fiber, ash, and crude protein were determined using AOAC (2012) method and carbohydrate was calculated by difference using equation 1;

$$\%\text{Carbohydrate} = 100 - (\text{Moisture} + \text{Crude fibre} + \text{Crude protein} + \text{Ash} + \text{Crude fat}) \quad (1)$$

The phytochemical constituents of the cactus cladodes extracts, which include the flavonoids, alkaloids and glycoside were evaluated according to the method described by Mahadeva *et al.* (2016) while the saponin content was determined using the method described by Lawal *et al.* (2015).

### Statistical Analysis

All data were analyzed in triplicate and One Way Analysis of Variance (ANOVA) and Duncan Multiple Range Test at 5 % significance level were performed using SPSS software version 20 to separate the means.

## RESULTS AND DISCUSSION

### Proximate properties of cactus cladode (*Opuntia ficus-indica)* extract

The proximate composition of cactus pear *(Opuntia ficus-indica)* extracts (Table 1) reveals significant variations in moisture, crude fat, crude fiber, ash, crude protein, and carbohydrate contents, which can be attributed to the different extraction methods employed. The high moisture content in the FC indicates its potential as a hydrating agent, while the lower moisture in ME suggests that methanol effectively extracts with less water retention, making it more suitable for concentrated extract applications (Rao *et al.,* 2020). Fat content varied significantly, with the lowest in ME (0.87%). This implies that polar solvents like methanol are less effective in extracting lipophilic compounds compared to aqueous methods, which may solubilize fats more (Zhang *et al.,* 2019). Fiber content was highest in the water-methanolic extract (WME) at 3.76%, followed closely by WE (3.63%). Concentration factor could probably have played a role as the fresh cladode had the lower fiber content than the powder extract. The significant fiber content in the extracts indicates their potential for promoting digestive health and may also enhance the functional properties of food products (Kumar *et al.,* 2022). Ash content, which reflects the mineral content, was highest in WME (6.26%). The elevated ash content in WME suggests that it effectively extracts essential minerals, making it beneficial for supplementation and health applications (Ali *et al.,* 2023). The protein content varied, with the highest concentration in WE (4.89%) and the lowest in ME (3.40%). This variation may indicate high solubility of proteins in water solvents than methanol. The higher protein content in WE may contribute to its nutritional value, as proteins play a crucial role in various physiological functions (Sahu *et al.,* 2021). The carbohydrate content was significantly high in ME (80.85%), suggesting that methanol extraction is effective in solubilizing carbohydrates, which can serve as a valuable energy source (Odeyemi *et al.,* 2022). The lower carbohydrate content in FC (5.64%) indicates the potential for utilizing the extracts in functional food formulations that require low carbohydrate profiles.

**Table 1. Proximate composition of cactus cladode *(Opuntia ficus-indica)* plants extracts using different solvent**

| **Samples** | **Parameters (%)** | | | | | |
|---|---|---|---|---|---|---|
| | **Moisture content** | **Crude Fat** | **Crude fiber** | **Ash** | **Crude Protein** | **Carbohydrate** |
| WE | $6.52^{bc}\pm0.08$ | $1.25^{a}\pm0.02$ | $3.63^{b}\pm0.02$ | $5.73^{b}\pm0.02$ | $4.89^{a}\pm0.04$ | 77.98b±0.07 |
| WME | $6.66^{b}\pm0.06$ | $1.25^{a}\pm0.00$ | $3.76^{a}\pm0.00$ | $6.26^{a}\pm0.33$ | $4.89^{a}\pm0.00$ | 77.17c±0.39 |
| ME | $5.90^{d}\pm0.03$ | $0.87^{c}\pm0.02$ | $2.87^{c}\pm0.04$ | $6.12^{ab}\pm0.06$ | 3.40c±0.06 | 80.85a±0.06 |
| FC | $82.42^{a}\pm0.10$ | $1.01^{b}\pm0.00$ | $2.17^{d}\pm0.05$ | $4.01^{c}\pm0.01$ | 4.75b±0.02 | 5.64d±0.03 |

Values are means±standard deviation of triplicate determination; means with different superscript in the same column are significantly ($p\geq0.05$) different
WE= Cladodes extract produced using 100% water
WME= Cladodes extract produced using 50% Water and 50% methanol
ME= Cladodes extract produced using 100% methanol
FC= Fresh cladode

**Phytochemical constituents of Cactus cladode *(Opuntia ficus-indica)***

The results of the phytochemical constituents are presented in Table 2. Flavonoids were found in varying concentrations across the different extraction methods, with the methanol extract (ME) showing the highest concentration at 122.19 mg/100g. This increase may be attributed to the efficient extraction properties of methanol in solubilizing flavonoids, aligning with findings by Zbinden *et al.* (2020), who reported enhanced flavonoid extraction with polar solvents such as methanol. Flavonoids are well-documented for their anti-inflammatory and, antioxidant effects (Gani *et al.,* 2012,) indicating the potential health benefits of cactus cladode extracts. Alkaloids were also present, with the highest concentration observed in the methanolic extract (12.46 mg/100g). The presence of alkaloids in *Opuntia* species suggests a possible role in plant defense mechanisms (Ali *et al.,* 2023). Alkaloids have been noted for their therapeutic effects, including anti-inflammatory and antimicrobial properties (Krishnamoorthi *et al.,* 2022). The variation in alkaloid content with different extraction methods emphasizes the significance of extraction parameters in obtaining phytochemicals. The concentration of saponins varied, with the highest level recorded in the fresh cactus pear (7.42 mg/100g) and the lowest in the methanolic extract (2.44 mg/100g). Saponins are known for their amphipathic nature, which contributes to their surfactant properties and may exhibit cholesterol-lowering effects (Sharma *et al.,* 2023). The presence of saponins in cactus pear highlights its medicinal potential, although caution is advised regarding their gastrointestinal effects at high concentrations (Johnson, 2013). Glycosides were found in very low amount compared to other phytochemicals examined and it ranged from 1.42 (ME) - 2.25

mg/100g (WE). Glycosides play essential roles in various biological processes and possess various health benefits, including antioxidant and anti-inflammatory activities (Kregiel *et al.,* 2017). The higher glycoside content in the methanolic extract underscores the efficiency of methanol as a solvent for extracting these compounds.

**Table 2. Phytochemical composition of cactus cladode *(Opuntia ficus-indica)* plants extracts using different solvent**

| Sample | Phytochemicals (mg/100g) | | | |
|---|---|---|---|---|
| | Flavonoid | Alkaloid | Saponin | Glycoside |
| WE | $85.38^{c}\pm0.04$ | $7.65^{c}\pm0.00$ | $5.79^{b}\pm0.00$ | $1.42^{d}\pm0.01$ |
| WME | $108.55^{b}\pm0.09$ | $12.14^{b}\pm0.00$ | $3.53^{c}\pm0.02$ | $1.76^{b}\pm0.00$ |
| ME | $122.19^{a}\pm1.18$ | $12.46^{a}\pm0.10$ | $2.44^{d}\pm0.01$ | $2.25^{a}\pm0.00$ |
| FC | $57.83^{d}\pm0.03$ | $4.32^{d}\pm0.01$ | $7.42^{a}\pm0.00$ | $1.55^{c}\pm0.00$ |

Values are means±standard deviation of triplicate determination; means with different superscript in the same column are significantly ($p\geq0.05$) different

WE= Cladodes extract produced using 100% water
WME= Cladodes extract produced using 50% Water and 50% methanol
ME= Cladodes extract produced using 100% methanol
FC= Fresh cladode

## CONCLUSION

The type of solvents used significantly influenced the proximate and phytochemical parameters of cactus pear extracts using different solvents. These extracts had varied proximate composition with no significant difference in crude protein composition in the 100 % water and 50:50 (water: methanol) extract. In addition, the pear cactus extract using WME had higher ash content. However, the pear cactus extract produced using 100 % ethanol had higher amount of flavonoids, alkaloids, and glycosides. This reveals substantial potential for health benefits, driven by their diverse bioactive compounds. The result confirms the effectiveness of methanol or combined with water in this extraction and this can be utilized in the food and pharmaceutical industries.

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# AMINO ACID PROFILE AND COLOUR CHARACTERISTICS OF PASTA PRODUCED FROM WHOLE WHEAT AND DEFATTED SESAME SEED COMPOSITE FLOUR

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## ABSTRACT

This study assessed the amino acid profile and colour characteristics of pasta produced from flour blends of whole wheat and defatted sesame seeds flour at percentages ratio of 100:00 (WF0), 95:5 (WDS1), 90:10 (WDS2), 85:15 (WDS3) and 80:20 (WDS4). The 100 % (WF0) served as the control and standard analytical protocols were used. The results showed an increase in essential amino acids with leucine, lysine and phenylalanine having dominance and ranged between 6.12 – 7.35 g/100g protein, 3.48 – 6.33 g/100 g protein and 4.36- 4.40 g/100g protein respectively. The defatted sesame seeds showed an appreciable increase in both the essential and non-essential amino acids. The colour of the pasta deepened as the defatted sesame seeds flour substitution increased. The control (WF0) had a higher lightness (L*) and b* values compared with the pasta made from the composite flour blends. Substitution with defatted sesame seeds flour improved the amino acids profile and this could be of nutritional advantage especially in the rural areas in developing countries.

**Keywords**: Composite flour, Wheat grains, Amino acid, Defatted sesame seeds, Pasta

## INTRODUCTION

The high cost of wheat importation has paved way for the use of alternate flours referred to as composite flours. These are produced from locally available crops used to replace or in combination with wheat. It has lately become the subject of focus in innovative flour development in a bid to majorly boost the economy of non-wheat producing countries and minimize total dependence of wheat importation (Ayo- Omogie, 2023). Composite flour has the advantage of providing an improved supply of proteins and other nutrients to better human nutrition and overall health (Hasmadi *et al.,* 2020). Pasta is a common staple food worldwide due to its ease of preparation, good storage stability (dried form), low cost and simple preparation. Conventional pasta contains has low amount of essential amino acids, vitamins and minerals (Sisson, 2022). The role and importance of pasta as a staple food in the human diet has spurred the interest of enriching pasta by fortifying wheat with flour from legumes, vegetable, marine foods, and refined or whole flour from other cereals (Di Pede *et al*., 2021).

Whole Wheat (*Triticum spp.)* grains are mainly milled for the production of wheat flour. Its flour is used in the production of pasta, bread, noodles, biscuits and confectionaries (Shima *et al.,* 2019). Though healthy positive effects and nutritional are ascribed to whole wheat flours due to the fibre and the phytochemicals contents the consumption is reported to be extremely lower than the recommended levels (Li *et al*., 2019). Sesame seeds (*Sesamum indicum* L.), also known as beniseed are an underutilized essential, 'all-purpose nutrient bank' and ancient oil seed crop from the *Pedaliacae* family (Ayo-Omogie, 2023; Wei *et al*., 2022). Defatted sesame is a nutritious by-product obtained after sesame oil extraction (Prakash *et al.,* 2018). It possesses exceptional nutritional value because of its high dietary fibre, certain micronutrients, high-quality protein with a balanced amino acid composition. It is however mostly used in animal feed or discarded (Han *et al*., 2024)

Flour blends formulation using whole wheat and defatted sesame seed flours has been reported to improve the chemical properties of the composite flour and their use in production of food such as pasta has recommended (Ojo *et al*., 2024). Pasta has also been identified as a vehicle delivering a more balanced nutrient and subsequent improvement in human nutrition. This study therefore attempts to further establish and provide a detailed knowledge of the amino acid profile and colour characteristics of the pasta produced. This can facilitate the development of a nutritionally enhanced novel pasta products with visual appeal thereby meeting the needs of the consumers.

## MATERIALS AND METHODS

Materials Procurement and Sample Preparation

Whole wheat flour was purchased from Crown flour mills, Port-harcourt, Rivers state while the sesame seeds (Ex-Sudan) was purchased from the National Cereals and Research Institute, Badeggi, Niger state. The research was carried out in the Food Processing Laboratory, Department of Food Science and Technology, Federal University of Technology Minna

### Production of whole wheat and defatted sesame seeds flour

The whole wheat grains were sorted and wet cleaned to further remove extraneous particles. Wet cleaned grains werenthen solar dried for 48 h, milled and sieving (70 µm sieves) to fine flour and packaged in a Ziplock bag. While the defatted sesame seed flour was prepared using the method described by Chinma *et al*. (2012) with slight modification using n-hexane for oil extraction. The sesame seeds were sorted, soaked (12 h) in a clean tap water at ambient temperature, hand-dehulled by rubbing between palms and drained after the coating has been separated using floatation technique. The dehulled seeds were blanched in water (80 ºC, 5 min), solar dried for 72 h, and milled into flour using attrition mill to obtain fat sesame seeds flour. Exactly, 500 g of sesame seed flour was poured in a white muslin cloth and immersed in an aluminium pan containing 1 L of n-hexane for 12 h to extract the oil. Thereafter, the top layer was decanted and the defatted sesame seed flour was air dried for 3 h and milled using a blender (Kenwood, model: BY-823). The flour was passed through a 70 µm mesh size sieve and stored in plastic containers with lids at 4 °C prior to further analyses

**Production of pasta**

Whole wheat flour and defatted sesame flour formulation for the various pasta were prepared in the ratio of 100:00, 95:5, 90:10, 85:15 and 80:20 respectively. The slightly modified method described by Raji *et al.* (2023) was employed for the production of pasta. In each case, 180 g of flour, 0.15 g of salt and 0.30 g of carboxyl methyl cellulose (CMC) were mixed with 60 mL of water and kneaded for 15 mins to form a dough. The dough was rolled out to form sheets and manually cold-extruded using hand pasta machine at room temperature and passed through 0.28 mm die aperture, dried in an oven at 60 °C for 5 h and packaged in Ziplock bags.

**Determination of amino acid profile**

The method previously described by Chinma *et al*. (2015) was adopted for the determination of amino acid profiles of the pasta samples. The samples were hydrolyzed with 6mol/L HCL at 116 ºC for 24 h prior to analysis. subsequent profiling of amino acids composition of the sample was determined using a high- performance liquid chromatograph (Quasar, PerkinElmer, Hopkinton, USA) coupled with a photodiode array detector (ModelMD-2010; JASCO, Tokyo, Japan), operating at 254nm. The temperature was kept at 40 ºC and the mobile phase was a mixture of chromatographic grade acetonitrile, methanol and acetic acid (10:40:50mL/mL/mL).

**Colour Analysis**

The colour of the pasta samples was measured with a Chroma-meter (Minolta, Tokyo, Japan) equipped with a D 65 illuminant using the CIE L*a*b* system. The L*a*b* (lightness, redness, yellowness) readings were obtained directly from the instrument.

**Statistical Analysis**

Triplicate analysis was performed and the data obtained from all analyses were subjected to statistical analysis. Analysis of variance (ANOVA) was done and significant difference was separated by simple means ($p<0.05$). To distinguish means of significant differences from the ANOVA, the Duncan multiple range test was performed.

## RESULTS AND DISCUSSION

The result of the amino acid composition of the pasta samples are shown in Table 1. Among the essential amino acids, leucine, lysine and phenylalanine were dominant and as expected, higher values of essential and non- essential amino acids were observed in the pasta produced from the composite flour blends and generally increase as the defatted sesame seeds substitution increases. The total essential amino acids were highest in WDS4 at 32.69 g/100g protein which translates to a 27.30 % increase. Likewise, the hydrophobic and hydrophilic amino acids of the control (100 % whole wheat) were the lowest at 26.32 and 13.21 g/100 g respectively. It is interesting to note that a 10.87 % and 36.71 % change were observed also for the hydrophobic and hydrophilic amino acids in this study. Arise *et al*., (2016) reported that the hydrophobic amino acids act as antioxidants by increasing the solubility of peptides in lipids which then facilitates better interaction with free radicals and this could be of health benefit as the pasta samples can be consumed as functional food (Arise *et al.,* 2022). The amount of polar (basic and acid) amino acids ranged between 10.44- 15.00 g/100g protein and 18.13-19.56 g/100g protein respectively. The basic acid is higher in WDS4 (20 % defatted sesame seeds substituted pasta) while the acidic amino acid in sample WH0 (control) was slightly higher than the pasta sample WDS4. This suggests higher protein solubility in sample WDS4. The values of the polar acids are slightly higher than the value reported by Arise *et al*. (2022) on wheat -Bambara nut isolate pasta samples. The sulphur amino acids ranged between 2.80-3.31g/100 g of protein with the highest value at WDS4. These are essential in the initiation of protein synthesis and an average adult requires a 0.9 g/day of methionine and cysteine. This pasta can adequately provide a substantial amount in the human daily requirements.

**Colour characteristics of whole wheat and defatted sesame seeds-based pasta**

The colour of pasta is an important factor in pasta products, its plays an essential role in consumer perception and acceptance. The various pasta samples colour characteristics evaluated in terms of CIE (International Commission on Illumination) values is as summarized in Table 2. Statistical analysis revealed a significant ($p \leq 0.05$) difference in $L^*$, $a^*$, and $b^*$ among the pasta samples. Lightness ($L^*$: 0 is black and 100 is white), was observed in the range of 45.34 – 61.67. The highest L* value was observed in the control sample and there was no significance between the WDS3 and WDS4 pasta samples.

*Table 1. Amino acid profile of pasta produced from wheat and defatted sesames seed composite flour*

| **Amino acid g/100g protein** | **WF0** | **WDS1** | **WDS2** | **WDS3** | **WDS4** |
|---|---|---|---|---|---|
| Valine | $3.32^{d}$±0.03 | $3.43^{c}$±0.04 | $3.34^{c}$±0.04 | $3.60^{b}$±0.03 | $3.73^{a}$±0.06 |
| Isoleucine | $3.02^{e}$±0.04 | $3.21^{d}$±0.01 | $3.26^{c}$±0.03 | $3.68^{a}$±0.08 | $3.49^{b}$±0.05 |
| Leucine | $6.12^{e}$±0.12 | $6.80^{d}$ ± 0.04 | 6. $97^{c}$±0.00 | $7.02^{b}$±0.10 | $7.35^{a}$±0,05 |
| Threonine | $1.34^{d}$±0.04 | $3.34^{c}$±0.15 | $3.50^{b}$±0.31 | $3.51^{b}$±0.90 | $3.62^{a}$±0.04 |
| Methionine | $1.73^{a}$±0.06 | $1.47^{b}$±0.03 | $1.34^{c}$±0.10 | $1.32^{c}$±0.20 | $1.22^{d}$±0.02 |
| Lysine | $3.48^{e}$±0.04 | $5.54^{d}$±0.03 | $5.77^{b}$±0.04 | $5.68^{c}$±0.05 | $6.33^{a}$±0.02 |
| Histidine | $2.31^{c}$±0.01 | $2.30^{c}$±0.01 | $2.43^{b}$±0.15 | $2.43^{b}$±0.03 | $2.57^{a}$±0.03 |
| Phenylalanine | $4.36^{a}$±0.06 | $4.40^{a}$±0.10 | $3.90^{b}$±0.28 | $4.40^{a}$±0.11 | $4.38^{a}$±0.04 |
| TEAA | 25.68 | 30.49 | 30.51 | 31.64 | 32.69 |
| Arginine | $4.65^{e}$±0.04 | $4.93^{d}$±0.05 | $5.52^{b}$±0.06 | $5.41^{c}$±0.01 | $6.10^{a}$±0.01 |
| Proline | $3.51^{bc}$±0.13 | $3.37^{c}$±0.06 | $3.44^{c}$±0.17 | $3.68^{ab}$±0.07 | $3.85^{a}$±0.14 |
| Tyrosine | $3.37^{b}$±0.09 | $3.42^{b}$±0.02 | $3.34^{b}$±0.15 | $3.48^{b}$±0.10 | $4.12^{a}$±0.01 |
| Cystine | $1.28^{d}$±0.04 | $1.49^{c}$±0.09 | $1.46^{c}$±0.06 | $1.71^{b}$±0.04 | $2.09^{a}$±0.03 |
| Alanine | $4.26^{c}$±0.05 | $4.40^{b}$±0.57 | $4.70^{b}$±0.03 | $4.68^{b}$±0.04 | $5.16^{a}$±0.03 |
| Glutamic acid | $12.61^{a}$±0.04 | $11.53^{b}$±0.09 | $11.44^{c}$±0.01 | $11.83^{d}$±0.03 | $11.81^{d}$±0.08 |
| Glycine | $3.15^{c}$±0.05 | $3.26^{c}$±0.11 | $3.58^{a}$±0.02 | $3.41^{b}$±0.05 | $3.60^{a}$±0.02 |
| Serine | $4.07^{abc}$±0.07 | $3.55^{c}$±0.67 | $3.98^{bc}$±0.07 | $4.42^{ab}$±0.07 | $4.63^{a}$±0.08 |
| Aspartic acid | $6.70^{c}$±0.03 | $6.73^{c}$±0.05 | $6.69^{c}$±0.03 | $7.05^{b}$±0.10 | $7.75^{a}$±0.08 |
| TNEAA | 43.60 | 42.68 | 44.15 | 45.67 | 49.11 |
| TAA | 69.28 | 73.17 | 74.66 | 77.31 | 81.80 |
| Hydrophobic AA | 26.32 | 27.08 | 26.95 | 28.38 | 29.18 |
| Hydrophilic AA | 13.21 | 15.06 | 15.86 | 16.53 | 18.06 |
| Basic AA | 10.44 | 12.77 | 13.72 | 13.52 | 15.00 |
| Acidic AA | 19.31 | 18.26 | 18.13 | 18.88 | 19.56 |
| TSulfurAA | 3.00 | 2.96 | 2.80 | 3.03 | 3.31 |

The value are mean of replicate determination. Mean with different superscript in the same row are significantly different ($p>0.05$) while those with same superscript are not significantly different ($p>0.05$).

WF0=100% Wheat flour, WDS1=95% Wheat flour 5% of defatted sesame seed flour, WDS2=90% Wheat flour 10% of defatted sesame seed flour, WDS3=85%Wheat flour 15% OF defatted sesame seed flour and WDS4=80% Wheat flour 20% of defatted sesame seed flour.

TEAA =Total essential Amino acids (phenyalanine + valine + methionine + lysine + leucine + isoleucine + thronine + histidine)

TNAA =Total non-essential Amino acids (Arginine + cystene + glycine + tyrosine + proline + serine + glutamine + alanine + aspartate)

Hydrophobic AA= Hydrophobic amino acids (methionine+ alanine+valine+ leucine+ isoleucine+ proline+ phenyalanine). Hydrophilic AA= Hydrophilic amino acids; serine+ threonine + cystene + tyrosine + glycine

Basic amino acids; lysine +histidine + arginine

Acidic amino acids = glutamic acid + aspartic acid. TsulfurAA= Total sulfur amino acids; methionine + cysteine

*Table 1: Color characteristics of pasta produced from whole wheat and defatted sesame seeds*

| Parameters | WF | WDS1 | WDS2 | WDS3 | WDS4 |
|---|---|---|---|---|---|
| L* | $61.67±1.31^{a}$ | $58.79±0.31^{b}$ | $56.82±1.33^{c}$ | $44.20±0.24^{d}$ | $45.34±0.96^{d}$ |
| a* | $0.13±0.04^{d}$ | $1.21±0.18^{c}$ | $0.96±0.07^{c}$ | $3.65±0.38^{b}$ | $4.55±0.46^{a}$ |
| b* | $20.01±0.46^{a}$ | $11.20±0.48^{b}$ | $9.15±0.47^{c}$ | $7.50±1.00^{d}$ | $8.07±0.44^{cd}$ |

*Values are means ± standard deviation of triplicate determinations. Values in the same row with different superscript are significantly different ($p<0.05$). L*= Lightness, b*= Yellowness, a*= Redness

WFO = 100% Wheat fLour (control), WDS1 = 95% Wheat flour: 5% Defatted sesame seeds flour, WDS2 = 90% Wheat flour: 10% Defatted sesame seeds flour, WDS3 = 85% Wheat flour: 15% Defatted sesame seeds flour

WDS4 = 80% Wheat flour: 20% Defatted sesame seeds flour

*WF0 and the lowest in WDS4. This implies that the pasta produced from the 100 % whole wheat had lighter colour and the lightness decreased with increase concentration of defatted sesame seeds flour substitution. The CIE a* value which indicates red and green colour difference ranged from 0.13 (WH0) to 4.55 (WDS4). L* values have been negatively related with a* values (Gałkowska et al. 2022) and this is evident in this study as the a* value was the lowest at WF0.*

The *b** value ranged from 8.07 to 20.01with the WF0 pasta having higher values than the defatted sesame seeds substituted pasta. The b* measures the yellow (positive values) and blue (negative values) coordinate. This implies that the pasta produced from the control (100 % whole wheat) tends more to the yellowish attributes hence may have more acceptability and consumer preference may shift towards the control more than the substituted (Ainsa *et al.*, 2022). The decrease in yellowness could be due to increase ash content (Bhuvaneswari and Nazni, 2021) and the presence of plants pigments observed in the defatted sesame seeds flour. Also, non-enzymic reaction between the reducing sugars and the amino acids during the heating process (Gałkowska *et al.*, 2022)). Darkening which results in significant decrease in L value of pasta colours has been reported with wheat composite pasta samples (Arribas *et al.,* 2020).

## CONCLUSION

This study has revealed enhanced amino acid status of pasta produced from the substitution of whole wheat with defatted sesame seeds flour 20 % inclusion of defatted sesame seeds flour. Increase in defatted sesame seeds flour addition resulted in deeper colour intensity. Since pasta are mainly consumed by children in this part of the world, this product could provide a more nutritious food and help mitigate malnutrition. Further work can be carried out on the sensory and cooking characteristics of the pasta.

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# EFFECTS OF FEEDING *Aspergillus niger* FERMENTED SHEA BUTTER CAKE ON GROWTH PERFORMANCE AND APPARENT NUTRIENT DIGESTIBILITY OF WEANER RABBITS

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## ABSTRACT

Shea nut cake is an agro-industrial by-product obtained after the extraction of fat from the seed of the shea butter tree (*Vitellaria paradoxa*, Gaertn). The cake was subjected to solid state fermentation at different hours 0, 72, 144, 216 and 288 hours, using the fungus *Aspergillus niger*. At the end of the fermentation period, the residue was dried in the oven at 105ºC for five hours, and packaged in plastic containers, as fermented shea nut meal (SNM) until needed. Six experimental diets were compounded thus: T1 (Control diet containing no SNM), T2 (containing SNM fermented for 0 hours, replacing 10 % groundnut cake), T3 (containing SNM fermented for 72 hours, replacing 10 % groundnut cake), T4 (containing SNM fermented for 144 hours, replacing 10 % groundnut cake), T5 ((containing SNM fermented for 216 hours, replacing 10 % groundnut cake), and T6 ((containing SNM fermented for 288 hours, replacing 10 % groundnut cake). A total of 72 weaner rabbits were used for the study and allotted to the six treatments, with two rabbits per replicate of six replicates per treatment. The feeding trial was conducted for 12 weeks, and digestibility trial carried out at the end of the 11$^{th}$ week. Results showed that final body weight, total body weight gain, average daily body weight gain and feed conversion ratio were significantly (P<0.05) better for rabbits fed diets containing SNM fermented for 216 and 288 hours (Diets 5 and 6), though not significantly (P>0.05) from that of the Control Diet. Similarly, the total digestible nutrient (TDN) was significantly higher for T3 (94.31 %); followed by T2 (91.23 %), T4 (91.87 %) and T5 (91.03 %) which were not significantly (P>0.05) different from that of the Control Diet (T1, 90.76 %). Hence, it can be concluded that fermenting SNM for 216 hours (9 days) gave optimum growth performance and apparent nutrients digestibility of weaner rabbits.

**Keywords:** Fermented shea nut cake, growth performance, apparent nutrient digestibility, rabbits.

## INTRODUCTION

The astronomical increase in world population has led to a high demand in animal protein consumption from poultry, cattle, sheep and goats in developing countries (Mohammed and Agwunobi, 2009). Rabbits have been identified to have the potential for filling the gap between demand and supply of high-quality protein in developing countries like Nigeria (Wafar *et al.*, 2018). Rabbits have high genetic potential, short generation interval, high fecundity, high meat quality with low cholesterol. They are also reported to be efficient converters of fibrous feed ingredients and agro-industrial by-products than other livestock species (Bassey *et al.,* 2008). However, feeding and nutrition of rabbits requires adequate supply of feed in both quantity and quality for optimal growth (Abonyi *et al.,* 2012). In developing countries, rabbit production is based primarily on grasses and legumes whose availability during the rainy season and growth during dry season cannot sustain rabbit production (Olomu *et al.,* 2012). Thus, the search for cheaper and readily available feed stuffs that can sustain all-year-round rabbit production has been the focus of animal nutritionists in recent years. The use of agro by-products in rabbit nutrition has been documented (Okorie, 2003; Odeyinka *et al.,* 2007). One of such agro by- products is shea butter cake. Shea butter cake is obtained during the processing of Shea nut to produce Shea butter and shea nut cake. Shea nut cake or meal is receiving increased attention as a potential feed ingredient due to its availability and cheapness.

## MATERIALS AND METHODS

### Location of the Study

The study was conducted at the Rabbitry Unit of the Animal Production Teaching and Research Farm, Federal University of Technology, Minna, Niger State. Minna lies within Latitude $9^0$ 39′11′′N and Longitude $60^0$ 30′ 57′′E (Yahaya *et al*, 2020).

### Source of Experimental Materials and Preparation of Shea Butter Cake

A total of 72 weaned rabbits were used for the study. The rabbits were purchased from the Rabbitry Unit of the National Veterinary Research Institute, Vom, Plateau State. Shea butter cake was sourced from villages around Bida Local Government Area in Niger State. The shea butter cake was air- dried for seven days, and winnowed to remove impurities, then pulverized into powdery form. It was then mixed with water in the ratio 1:2 (1kg of shea butter cake to 2 litres of water) after which the spores of *Aspergillus niger* from potatoes dextrose agar (PDA) broth (2.5g/kg) was mixed with it properly for homogeneity. The mixture was packed in a plastic container, gently firmed, and sealed with adhesive film to provide anaerobic condition before being kept in an air-tight container at an ambient temperature of 28ºC and allowed to undergo solid state fermentation. The Shea cake was allowed to ferment for 72 hours (3 days), 144 hours (6 days), 216 hours (9 days) and 288 hours (12 days) respectively. The *Aspergillus niger* strain that was used for this study was obtained from the Microbiology Department Laboratory of the Federal University of Technology, Minna.

### Experimental Design and the Experimental Diets

A total of 72 weaned rabbits were allocated into six treatments and six replicates per treatment, with two rabbits per replicate, in a completely randomized design model. The feeding trial was carried out for twelve weeks and the rabbits were fed *ad-libitum*. The experimental diets were formulated to be isocaloric and isonitrogenous (16 % CP and 3000 kcal/kg ME) to contain six (6) dietary treatments. Diet 1 was a maize-groundnut cake-based control diet having 0 % Shea nut cake. Diets 2, 3, 4, 5 and 6 contained 0, 3, 6, 9 and 12-days fermented Shea nut cake replacing groundnut cake (GNC) at 10 % replacement level.

### Apparent Nutrients Digestibility Evaluation

At the end of the $11^{th}$ week, one rabbit per replicate was selected randomly and taken into the metabolism cages. Three days of adaptation period were observed and the rabbits were fed known quantities of feed *ad-libitum* for four days; followed by daily faecal collection the following day for each of the replicate. The faecal samples collected were pooled together on a replicate basis after oven-drying at 105ºC for 24 hours. At the end of the faecal collection period, 20 grammes of the faecal samples were taken for proximate analysis based on the methods described by AOAC (2018).

### Laboratory analysis

The proximate composition of the experimental diets and the collected faecal samples were determined following the methods described by AOAC (2018). Using these procedures, dry matter, crude protein, ether extract, ash, crude fibre, and nitrogen free extracts were all determined.

### Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the Statistical Analytical System Package (SAS, 2014). Variations in means were separated using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

The proximate composition of fermented shea butter cake as shown in Table 2. The results obtained shows raw sample to have moisture (5.68 %), crude protein (13.04 %), crude fibre (5.87 %), ash (4.78 %), ether extract (15.13 %) and the nitrogen free extracts (56.02 %). The result also showed an increase in the moisture content as the fermentation hours increased (9.40- 11,62 %), and a decrease in the dry matter (90.60-88.38 %) and NFE (61.02-59.31 %). However, the crude protein

**Table 1: INGREDIENT COMPOSITION OF THE EXPERIMENTAL DIETS**

| Parameters | T1 | T2 | T3 | T4 | T5 | T6 |
|---|---|---|---|---|---|---|
| Maize | 36.00 | 36.00 | 36.00 | 36.00 | 36.00 | 36.00 |
| Rice Husk | 27.75 | 27.75 | 27.75 | 27.75 | 27.75 | 27.75 |
| Shea Butter Cake | 0.00 | 0.55 | 0.55 | 0.55 | 0.55 | 0.55 |
| Groundnut Cake | 5.50 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 |
| Full Fat soya | 26.00 | 26.00 | 26.00 | 26.00 | 26.00 | 26.00 |
| Limestone | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Bone Meal | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Salt | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Lysine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Methionine | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| **Total** | **100.00** | **100.00** | **100.00** | **100.00** | **100.00** | **100.00** |
| **Calculated Values** | | | | | | |
| Crude Protein | 16.22 | 16.07 | 16.08 | 16.08 | 16.08 | 16.08 |
| Metabolizable Energy (kcal/kg) | 2513.29 | 2508.45 | 2503.61 | 2503.61 | 2503.61 | 2503.61 |
| Ether extract (%) | 6.66 | 6.68 | 6.64 | 6.64 | 6.64 | 6.64 |
| Crude Fibre (%) | 11.89 | 11.92 | 11.87 | 11.87 | 11.87 | 11.87 |
| Calcium (%) | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| Available phosphorus (%) | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 |
| Lysine (%) | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 |
| Methionine+Cystine (%) | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 | 0.71 |

T1 = Control diet containing no shea nut meal

T2 = Diet containing SNM fermented for 0 hours, replacing 10 % GNC

T3 = Diet containing SNM fermented for 72 hours, replacing 10 % GNC

T4 = Diet containing SNM fermented for 144 hours, replacing 10 % GNC

T5 = Diet containing SNM fermented for 216 hours, replacing 10 % GNC

T6 = Diet containing SNM fermented for 288 hours, replacing 10 % GNC

increased as the fermentation hour increased (13.04-16.15 %). The result revealed fermentation enhanced nutritional content of shea butter cake especially crude protein compared to the raw shea butter cake. This finding is in line with the results obtained by Mutayoba *et al*., (2011) who opined that fermentation improves the nutrient composition of feed stuffs.

The result obtained in Table 3 shows the effects of 10 % replacement level of fermented shea butter cake diets on the growth performance of weaner rabbits. The initial body weight of the rabbits used were all within the same range, to represent an unbiased feeding trial.

**TABLE 2: PROXIMATE COMPOSITION OF FERMENTED SHEA BUTTER CAKE**

| Parameters (%) | 0 hours | 72 hours | 144 hours | 216 hours | 288 hours |
|---|---|---|---|---|---|
| Moisture | 5.68 | 9.40 | 9.60 | 10.13 | 11.62 |
| Dry matter | 94.42 | 90.60 | 90.40 | 89.87 | 88.38 |
| Crude protein | 13.04 | 13.81 | 16.15 | 16.45 | 16.10 |
| Crude fibre | 5.87 | 2.50 | 2.50 | 2.20 | 2.25 |
| Ash | 4.78 | 10.0 | 8.50 | 9.00 | 8.00 |
| Ether extract | 10.13 | 3.40 | 3.21 | 2.98 | 2.72 |
| Nitrogen free extract | 61.02 | 60.89 | 59.04 | 59.24 | 59.31 |

However, the final body weight, total body weight gain and average daily body weight gain were significantly ($P<0.05$) higher for rabbits fed shea nut cake fermented for 9 and 12 hours (Diets 5 and 6); though not significant ($P>0.05$) from those fed the Control Diet (Diet 1). Also, the feed conversion ratio (FCR) was the most optimum for rabbits on Diet 5 and Diet 6, though not significantly ($P>0.05$) different from that of the Control Diet. This could be attributed to the reduction in the levels of antinutritional factors in the shea butter cake because of the solid-state fermentation with *Aspergillus niger*. The feed intake was also significantly higher in fermented diets than in the diet with zero fermentation (Diet 2). This could be attributed to the high level of antinutrients that might be present in the shea butter cake (Afolabi *et al.,* 2015). The result is similar to the one reported by Afolabi *et al.* (2015) who observed an increase in nutrients and a decrease in the antinutrient profile of fermented shea butter cake. This low FCR observed in T5 and T6, and being not significantly ($P>0.05$) from that of the Control Diet (T1) could be attributed to high acceptability of the diet due to reduction in the antinutrient profile and increase in the nutrient content due to fermentation, as reported by Afolabi *et al.* (2015). The apparent nutrient digestibility of rabbit fed 10 % replacement level of shea butter cake at different fermentation periods in rabbit is shown in Table 4. Crude protein and crude fibre digestibility were significantly higher for T3 (shea nut meal fermented for three days); though values obtained for T5 and T6 were not significantly different from the Control Diet (T1). The superior value obtained for the crude protein and crude fibre digestibility is an indication of the efficient utilization of dietary protein and crude fibre for these diets (Kehinde *et al*., 2020). Also, the total digestible nutrient (TDN) of T3 was significantly ($P<0.05$) than those of the other treatments. However, there were no significant ($P>0.05$) differences in the TDN between the Control Diet (T1) and diets T2, T4 and T5. This could be an indication of improved protein quality of the test ingredient due to fermentation and significant reduction in the antinutritional factors, like tannin, which have been incriminated in forming complexes with dietary proteins including enzymes in the gastrointestinal tract and thereby inhibiting the digestibility of proteins (Kehinde *et al*., 2020).

## CONCLUSION AND RECOMMENDATION

The results obtained in this study revealed that shea butter cake (an agro-industrial waste and by-product) can be incorporated into the diets of rabbit, replacing up to 10 % groundnut cake.
Fermenting the shea nut cake or meal with *Aspergillus niger* for 216 hours (9 days) using the solid-state fermentation technique, gave optimum growth performance and apparent nutrients digestibility in weaner rabbits. Hence, rabbit farmers and animal scientists are encouraged to use shea nut cake fermented with *Aspergillus niger* for 216 hours (9 days) to compound feed for rabbits. It is a cheap and readily available feed resource and agro-industrial waste.

**Table 3: GROWTH PERFORMANCE OF RABBITS FED *Aspergillus niger* FERMENTED SHEA BUTTER CAKE**

| Parameters | T1 | T2 | T3 | T4 | T5 | T6 | SEM | LOS | P-VALUE |
|---|---|---|---|---|---|---|---|---|---|
| **Initial body weight (g)** | 682.50 | 645.50 | 682.50 | 665.93 | 709.50 | 720.00$^{S}$ | 12.90 | NS | 0.612 |
| **Final Body weight (g)** | 1434.74$^{a}$ | 1121.82$^{b}$ | 1193.75$^{b}$ | 1188.65$^{b}$ | 1462.47$^{a}$ | 1448.03$^{a}$ | 28.57 | ** | 0.00 |
| **Total body weight gain (g)** | 752.24$^{a}$ | 476.32$^{b}$ | 511.25$^{b}$ | 522.73$^{b}$ | 752.97$^{a}$ | 728.03$^{a}$ | 25.47 | ** | 0.00 |
| **Average body weight gain (g)** | 8.95$^{a}$ | 5.67$^{b}$ | 6.08$^{b}$ | 6.22$^{b}$ | 8.96$^{a}$ | 8.66$^{a}$ | 0.30 | ** | 0.00 |
| **Total Feed intake (g)** | 3991.91$^{a}$ | 3875.23$^{b}$ | 3969.48$^{ab}$ | 3944.94$^{ab}$ | 3967.93$^{ab}$ | 3954.24$^{ab}$ | 13.62 | ** | 0.019 |
| **Average daily feed intake (g)** | 47.52$^{a}$ | 46.13$^{b}$ | 47.25$^{ab}$ | 46.96$^{ab}$ | 47.23$^{ab}$ | 47.07$^{ab}$ | 0.16 | ** | 0.019 |
| **FCR** | 5.46$^{b}$ | 8.22$^{a}$ | 7.89$^{a}$ | 7.59$^{a}$ | 5.39$^{b}$ | 5.56$^{b}$ | 0.25 | ** | 0.00 |
| **Mortality (%)** | 0.33 | 0.33 | 0.33 | 0.50 | 0.33 | 0.16 | 0.07 | NS | 0.931 |

$^{abc}$Means in the same row with different superscripts were significantly ($P<0.05$) different.

T1 = Control diet containing no shea nut meal
T2 = Diet containing SNM fermented for 0 hours, replacing 10 % GNC
T3 = Diet containing SNM fermented for 72 hours, replacing 10 % GNC
T4 = Diet containing SNM fermented for 144 hours, replacing 10 % GNC
T5 = Diet containing SNM fermented for 216 hours, replacing 10 % GNC
T6 = Diet containing SNM fermented for 288 hours, replacing 10 % GNC
FCR = Feed conversion ratio
SEM = Standard error of the means
LOS = Level of significance
p-value = Probability value
SNM = Shea nut meal
GNC = Groundnut cake

**Table 4: APPARENT NUTRIENTS DIGESTIBILITY OF DIETS CONTAINING *Aspergillus Niger* FERMENTED SHEA BUTTER CAKE FED TO RABBITS**

| Parameters (%) | T1 | T2 | T3 | T4 | T5 | T6 | SEM | LOS | P-VALUE |
|---|---|---|---|---|---|---|---|---|---|
| **Dry matter** | 91.01[a] | 88.93[ab] | 92.21[a] | 89.98[a] | 89.94[a] | 86.13[b] | 0.51 | ** | 0.00 |
| **Crude protein** | 95.63[a] | 95.83[a] | 96.72[a] | 94.29[b] | 94.21[b] | 92.51[b] | 0.27 | ** | 0.00 |
| **Ether extract** | 97.10[a] | 96.38[b] | 97.68[a] | 97.51[a] | 97.091 | 96.12[b] | 0.12 | ** | 0.00 |
| **Crude fibre** | 84.54[c] | 89.76[b] | 93.77[a] | 89.53[b] | 88.07[b] | 84.73[c] | 0.65 | ** | 0.00 |
| **Ash** | 82.85[ab] | 82.23[ab] | 86.49[a] | 83.01[ab] | 81.49[b] | 72.34[c] | 2.02 | ** | 0.019 |
| **Nitrogen free extracts** | 90.26[a] | 85.75[b] | 90.44[a] | 87.40[b] | 85.87[b] | 81.47[c] | 0.63 | ** | 0.019 |
| **TDN** | 90.76[b] | 91.23[b] | 94.31[a] | 91.87[b] | 91.03[b] | 88.00[c] | 0.39 | ** | 0.00 |

[abc]Means in the same row with different superscripts were significantly ($P<0.05$) different.

T1 = Control diet containing no shea nut meal
T2 = Diet containing SNM fermented for 0 hours, replacing 10 % GNC
T3 = Diet containing SNM fermented for 72 hours, replacing 10 % GNC
T4 = Diet containing SNM fermented for 144 hours, replacing 10 % GNC
T5 = Diet containing SNM fermented for 216 hours, replacing 10 % GNC
T6 = Diet containing SNM fermented for 288 hours, replacing 10 % GNC
TDN = Total digestible nutrient SEM = Standard error of the means LOS = Level of significance p-value = Probability value
SNM = Shea nut meal GNC = Groundnut cake

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# EVALUATION OF PROXIMATE AND ANTI-NUTRITIONAL COMPOSITION OF *MUCUNA PRURIENS* SEED MEAL SUBJECTED TO COMBINED PROCESSING

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## ABSTRACT

*Mucuna pruriens* is a tropical legume, and a sustainable protein source due to its high protein content (23-35 %). However, its utilization is hindered by anti-nutritional compounds. This study aimed to evaluate the effects of combined processing method (soaking, boiling, and roasting) on the proximate and anti-nutritional composition of *Mucuna pruriens* seed meal. The experiment was conducted at the Federal University of Technology, Minna, Nigeria. *Mucuna pruriens* seeds were obtained from the National Animal Production Research Institute, Kaduna. Seeds were subjected to triple combined treatment and analyzed for proximate and phytochemical composition using standard method. Results showed significant ($p<0.05$) reduction in quantity of anti-nutritional compounds, including saponin (76.32 %), alkaloid (72.72 %), and L-Dopa (74.82 %), while tannin (52.63 %), oxalates (54.63 %), phytates (52.25 %), phenol (61.32 %), and flavonoids (54.76 %) were all reduced below average respectively. Proximate analysis showed changes in nutritional composition, with increased nitrogen-free extract and reduced crude protein and ether extract. The combined treatment improved the overall nutritional value and safety of *Mucuna pruriens* seed meal. It was concluded that combined processing method is an effective method for reducing anti-nutritional compounds and enhancing the nutritional value of *Mucuna pruriens* seed meal, making it a viable alternative feed option for sustainable protein production and contributing to global food security and animal welfare.

**Keywords**: Velvet beans, Phytochemicals, Sustainable protein, Animal nutrition, Legume utilization

## INTRODUCTION

Mucuna, belonging to the Fabaceae family, sub family Papilionaceae, includes approximately 150 species of annual and perennial legumes and belongs to the various under-utilized wild legumes. The velvet bean *Mucuna pruriens* is widespread in tropical and sub-tropical regions of the world. It is considered a viable source of dietary proteins (Janardhanan *et al.,* 2003; Pugalenthi *et al.,* 2005) due to its high protein content (23–35%) in addition to its digestibility, which is comparable to that of other pulses such as soybean, and lima bean (Gurumoorthi *et al.,* 2003). Mucuna is a valuable plant due to its nutritional potential. (Adepo *et al*., 2016) Comparably, its seeds have equal nutritional quality as soybeans, and lima beans, higher than chickpea, common bean, green pea, pigeon pea, lentils, peanuts, and black beans; hence it is treated as a cheap and alternative source of protein (Jadhav *et al.,* 2022).

Therefore, Mucuna seed could help reduce the demand for conventional feed and make more staple food available for human consumption, which is one of the most important goals of developing countries. This need for alternative protein sources for developing countries has led to much research on underutilized legumes and led to the supply of more valuable nutrients. The major drawback for utilizations of these novel plants is their high anti-nutritional factors like trypsin inhibitors, tannins and cyanide (Hussain, & Manyam, 1997). Levodopa (L Dopa), a potentially neurotoxic agent in raw bean has been reported (Ravindran, & Ravindran, 1988). These antinutrient may be poisonous to animal and may interfere with the nutrient availability in the body (Olaleye *et al.,* 2020). To improve nutritional composition and reduce these anti-nutritional factors, several processing methods have been used such as fermentation by (Obi, & Okoye, 2017). Comparative evaluations of soaked, roasted, boiled, and autoclave by (Nwajagu *et al.,*2021). And double treatments by (Ezegbe *et al.,* 2023). Both single and double treatments of *Mucuna pruriens* seed achieved reduction in antinutritional composition but there is need to have a standard method of processing to encourage utilization of *Mucuna pruriens* as viable alternative feedstuff, while there is limited research regarding how combined triple treatment will affect its proximate composition and reduce the antinutritional content. This gap in knowledge justifies the need for further research in improving the quality and consequently the utilization of *Mucuna pruriens* seed as alternative feed. Hence this study was carried out to evaluate the effects of combined treatments on the proximate and anti-nutritional factors in *Mucuna pruriens* (velvet bean) seed meal.

## MATERIALS AND METHODS

### Site of Experimental Study

The experiment was carried out at the Federal University of Technology Department of Animal Production, School of Agriculture and Agricultural Technology. Minna has land area of 6784 km, and it is situated between latitude 9° 37 North and South equator and longitude 60 33 East with mean annual temperature of 28 - 40°C and mean annual rainfall of 1000 - 1500mm. (Odegbenro & Ojoye. 2022).

### Source of Experimental Material

*Mucuna pruriens* (velvet bean) seeds were obtained from National Animal Production Research Institute (NAPRI) Kaduna State, Nigeria.

### Processing of Experimental Material

The *Mucuna pruriens* seeds were subjected to triple combined treatment by (soaking, boiling and roasting) to reduce its anti-nutritional components before grinding into meal.

250 g of the seeds were soaked in warm water at room temperature for 24 hours, the seeds were washed in two parts of the seed quantity, drained and then boiled for 1 hour and timed from the boiling point of water ($100^0$C). The boiled seed was sun dried to 90 % dry matter before further subjecting to 15 minutes roasting and thereafter were grounded into meal.

### Determination of the Proximate Composition

Proximate composition of velvet bean seeds was evaluated following the description of (AOAC, 2006). Analysis was done triplicate. Parameters were evaluated in triplicate include dry matter, crude protein, crude fibre, ether extract, ash, and nitrogen free extract.

### Phytochemical Composition

Antinutritional factors in velvet bean were evaluated following the description of [Ezegbe, *et al.,* 2023). The samples were subjected to triplicate analysis. Parameters were evaluated for L-dopa, saponin, tannin, oxalate, phytates, alkaloids, phenolic acid and flavonoids.

### Statistical analysis

Data collected were analyzed using statistical package for social sciences (SPSS). using descriptive statistics (means and percentage). Independent T-test was conducted to know the level of significant between raw and triple treatments.

## RESULTS AND DISCUSSION

The proximate compositions of Raw (RT) and Triple Treatment (TT) of *Mucuna pruriens* seed meal are presented in Table 1. The result revealed that RT showed higher crude protein (28.90 %) compared to TT (25.60 %), similar trend was observed for ether extract (9.00 %). while comparably values were observed for crude fibre (91.60 %; 90.40 %), ash (5.00 %; 4.00%), and dry matter (91.40 %; 90.40%) for RT and TT respectively. the result for nitrogen free extract indicates lower values for RT (38.20 %) while TT was observed to have higher values (45.50 %) respectively. The values obtained for crude protein, ash, crude fiber, ether extract, and nitrogen-free extract for both TT and RT collaborate with the findings of (Hussain, G., & Manyam, B. V. 1997; Kalidass *et al.,* 2011), who reported similar range for five varieties of *Mucuna pruriens*. The reduction suggests that TT has an effect on nutritional composition, which agrees with (Nwajagu *et al.,* 2021), who reported that the method of processing has a significant effect on the proximate composition of *Mucuna pruriens*. This observation is consistent with the reports of (Ezegbe *et al.,* 2023), who noted that cooking and soaking significantly ($p<0.05$) reduced all the proximate parameters. The nutritional compositions observed in this study for crude protein (25.90 %), ash (4.0 %), fiber (10.5 %), and ether extract (5 %) are comparable to those reported by (Ekpo *et al.,* 2022), who reported values of 25.45 %, 6.16 %, 10.06 %, and 6.98 %, respectively. However, the value observed for nitrogen-free extract for both RT and TT (38.20;45.50 %) is not in line with (Ekpo *et al.,* 2022) and (Ezegbe *et al.,* 2023), who reported higher values of 51.35% and 49.22-54.94% respectively. this difference may be attributed to species, and stage of plant maturity. The increase in nitrogen free extract may be attributed to the triple treatment (TT) in this present study, independent T-test indicate significant difference ($p<0.05$) were observed crude protein, ether extract, ash, and nitrogen free extract while no significant difference ($p>0.05$) was observed for dry matter and crude fibre. This observation is consistent with the study of (Ezegbe *et al.,* 2023) and this affirm, that processing methods affects the nutritional composition of *Mucuna pruriens*. It was observed that TT reduce crude protein and ether extract compositions, while there was an increasing in nitrogen free extract.

**Table 1: Effect of Combined Processing on Proximate Composition of *Mucuna pruriens Seed Meal (MPSM)***

| Proximate (%) | Raw (RT) | Triple Treatment (TT) | PV |
|---|---|---|---|
| Dry matter | 91.60 | 90.40 | 0.45 |
| Crude Protein | 28.90 | 25.90 | 0.00 |
| Crude fibre | 10.50 | 10.00 | 0.87 |
| Ether extract | 9.00 | 5.00 | 0.00 |
| Ash | 5.00 | 4.00 | 0.00 |
| Nitrogen free extract | 38.20 | 45.50 | 0.00 |

PV: Probability value

Table 2 The results of the phytochemical composition of Raw treatment (RT) and Triple Treatment (TT) of *Mucuna pruriens* meal indicate that RT contains 0.38 g/100g saponin, 0.38 g/100g tannin, 0.11 g/100g oxalate, 1.55 g/100g phytate, 1.98 g/100g alkaloids, 2.12 g/100g phenol, 1.68 g/100g flavonoids, and 6.83 g/100g L-dopa. In contrast, TT contains 0.09 g/100g saponin, 0.18 g/100g tannin, 0.05 g/100g oxalate, 0.74 g/100g phytate, 0.84 g/100g alkaloids, 0.82 g/100g phenol, 0.76 g/100g flavonoids, and 1.72 g/100g L-dopa. This shows that the phytochemical composition was reduced by the TT, which is consistent with the report of (Ezegbe *et al.,* 2023), who stated that different processing methods have a significant level of reducing phytochemical composition.
The results show that all the phytochemical composition was reduced below average with saponin, alkaloid and L-dopa having greater percent reduction of 76.32 %, 72.72 % and 74.82 respectively. while tannin, oxalates, phytates, phenol and flavonoids were reduced above average with 52.63 %, 54.63 %, 52.25 %, 61.32 %, and 54.76 % respectively.

Anti-nutritional compounds are toxic, and non-palatable which decrease the bioavailability of nutrients by inhibiting the activity of digestive enzymes such as α-amylase, trypsin, chymotrypsin and lipase, complex formation of phenolic with iron resulting in rupture of the mucosal cell wall of the digestive tract (Chinapolaiah *et al.,* 2019). This will reduce the digestibility of carbohydrates, and proteins, and will result in poor animal performance if not reduced to minimum and levels. independent T-test indicate significant difference ($p<0.05$) for all the parameter. This observation is in tandem with (Ezegbe *et al.,* 2023), who report that combined processing method were observed to affect nutritional composition. While this study affirms that TT treatment maybe safe method to reduces these antinutrient to greater percent and thus making the nutrient available to animal without affecting the performance and welfare of animal.

**Table 2 Effect of Combined Processing on Antinutritional Composition of *Mucuna pruriens* Seed Meal (MPSM)**

| Phytochemical (g/100g) | RT | (TT) | (%) Reduction | PV |
|---|---|---|---|---|
| Saponin | 0.38 | 0.09 | 76.32 | 0.01 |
| Tannin | 0.38 | 0.18 | 52.63 | 0.02 |
| Oxalate | 0.11 | 0.05 | 54.55 | 0.04 |
| Phytate | 1.55 | 0.74 | 52.25 | 0.02 |
| Alkaloid | 1.98 | 0.54 | 72.72 | 0.01 |
| Phenol | 2.12 | 0.82 | 61.32 | 0.02 |
| Flavonoids | 1.68 | 0.76 | 54.76 | 0.02 |
| L-Dopa | 6.83 | 1.72 | 74.82 | 0.01 |

RT: Raw Treatment, TT: Triple Treatment, PV: Probability value

## CONCLUSION

Based on this study the use a combined method of (soaking, boiling, and roasting), can effectively reduce the antinutritional compounds in *Mucuna pruriens* seeds, which will thus make its a more viable alternative feed option. This study indicates that combined treatment may be a standardized processing method, to improve the utilizations of this novel seed meal as a potential option for sustainable protein, by reducing the demands on conventional feedstuff, thereby contributing to global food security and animal welfare

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# PHYTOCHEMICAL EFFECTS OF AQUEOUS EXTRACTS OF "HOSPITAL TOO FAR (*Jatropha tanjorensis*) AND BITTER LEAF (*Vernonia amygdalina*) ON BIOCHEMICAL PARAMETERS OF COMPOSITE RABBIT DOES

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## ABSTRACT

This study investigated the effects of aqueous extracts of *Vernonia amygdalina* (bitter leaf) and *Jatropha tanjorensis* ("Hospital Too Far") on serum biochemistry and lipid profile in composite doe rabbits. The experiment was conducted at the Teaching and Research Farm, Federal University of Technology Minna, Niger State, Nigeria. Thirty (30) composite doe rabbits aged 3-4 month were randomly divided into five treatment groups designated as T1, T2, T3, T4 and T5 each comprising of three replicate, with two rabbits per replicate. The extract obtained from the bitter leaf and "hospital too far" were administered weekly at 0 + 0 ml, 2.5 + 2.5 ml, 2.5 + 5.0 ml, 5.0 + 2.5 ml, and 5.0 + 5.0 ml per kilo gram body weight weekly for the five treatment respectively. The experimental design was a Completely Randomized Design (CRD). Blood samples were collected for serum biochemistry and lipid profile analysis. Serum parameters including urea, creatinine, ALT, AST, and albumin were analyzed, while lipid profile parameters such as cholesterol, triglycerides, and lipoproteins (HDL, VLDL, LDL) were determined. Proximate and phytochemical analyses revealed the nutritional composition of the experimental diets and extracts. Results indicated significant ($p<0.05$) effects of the treatments on serum biochemistry and lipid profiles, with improved creatinine and albumin levels and reduced cholesterol concentrations observed in treated groups compared to the control. The findings suggest that the combined use of *Jatropha tanjorensis* and *Vernonia amygdalina* extracts can positively influence biochemical parameters in rabbits, offering potential benefits for rabbit production and health management. Further studies are recommended to optimize dosage levels and evaluate long-term effects.

**Key words:** Phytochemical, Aqueous, Biochemical, Rabbit, Extracts

## INTRODUCTION

Rabbit breeding is a growing branch within the livestock industry due to ease of handling and rearing in addition to the quality of protein in this species (Falcone *et al*., 2020). Over the years, this branch of livestock industry has been dominated by backyard rearing. Rabbit farming has gained attention due to its lower environmental impact and efficient feed conversion compared to other livestock (Cullere and Dalle Zotte, 2018). Rabbit meat is high in protein (22 %) low in fat (4 %) and cholesterol (5 %) and thus possesses health-promoting properties (Aduku and Olukosi, 2000). Due to its low calorie, fat, and hazardous cholesterol contents, rabbit's meat has been classified as one of the healthiest meats for humans by the United State Department of Agriculture (USDA) (Dalle-Zotte, 2014). With its distinct nutritional benefits, rabbit meat is becoming more and more well-liked as a global source of functional meat (Dalle-Zotte and Cullere, 2017).

In the last decades, there are increasing concerns about using natural feed additives as antibiotic alternatives for decreasing development of anti-microbial resistance bacteria and for producing safer animal products with minimal antibiotic residue of natural feed additives, those from phytogenic source including different parts of the plants or extracts are being widely included in animal nutrition due to their impressive range of phytochemicals. However, over time plant-based feed additives also known as phytogenic has been advocated to be included in animal feeds as growth promoting feed additives, because of their abundance in our natural environment and the fact that they do not have residual effect (Ndelekwute *et al*., 2015).

Antibiotics have traditionally been used in livestock farming to enhance growth, improve feed efficiency, and prevent diseases. However, their extensive use has led to significant concerns about antibiotic resistance, which poses a major risk to both animal and human health. Antibiotic resistance can lead to the emergence of resistant strains of bacteria that are difficult to treat, potentially resulting in severe infections and complicating disease management in both livestock and humans (Smith *et al*., 2020). Given these challenges, there is a pressing need to find alternatives to antibiotics that can maintain or improve animal health and productivity without contributing to resistance issues.

Phytogenic additives, derived from plant sources, have emerged as a promising solution. These natural compounds, including essential oils, extracts, and phytochemicals, are thought to offer various health benefits such as antimicrobial, anti-inflammatory, and antioxidant properties. *Jatropha tanjorensis* and bitter leaf (*Vernonia amygdalina*) are two such plant sources with documented medicinal properties. *Jatropha tanjorensis* is known for its antioxidant and anti-inflammatory effects, while bitter leaf has been recognized for its hypoglycemic and lipid-lowering properties (Smith *et al.,* 2021). Despite their traditional uses, there is lack of comprehensive scientific data on how theses plant extracts impact serum biochemistry and lipid profile in rabbit, which are critical indicators of metabolic health and disease risk. Thus, this study aims to address this gap by investigating the effects of aqueous extracts of *Jatropha tanjorensis* and bitter leaf (*Vernonia amygdalina*) on the serum biochemical parameters and lipid profiles of rabbit doe.

## METHODOLOGY

### Study Location

The Research was conducted at the Teaching and Research Farm, Department of Animal Production, Federal University of Technology Minna (Gidan Kwano Campus), Niger State. Minna is located between latitude 9038' and 9037' North, longitude 6023' and 6033'East, which has an annual rainfall of between 1000-1500mm and an average temperature of 320c (FUTMINNA Student Handbook, 2020).

### Experimental Animals and Management

Thirty (30) composite doe rabbits, aged three to four months, were used for this study. The animals were acquired from Blessed Heritage Organic (BHO) farm in Okuku, Osun State, Nigeria, and were quarantined for two (2) weeks before the start of experiment. The rabbits were paired into two and housed in wooden hutches, receiving a diet formulated with 16 % crude protein and 2581 ME/kg energy (Table 1) along with grass-legume forages. Vitalyte® plus was given orally to manage stress.

### Source of Experimental Material

A large quantity of *Jatropha tanjorensis* ("Hospital too far") and *Vernonia amygdalina* (bitter leaf) were sourced within Minna metropolis, Niger state. Other feed ingredients such as maize, groundnut cake, fish meal, maize offal, salt, and vitamin premix were also obtained within Minna metropolis, Niger State.

A large quantity of *Jatropha tanjorensis* ("Hospital too far") and *Vernonia amygdalina* (bitter leaf) leaves was collected, gently washed without squeezing, and air-dried indoors for 72 hours. Afterward, they were placed in an oven at approximately 40°C for 2 hours. The leaves were then ground into powder separately using a (Multifunction blender robots "KENWOOD"; Model: KDB-805). A 100 g of the ground leaves were soaked in 1000 ml of distilled water in a ratio (1:10) for 72 hours in a chromatographic jar, agitated every 2 hours. The extract was concentrated by evaporation using boiling water in a water bath (Guo Hua Electrical Appliance Co., LTD fast thermostat digit shows water tank; Model: HH-60). The fluid extract was collected, weighed, and preserved for use as described by Ukoh *et al*., (2022). Upon usage, 1 g of the fluid extract was diluted with 10 ml of distilled water in a 1:10 ratio.

**Table 1: Experimental diet fed to the animals**

| Ingredient | Composition (%) |
|---|---|
| Maize | 50.99 |
| Soya bean | 20.01 |
| Rice offal | 20.00 |
| Fish meal | 3.50 |
| Bone meal | 3.50 |
| Methionine | 0.50 |
| Lysine | 0.50 |
| Premix | 0.50 |
| Salt | 0.50 |
| **Total** | **100.00** |
| **Calculated value of experimental diet (%)** | |
| Crude protein | 16.00 |
| ME (Kcal/kg) | 2582.00 |
| Crude fibre | 9.90 |
| Calcium | 0.30 |
| Phosphorus | 0.37 |

**Processing of "Hospital Too Far" and Bitter Leaf**

**Experimental Design**

The experiment involved thirty (30) composite doe rabbits. The rabbits were weighed and randomly divided into five treatment groups (six per treatment) and further replicated into three replicates (two per replicate) using a Completely Randomized Design (CRD). Aqueous extracts of bitter leaf and "Hospital Too Far" were administered orally weekly per kg of body weight. T1 served as control (0 ml of "Hospital Too Far" and 0 ml of Bitter leaf), T2 received 2.5 ml of aqueous bitter leaf and 2.5 ml of "Hospital Too Far", T3 received 2.5 ml of aqueous bitter leaf and 5 ml of "Hospital Too Far", T4 5 ml of aqueous bitter leaf and 2.5 ml of "Hospital Too Far", and T5 received 5 ml of aqueous bitter leaf and 5 ml of "Hospital Too Far"

**Data collection**

Five (5) mls of blood sample were collected from the does at slaughter from the jugular vein at the neck region, and put into ethylene diamine tetra acetic acid (EDTA) treated bottles and taken to the lab for serum biochemistry and lipid profile analysis, following the methods of (Doumas, 1975) and (Fletcher, 1968) respectively. The serum profile evaluated include Albumin, Urea, Creatine, Protein, Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), Alkaline Phosphate (ALP), direct bilirubin, total bilirubin. Lipid profile evaluated were cholesterol, triglyceride (TG), and high-density lipoprotein (HDL) concentrations, Very-low-density lipoprotein (vLDL) was calculated by dividing the values of TG by a factor of five and low-density lipoprotein (LDL) concentration.

**Data Analysis**

Data collected were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 17.0. Differences among means was separated using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

The proximate composition of bitter leaf (BL), "hospital too far" (H2F) and formulated diet as presented in table 2 reveals that BL and H2F are rich in crude protein 28.20 % and 25.50 %, crude fibre 15.50 % and 18.10 % respectively and low in ether extract 5.10 % and 6.20 % respectively. Relatively, experimental diet had higher values of crude protein and crude fibre 17.50 % and 13.50 % respectively. The high values obtained in BL and H2F for crude protein and crude is an indication that they are suitable component of additive in rabbits due to their ability to digest fibrous feed material as reported by (Akinwumi and Omotayo, 2016

Table 3 showed results of the phytochemical composition of BL and H2F. The results reveal significant amount of phytochemical present in both leaves. High amount of flavonoid (2.05 mg/100g) and phytates (1.99 mg/100) were observed in BL. Similarly, flavonoids (1.5 mg/100g), phytates (2.58 mg/100g) and saponins (2.03 mg/100g) were observed in H2F. These unique phytochemical properties offer significant biochemical, physiological and morphological benefits (Garba *et al*., 2022).

The administration of BL and H2F aqueous extracts significantly influenced serum biochemistry and lipid profiles in rabbit does as shown in Table 4. Creatinine levels showed significant variations, with the highest level recorded in the T3 group (5.54 mg/dl) exceeding the normal range (NR) (0.5 – 2.5 mg/dl), suggesting potential renal stress. This finding aligns with Attia *et al*. (2016), who highlighted the impact of oxidative stress on renal function. Similarly, urea levels peaked in the T3 group (57.70 mg/dl), potentially indicating increased protein catabolism or reduced renal clearance, as supported by Oluwole *et al*. (2018).

Total protein and albumin levels were significantly elevated in the T5 group (7.75 g/dl and 3.44 g/dl, respectively), reflecting improved protein synthesis and liver function, consistent with Egesie *et al*. (2017). Liver enzymes such as ALT and AST varied significantly, with T2 showing the highest AST level (55.20 U/L), which may indicate mild hepatic stress. However, ALP levels remained moderated across treatments, suggesting no severe liver damage, corroborating Nwanjo *et al*. (2016). Total bilirubin level was notably elevated in the T2 group (0.78 mg/dl), indicative of dose-dependent effects, as noted by Olaleye *et al*. (2015).

Cholesterol and triglyceride levels showed significant increases in the T5 group (36.92 mmol/l and 18.57 mmol/l), revealing dose-dependent effects of the extracts on lipid metabolism. These findings are consistent with Iwalokun *et al*. (2017) and Adebayo *et al*. (2014), who demonstrated the hypo-cholesterolemic and lipid-modulating properties of BL at controlled doses. The T1 group had the highest HDL levels (14.98 mmol/l), while LDL and VLDL peaked in T5 (21.54 mmol/l and 3.71 mmol/l), supporting Ajiboye *et al*. (2018), who emphasized dose-dependent lipid modulation by the extracts.

## CONCLUSION AND RECOMMENDATION

The administration of aqueous extracts of BL and H2F significantly influenced serum biochemistry and lipid profiles in rabbit does. The observed variations in creatinine, urea, total protein, and albumin levels suggest dose-dependent effects on renal and liver functions, with higher extract doses potentially inducing mild renal and hepatic stress. Lipid metabolism was significantly modulated, with elevated cholesterol and triglyceride levels observed at higher doses, reflecting the extracts' lipid-modulating properties. Given their lipid-lowering and hepatoprotective effects, these extracts could be explored further as natural alternatives for managing hyperlipidemia and liver dysfunction.

**Table 2: Proximate Composition of Experimental Diet and Test Ingredients (%)**

| Parameters | FEED | BL | H2F |
|---|---|---|---|
| Dry matter | 90.00 | 89.00 | 90.00 |
| Crude protein | 17.50 | 28.20 | 25.50 |
| Crude fibre | 13.50 | 15.50 | 18.10 |
| Ether Extract | 4.50 | 5.10 | 6.20 |
| Ash | 6.00 | 10.40 | 8.00 |
| Nitrogen free Extracts | 58.50 | 40.80 | 42.00 |

Keys: BL: Bitter leaf; H2F: “hospital too far”

**Table 3: Phytochemical Composition of Bitter Leaf (*Vernonia amygdalina*) and “Hospital Too Far” (*Jatropha tanjorensis*)**

| Chemicals (mg/100g) | Bitter Leaf | “Hospital Too Far” |
|---|---|---|
| Flavonoids | 2.05 | 1.5 |
| Phytates | 1.99 | 2.58 |
| Glycosides | 0.45 | 0.27 |
| Tannins | 0.35 | 0.33 |
| Saponins | 1.07 | 2.03 |
| Alkaloids | 1.09 | 0.97 |

## CONCLUSION AND RECOMMENDATION

The administration of aqueous extracts of BL and H2F significantly influenced serum biochemistry and lipid profiles in rabbit does. The observed variations in creatinine, urea, total protein, and albumin levels suggest dose-dependent effects on renal and liver functions, with higher extract doses potentially inducing mild renal and hepatic stress. Lipid metabolism was significantly modulated, with elevated cholesterol and triglyceride levels observed at higher doses, reflecting the extracts’ lipid-modulating properties.  Given their lipid-lowering and hepatoprotective effects, these extracts could be explored further as natural alternatives for managing hyperlipidemia and liver dysfunction.

**Table 4: Serum Biochemistry and Lipid Profile of Composite Rabbit Doe Administered Aqueous Extracts of Bitter Leaf and "Hospital Too Far"**

| | | | Treatment | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | **1** | **2** | **3** | **4** | **5** | **SEM** | **P-value** | **NR** |
| Creatine (mg/dl) | 2.28$^{b}$ | 0.77$^{b}$ | 5.54$^{a}$ | 5.29$^{a}$ | 5.54$^{a}$ | 0.36 | 0.001 | 0.5 - 2.5 |
| Urea (mg/dl) | 43.50 | 28.28 | 57.70 | 51.34 | 49.59 | 5.21 | 0.610 | 20 – 45 |
| Protein (g/dl) | 5.87$^{ab}$ | 4.79c | 5.36$^{bc}$ | 5.94$^{ab}$ | 7.75$^{a}$ | 0.29 | 0.004 | 5.4 – 7.5 |
| ALT (U/L) | 47.73$^{ab}$ | 44.00$^{bc}$ | 53.48$^{a}$ | 42.97$^{bc}$ | 39.46$^{c}$ | 1.48 | 0.005 | 45 – 80 |
| AST (U/L) | 43.97$^{b}$ | 55.20$^{a}$ | 44.80$^{b}$ | 40.51$^{b}$ | 29.74$^{c}$ | 2.48 | 0.003 | 35 – 130 |
| ALP (U/L) | 35.31 | 41.97 | 46.03 | 42.17 | 36.33 | 2.21 | 0.576 | 12 - 96 |
| T.Bil (g/dl) | 0.69$^{a}$ | 0.78$^{a}$ | 0.72$^{a}$ | 0.73$^{a}$ | 0.52$^{b}$ | 0.05 | 0.003 | 0 – 0.7 |
| Albumin (mg/dl) | 2.81$^{c}$ | 2.37$^{d}$ | 2.41$^{d}$ | 3.06$^{b}$ | 3.44$^{a}$ | 0.12 | 0.000 | 2.7 – 5.0 |
| Cholesterol (mmol/l) | 29.54$^{c}$ | 23.55$^{d}$ | 33.50$^{b}$ | 28.47$^{c}$ | 36.92$^{a}$ | 1.23 | 0.000 | - |
| Triglyceride (mmol/l) | 10.82$^{b}$ | 10.07$^{b}$ | 9.89$^{b}$ | 11.43$^{b}$ | 18.57$^{a}$ | 0.97 | 0.002 | - |
| HDL(mmol/l) | 14.98$^{a}$ | 15.09$^{a}$ | 14.13$^{a}$ | 11.99$^{b}$ | 11.67$^{b}$ | 0.43 | 0.001 | - |
| VLDL (mmol/l) | 2.16$^{b}$ | 2.01$^{b}$ | 1.98$^{b}$ | 2.29$^{b}$ | 3.71$^{a}$ | 0.19 | 0.002 | - |
| LDL (mmol/l) | 12.39$^{d}$ | 6.44$^{e}$ | 17.39$^{b}$ | 14.200$^{c}$ | 21.54$^{a}$ | 1.36 | 0.000 | - |

Key: abcde means on the same column not followed by the same superscript are significantly ($p<0.05$) different; SEM: Standard Error of Mean; AST: Aspartate Transaminase; ALT: Alanine Transaminase; ALP: Alkaline Phosphate; T.Bil; Total Bilirubin; HDL: High-Density Lipoprotein; VLDL: Very-Low-Density Lipoprotein; LDL: Low-Density Lipoprotein; NR: Normal Range; T1: Control; T2: (2.5 ml bitter leaf + 2.5 ml "hospital too far" aqueous extracts); T3: (2.5 ml bitter leaf + 5 ml "hospital too far" aqueous extracts); T4: (5 ml bitter leaf + 2.5 ml "hospital too far" aqueous extracts); T5: (5 ml bitter leaf + 5 ml "hospital too far" aqueous extracts)

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# REPRODUCTIVE PERFORMANCE OF WEANER RABBITS DOES (*Oryctolagus cunniculus*) FED GARLIC AND GINGER SUPPLEMENTED BASAL DIETS

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## ABSTRACT
This study was carried out to investigate the reproductive performance of rabbits does fed diets supplemented with garlic and ginger. Twelve female Dutch belt weaner rabbits weighing between 714.33 g to 730.60 g were randomly allotted into four dietary treatments of 12 rabbits with three replicates and one rabbit per replicate in a completely randomized design. The dietary treatments were designated as follows; control containing 0 g garlic and ginger (T1), 100 g garlic per 100 Kg feed (T2), 100 g ginger per 100 Kg feed (T3), and 50 g garlic + 50 g ginger per 100 Kg feed (T4). The result showed that there were significant ($p<0.05$) differences in the Weight of Does Before Mating (WDBM) and Weight of Does Before Parturition (WDBP). The values were higher ($p<0.05$) in T4 (2171.43 g and 2595.53 g) than T2 (1783.40 g and 2100.00 g) for both WDBM and WDBP. In conclusion, garlic and ginger could be used up to 0.1 % inclusion in rabbit does diet without any adverse effect on their reproductive performance.
**Keywords**: Reproductive performance, weaner rabbit does, ginger, garlic.

## INTRODUCTION
Livestock agriculture apart from providing animal protein to man, has also played an important role in the standard of living of humans (Bettencourt *et al.,* 2015). Animal protein is an important necessity in human nutrition due to its balanced amino acid profile (Jon, 2018). In Nigeria, the production and availability of meat produced by some conventional sources like, cattle, poultry, sheep and goat to meet the growing demand for animal protein is insufficient for the growing population. Hence, the use of recognized micro herbivores and unconventional species of livestock such as rabbit (*Oryctolagus cuniculus*) may be a promising source of animal protein to mitigate protein shortage due to high cost of chicken, beef and pork (Mohammed *et al.,* 2018), thus making it emerge as a viable livestock specie. In previous years, much attention has been given to rabbit farming in order to facilitate the increase of productions without adversely affecting meat quality and animal wellness. Antibiotics were the most common feed additives used in time past, however, the use of synthetic antibiotics is being regulated because of the development of resistant microorganisms, and their effect on human health (Joseph *et al*., 2015). This has prompted the need for new initiatives in the livestock and pharmaceutical industries, to seek and promote the use of alternative materials that combine the effects of nutritional and medicinal properties, simultaneously (Esiegwu *et al*., 2014). This has prompted researchers to carry out studies on the addition of natural antioxidants as nutritional supplements in animal feeding to improve health, performance, meat quality and shelf-life of raw or cooked meat products (Jiang and Xiong, 2016). Safe supplements such as garlic and ginger which are natural growth promoters can be used as potential alternatives for common artificial growth promoters like antibiotics (Demir *et al.,* 2003). Garlic and ginger powder and their extracts, have been studied for their antioxidant and antimicrobial properties both in dietary supplementation, and in

food preservation (Zomrawi *et al.,* 2012). These natural antioxidants have been recognized to be better than synthetic antioxidants due to their lower cytotoxicity and tissue residue (Sen *et al*., 2010), and ability to mitigate or prevent generation of free radicals or reactive oxygen species (Ali *et al*., 2008). Hence, garlic and ginger could play an important role in rabbit feeding strategies. Therefore, the main aim of this study is to determine the reproductive performance of weaner rabbit does fed garlic and ginger supplemented basal diets.

## MATERIALS AND METHODS

### Experimental site

The experiment was conducted at the Rabbit Research Unit of the Department of Animal Production Teaching and Research Farm, School of Agriculture and Agricultural Technology of the Federal University of Technology, Minna, Niger State, Nigeria. Minna is located within latitude $9^0$ 30' and $6^0$ 45' North and longitude $6^0$ 30' N and $6^0$ 45' East of the equator. It falls within the Southern Guinea Savanna agro-ecological zone of Nigeria. It is characterized by a mean annual temperature which lies between 21 $^0$C and 35 $^0$C, and mean annual rainfall varying from 1100 to 1600 mm (FMSN, 2015).

### Sources and Processing of Feed Ingredients.

Methionine, lysine, fish meal, vitamin premix, salt, bone meal, limestone, soybean meal and wheat offal were purchased from Animal Care retailer shop, Gidan Matasa, Okada Road, Minna; dried ginger and garlic were purchased from Kure Ultra-Modern market, Minna, while maize was purchased from Garatu market, Niger State. Dried garlic and ginger were ground into powder and incorporated into the rabbit diets.

### Experimental Diets

The feed ingredients were weighed and ground to particle size of 1 mm and mixed for proper circulation of micro and macro nutrients. Four diets were formulated and designated as follows; Treatment 1 = diet without garlic and ginger supplement, treatment 2 = diet containing 100 g garlic supplement per 100 Kg feed, treatment 3 = diet containing 100 g ginger supplement per 100 Kg feed, and treatment 4 = diet containing 50 g garlic and 50 g ginger supplement per 100 Kg feed (Table 1).

### Experimental Animals and Management

Twelve female Dutch belt weaner rabbit does were used for the experiment. Before the arrival of the rabbits, the experimental house and rabbit hutches were properly washed and fully disinfected. The rabbits were randomly shared into four (4) nutritional treatments in a completely randomized design. Each treatment had three replicates with one rabbit per replicate. Rabbits were reared in hutches measuring 0.6 × 0.5 × 0.4 m, for twenty- three weeks. Medications were given as at when due. The rabbits were fed 5 % of their body weight of the experimental diets in the morning at 8:00, 100 g roughage (groundnut haulms) in the evening at 5:00 pm to aid proper digestion, and water was given *ad-libitum*. Four bucks were reared alongside with the does for the purpose of mating at a mating ratio of one buck to nine does (1:3) regardless of the experimental treatments of the does. The bucks were fed with the control experimental diet throughout the duration of the experiment. The experimental diet was further balanced up to a crude protein content of 18 % to meet the requirement necessary for gestation and lactating does (Pond *et al.,* 1995).

**Table 1: Gross and chemical composition of the experimental diets (%)**

| | Dietary treatments (kg) | | | |
|---|---|---|---|---|
| **Ingredients** | T1 (control) | T2 (100 g garlic) | T3 (100 g ginger) | T4 (50 g garlic+ 50 g ginger) |
| Maize | 49.00 | 49.00 | 49.00 | 49.00 |
| Groundnut cake | 12.00 | 12.00 | 12.00 | 12.00 |
| Fishmeal | 03.00 | 03.00 | 03.00 | 03.00 |
| Rice bran | 18.00 | 17.90 | 17.90 | 17.90 |
| Wheat offal | 14.00 | 14.00 | 14.00 | 14.00 |
| Limestone | 01.00 | 01.00 | 01.00 | 01.00 |
| Garlic | - | 00.10 | - | - |
| Ginger | - | - | 00.10 | - |
| Garlic + ginger | - | - | - | 00.10 |
| Bonemeal | 02.00 | 02.00 | 02.00 | 02.00 |
| Salt | 00.25 | 00.25 | 00.25 | 00.25 |
| Lysine | 00.25 | 00.25 | 00.25 | 00.25 |
| Methionine | 00.25 | 00.25 | 00.25 | 00.25 |
| Vitamin premix | 00.25 | 00.25 | 00.25 | 00.25 |
| **Total** | 100.00 | 100.00 | 100.00 | 100.00 |
| **Calculated content** | | | | |
| Crude fibre | 10.70 | 10.65 | 10.66 | 10.65 |
| Crude protein (%) | 16.08 | 16.11 | 16.10 | 16.10 |
| ME (kcal/kg) | 2526.10 | 2526.05 | 2526.08 | 2526.07 |

Premix supplied per Kg of diet: Vit. A, 10,000iu; Vit D3, 2000iu; Vit E, 23mg; Vit. K, 2mg; Vit, B1, 1.8mg; Vit B2, 5.5mg; pantothenic acid, 7.5mg; Vit. B12, 0.015mg; Folic acid, 0.75mg; Biotin, 0.06mg; Choline chloride, 300mg; Cobalt, 0.2mg; Copper,3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Zinc, 30mg; Antioxidant, 1.25mg.

**Data Analysis**

Data were collected on reproductive performance, and differences between parameters were analyzed by one-way analysis of variance. Statistical assessment of data was carried out using SSPS software version 15 and means were separated using the Duncan multiple range test, where there were statistically significant differences (P<0.05).

**RESULTS AND DISCUSSIONS**

Table 2 shows the reproductive performance of rabbit does fed diets containing garlic and ginger supplementation. The result showed that there were significant differences (P<0.05) in the values obtained for WDBM and WDBP. However, the result obtained for the frequency of mating, conception rate, gestation period, gestation gain, litter weight at birth, AWLW, litter size at birth, mortality, litter size at 21 days, and milk yield were not significantly different (P>0.05). The result obtained revealed that rabbit does fed 50 g garlic + 50 g ginger supplemented diets had higher WDBM and WDBP than rabbit does fed the 100 g garlic supplemented diets. This variation in the weights of the does could be attributed to the improved flavour, palatability and taste of this particular diet. This inclusion of 50 g garlic and 50 g ginger in the diet may have enhanced the appetite of the rabbit does thereby stimulating increased consumption. According to Kunyima *et al.* (2022), ginger and garlic spices are rich in proteinous additives and other nutrients like vitamin B and C, minerals in particular iron, and sulphur containing amino acids, and methionine and cysteine which help in the reproduction process. The non-significant effect of treatments on litter weight at birth, litter size at birth, and litter size at 21 days, concurs with the reports of Montessuy et al. (2005). However, the results of the litter weight at birth is contrary to the reports of Abdel-Azeem (2010) that anti-oxidants present in these spices increase litter weight at birth possibly by increasing or maintaining the competency of oocytes produced at ovulation. This variation in results might be as a result of the different levels of garlic and ginger used, or differences in other ingredients that formed the rabbit feed. The gestation period observed amongst the rabbit does fed ginger and garlic, and the control falls within the normal gestation period of 29 to 35 days reported for rabbits does (McNitt et al., 2013). Also, the non-significant incidence of mortality observed in the study at birth for all the treatment groups contradicts the reports of Montessuy *et al.* (2004).

**Table 2: Reproductive performance of rabbits fed garlic and ginger supplemented diets**

| Parameters | T1 | T2 | T3 | T4 | SEM | P-value |
|---|---|---|---|---|---|---|
| Total number of does used (n) | 3 | 3 | 3 | 3 | | |
| Frequency of mating (n) | 1.67 | 2.00 | 2.50 | 2.33 | 0.18 | 0.40 |
| Conception rate (%) | 100.00 | 100.00 | 100.00 | 100.00 | 3.94 | 1.00 |
| WDBM (g) | $1974.83^{ab}$ | $1783.40^{b}$ | $1956.25^{ab}$ | $2171.43^{a}$ | 50.94 | 0.03 |
| WDBP (g) | $2360.13^{ab}$ | $2100.00^{b}$ | $2375.55^{ab}$ | $2595.53^{a}$ | 69.37 | 0.05 |
| Gestation period (days) | 30.33 | 30.00 | 29.67 | 29.67 | 0.18 | 0.40 |
| Gestation gain (g) | 385.30 | 316.60 | 419.30 | 424.10 | 19.96 | 0.20 |
| Litter weight at birth (g) | 41.97 | 41.20 | 38.13 | 41.88 | 0.28 | 0.60 |
| AWLW (g) | 69.21 | 21.49 | 49.91 | 67.01 | 2.35 | 0.61 |
| Litter size at birth (n) | 4.67 | 4.67 | 4.33 | 4.33 | 0.33 | 0.93 |
| Mortality (n) | 0.33 | 0.00 | 0.33 | 0.33 | 1.67 | 0.57 |
| Litter size at 21 days (n) | 4.33 | 1.33 | 3.00 | 5.00 | 0.27 | 0.69 |
| Milk yield (g) | 245.33 | 76.33 | 176.67 | 237.20 | 8.31 | 0.63 |

$^{abc}$: means along the rows with different superscripts are significantly (P≤0.05) different, WDBM: Weight of doe before mating, WDBP: Weight of doe before parturition, AWLW: Average weekly litter weight, P-value: Probability level, SEM: Standard error of mean.

## CONCLUSION AND APPLICATION

It can be concluded from the results obtained that, the inclusion of garlic and ginger supplements in the diet of rabbit does up to the level of 0.1 % can be tolerated by rabbits, and does not pose any negative effect on the rabbits in terms of their reproductive performance. This was established from the results obtained in the WDBM and WDBP. Thus, garlic and ginger supplement up to 0.1 % inclusion level can be incorporated into the diet of rabbit does.

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# FREE RADICAL SCAVENGING POTENTIAL OF THE MIXTURE OF TURMERIC (*Curcuma longa*) AND BLACK PEPPER (*Piper guineense*)

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**ABSTRACT**

This study was carried out to determine the free radical scavenging activity of the mixture of turmeric and black pepper. This was investigated in the presence of 2, 2-diphenyl-1-picrylhydrazyl (DPPH), using ascorbic acid as the standard antioxidant. The results revealed that with an increase in the concentration of the extract of an equal mixture of black pepper and turmeric from 0.2 to 1.0 mg/ml, its free radical scavenging activity also increased from 43.07% to 79.15%. This shows the existence of a dose-dependent pattern in its antioxidant activity. Moreover, in ascorbic acid with the same concentrations, inhibition activity against DPPH increased from 49.43% to 97.44%. The synergistic interaction between black pepper and turmeric may enhance their combined antioxidant effects. Piperine, a key component of black pepper, is known to increase the bioavailability of curcumin found in turmeric, potentially intensifying its antioxidant activity. The half-maximal (50%) Inhibitory Concentration (IC50) values for the mixture of black pepper and turmeric, and ascorbic acid were 0.53 and 0.42 respectively. It is recommended that black pepper and turmeric mixtures be incorporated into livestock feed supplements, functional foods, or nutraceuticals to harness their antioxidant benefits. Likewise, promoting this mixture's use in dietary interventions aimed at reducing oxidative stress and managing conditions associated with free radical damage may be beneficial.
**Keywords**: Scavenging activities, spices, antioxidants, turmeric, black pepper

## INTRODUCTION

Food safety and nutritional security are crucial to achieving sustainable national and economic development. Spices are rich in bioactive compounds such as polyphenols, flavonoids, and alkaloids, which exhibit potent antioxidant properties. These compounds help neutralize free radicals, reducing oxidative stress and mitigating the risk of chronic diseases. For instance, curcumin in turmeric and eugenol in cloves are well documented for their antioxidant effects (Gupta *et al*., 2013). By incorporating spices into diets or functional foods, natural antioxidants can be harnessed to enhance public health without the adverse effects associated with synthetic antioxidants. Nigeria is abundant in spices possessing beneficial bioactive properties and antioxidant activity that are still undergoing scientific exploitation. However, for this research, an equal ratio (1:1) of mixture of turmeric (*Curcuma longa*) and black pepper (*Piper guineense*) was evaluated for its antioxidant activity. Black pepper (*Piper guineense*) contains rich bioactive compounds, particularly piperine, that enhance digestive efficiency, nutrient absorption, and immune function. Black pepper and turmeric are readily available, and they have several beneficial properties and may be capable of boosting poultry production. Medicinal plants compete with synthetic drugs, most medicinal plants do not have residual effects (Tipu *et al*., 2006). Turmeric is a spice used for seasoning and flavouring in food preparation, and it has long been recognised for its medicinal properties. A tropical medicinal herb that leaves no residues in animal products, it is prized for its antioxidant, antifungal, immunomodulatory, and antimutagenic qualities (Nisar *et al*., 2015). Therefore, it is a matter of great interest to conduct research on these indigenous spices, as a source of natural antioxidants.

## MATERIALS AND METHODS

The turmeric was thoroughly washed with clean water, sliced into pieces and sun-dried for four days. After drying, it was ground using an electric blender (Model Bajaj Stormix). The black pepper which was purchased dried, was also ground using an electric blender (Model Bajaj Stormix). Both spices were afterwards, packed separately in airtight containers.

**Source of Test Samples:** Phytobiotics (spices) black pepper and turmeric were purchased from the Kure ultra-modern market, Minna, Niger State, Nigeria.

**Preparation of Sample Extract:** The extract preparation of black pepper and turmeric was carried out by weighing (1g) each of the ground samples mixed into a conical flask. Afterwards, 100ml of ethanol was measured and then added to the weighed sample in the flask. The extraction was conducted for 40 minutes with the use of a digital 4-hole water bath (Model: E-Track England) at 70 degrees centigrade. The resultant extracts were allowed to cool at room temperature and then filtered using a Whatman filter paper (No. 1).

**Determination of the Antioxidant Activity of Test Samples:** In evaluating the antioxidant activity of the sample, 2, 2-diphenyl-1 picrylhydrazyl (DPPH) was used as the standard free radical according to the method outlined by Mukherjee *et al*. (2011) with minor modifications. Ascorbic acid (vitamin C) was used as the standard control antioxidant. 2, 2-diphenyl-1-picrylhydrazyl of 100 µM concentration was dissolved in methanol to a final concentration of 0.03mM. Serial dilutions were made to determine the half-maximal (50%) Inhibitory Concentration (IC50). Different concentrations (0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 mg/ml) of the extracts of the test samples and ascorbic acid (the standard antioxidant) were used. An ultraviolet spectrophotometer was used to determine the absorbance at 517 nm. The percentage inhibition of the samples was calculated using the formula below;

$$\% \text{ Inhibition} = \frac{Ac - As}{Ac} \times 100$$

Where Ac = absorbance of the control; As = absorbance of the test sample

## RESULTS AND DISCUSSION

The inhibition activity of the equal mixture of black pepper and turmeric against DPPH free radical is shown in Figure 1. The results revealed that as the mixture of black pepper and turmeric concentration increases from 0.2 to 1.0 mg/ml, its free radical scavenging activity rose substantially, from 43.07 % to 79.15 %. This shows a dose-dependent trend. The mixture of black pepper and turmeric demonstrated notable antioxidant potential in scavenging DPPH free radicals. This property may be linked to the presence of bioactive compounds such as piperine and curcumin. These compounds effectively neutralized free radicals by donating hydrogen atoms or electrons, thereby mitigating oxidative stress. In contrast, ascorbic acid exhibited superior inhibition activity within the same concentration range, increasing from 49.43 % to 97.44 %. Ascorbic acid (vitamin C) is a well-established antioxidant that neutralizes free radicals by donating electrons, and its greater effectiveness in this scenario may be attributed to its highly concentrated and potent antioxidant properties. The IC50 values for the mixture of black pepper and turmeric, and ascorbic acid were 0.53 and 0.42 respectively.

Additionally, the synergistic interaction between black pepper and turmeric may enhance their combined antioxidant effects. Piperine, a key component of black pepper, is known to increase the bioavailability of curcumin, potentially intensifying its antioxidant activity. This study indicates that the combination of these spices can create a cumulative or synergistic effect on free radical scavenging, likely contributing to the relatively high inhibition rates observed at higher mixture concentrations. These findings align with prior studies that highlight the strong antioxidant properties of both turmeric and black pepper. For instance, Amalraj *et al*. (2017) emphasized the enhanced bioavailability and effectiveness of curcumin when paired with piperine, similarly, Singleton *et al*. (1999) noted a positive correlation between phenolic content and antioxidant capacity, supporting the role of phenolic compounds in the observed antioxidant activity of the mixture.

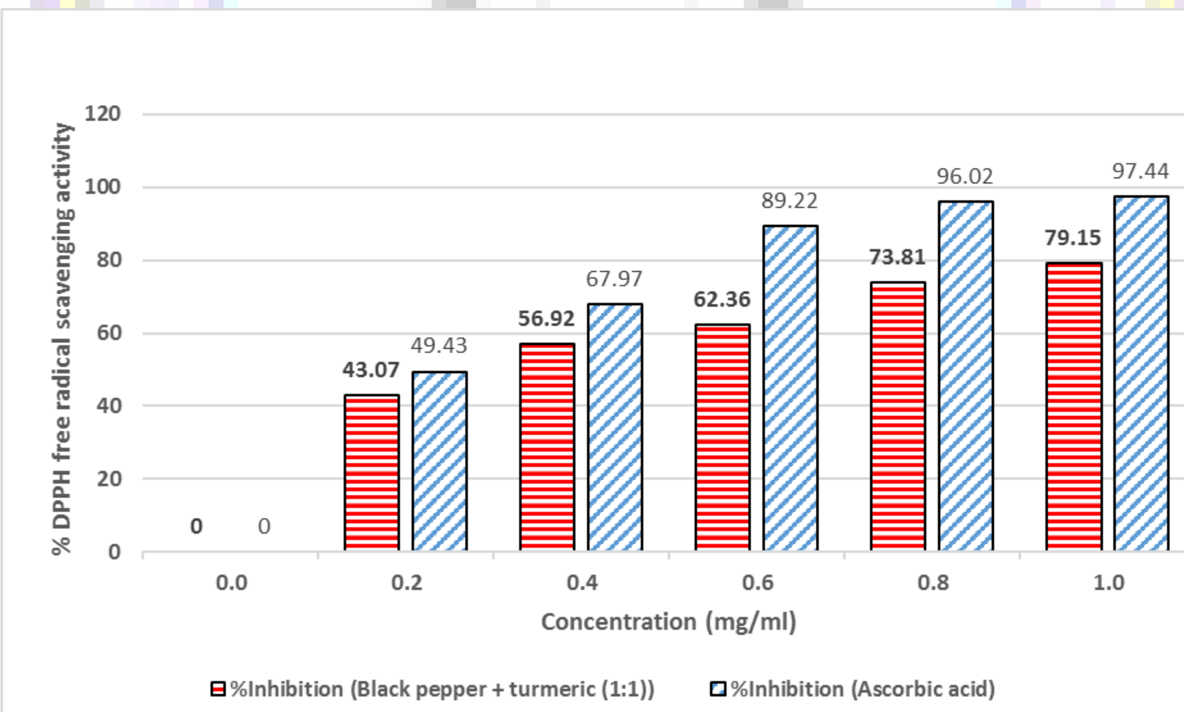


**Figure 1: Antioxidant activity of the mixture of black pepper and turmeric**

## CONCLUSION AND RECOMMENDATIONS

The study demonstrated that the mixture of black pepper and turmeric exhibits substantial antioxidant activity, as evidenced by its ability to scavenge DPPH free radicals in a dose-dependent manner. While ascorbic acid shows superior antioxidant efficacy within the same concentration range, the notable activity of the black pepper and turmeric mixture highlights its potential as a natural antioxidant source. The synergistic interaction between piperine and curcumin likely enhanced the antioxidant capacity of the mixture, further supporting its effectiveness.

It is recommended that black pepper and turmeric mixtures be incorporated into livestock feed supplements, functional foods, or nutraceuticals to harness their antioxidant benefits. Likewise, promoting this mixture's use in dietary interventions aimed at reducing oxidative stress and managing conditions associated with free radical damage may be beneficial.

Further research may investigate the underlying mechanisms of the synergistic effects between piperine and curcumin on antioxidant activity.

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# EFFECT OF GARLIC (*Allium sativum*) AND GINGER (*Zingiber officinale*) THE APPARENT NUTRIENT AND CARCASS CHARACTERISTICS IN BROILER CHICKENS

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## ABSTRACT

One hundred and fifty (150) Ross 308 broiler chickens were used in a eight weeks feeding trial to investigate the effect of garlic and ginger on digestibility and carcass characteristics of broiler chickens at the finisher phase. The birds were allotted to five treatments labelled as T1, T2, T3, T4 and T5 containing 0, 2.0, 2.0, 2.0 and 2.0% of garlic and ginger extract respectively in their drinking water. The five treatments were replicated three times with 10 birds per replicate in a completely randomized experimental design. Feed and portable water were supplied ad libitum. Data collected included weight gain, weekly weight gain, daily feed intake, feed conversion ratio, apparent nutrient digestibility and carcass characteristics. The result revealed significant (P<0.05) differences in carcass and nutrient digestibility. It was concluded that garlic and ginger extract could be incorporated in the water of broiler finisher chicken up to 2.0% without any deleterious effect on the carcass and nutrient digestibility of the birds.

Keywords: Garlic; Ginger; Carcass; Broiler; Feed intake; Digestibility

## INTRODUCTION

The inability of poultry birds to withstand various poultry diseases, due to their weak physiological structures which leads poultry farmers to administer several industrial antibiotics [1] which in reducing the rate at which they are being attacked by bacterial. Drug residue and drug resistance in meat are some the vital reasons that limits the use of antibiotics [2,3]. Legislative actions have severely restricted the use of antibiotics in other countries due to the distress associated with the growth of anti-biotic resistant human pathogenic bacteria effects [4,5]. Antibiotics in poultry feeds have been banned completely, hence the withdrawal of sub-therapeutic level antibiotics for promotional growth (Antibiotic Growth Promoters, AGP's) in poultry feeds [6,7]. Attempts have been made to find other substitutes to improve the susceptibility to poultry diseases and conquer poor performance of poultry that will spring up from the withdrawal of antibiotics from poultry diets. Growth promoters of natural origin has been utilized such as spices and natural herbs became of concern in recent years [8,9,10,11]. Garlic (*Allium sativum*) and Ginger (*Zingiber officinale*) has been fed as feed additives in poultry diet which has led to reduction in carcass yield [12,13]. However, no research has been carried out on addition of garlic and ginger extract in the water of poultry birds. The use of commercial antibiotics has resulted in the deposition of harmful substances to the poultry meat consumed by humans. The use of herbal plants to replace antibiotics will result in the production of safe meat. Hence, the possible use of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) extract as an antibiotic to prevent various broiler diseases and also to determine the effect of garlic and ginger at varying inclusion level is the need for this present study. The aim of this experiment was to assess the effect of Garlic (*Allium sativum*) and ginger (*Zingiber officinale*) on digestibility and carcass characteristics in broilder chickens

## MATERIALS AND METHODS

### Site for Experimental Study

The research was carried out at the Teaching and Research Farming poultry unit in Animal Production Department, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna. Gidan Kwano main campus. The test site is situated on a geological scope between $9^0$32' and $9^0$42'N and Longitude $6^0$30' and $6^0$40'E. The light temperature changes between $24^0$C at the center of the wet season and $35^0$C during the peak of a dry season and yearly precipitation is between 1200-1300. Minna is situated in the southern guinea savannah vegetation zone of Nigerian (FUT Minna Student hand book, 2018).

### Sources and Management of Experimental Birds

A total of 150 Ross 308-day old Agric-tech, broiler chickens were bought from Ibadan, Oyo State Nigeria, Prior to the arrival of the birds, the poultry house was divided into little pens (units) It was cleared and rinses using sanitizer (izal) and permitted to dry. Feeders, drinkers and charcoal pots as warmth source were set in the pens. All vital immunization and prophylactic treatment were given to the birds fittingly in the reason for the examination.

### Experimental Design Treatment and Procedures

The broiler chicken was allotted to five treatment groups T1 Control), T2 (2% of ginger two days in a week), T3 (2% of garlic two days in a week), T4 (2% of ginger everyday) and T5 (2% of garlic everyday) each treatment had three replicates each containing 10 birds. which was observed in a completely randomized block design.

### Source of Garlic/Ginger

The Garlic & Ginger was purchased at Kure market Minna, Niger state, Nigeria.

### Source of Feed

Commercial feeds (Ultima) were purchased from Kpagungu Minna, Niger State for the two phases (starter and finisher phase) of the experiment. The composition of the feed is shown in Table 1.

**Table 1: Proximate Composition of Experimental Diet**

| Parameters | Percentag (%) |
|---|---|
| Moisture | 4.3 |
| Crude protein | 14.75 |
| Ether extract | 5.0 |
| Ash | 11.25 |
| Crude fibre | 6.0 |
| Nitrogen free extract | 58.7 |

### Experimental Processing

Garlic and Ginger obtained from Kure Ultra-Modern Market Minna was weighed, peeled, washed, blended, soaked in water for 24hrs, filtered, the filtrate was kept in a water bath for derivation of active ingredients.

## RESULTS AND DISCUSSION

### Proximate Consumption of Garlic Extract

Table 2 presents the proximate analysis of Garlic used. The garlic used in the experiment had a moisture content of 8.2%, crude protein of 15.23%, ether extract of 7.5%, crude fibre 2.0%, ash of 4.85% and with a nitrogen free extract of (62.22%).

**Table 2: Proximate Consumption of Garlic Extract**

| Parameters | Percentage (%) |
|---|---|
| Moisture | 8.2 |
| Ash | 4.85 |
| Crude fibre | 2.0 |
| Ether extract | 7.5 |
| Crude protein | 15.23 |
| Nitrogen free extracts | 62.22 |

**Proximate Composition of Ginger Extract** The ginger used in the experiment had a moisture content of 6.5%, crude protein of 7.71%, ether extract of 6.23%, crude fibre 1.5%, ash of 5.5% and the nitrogen free extract was (72.56%).

**Table 3: Proximate composition of ginger extract**

| Parameters | Percentage (%) |
|---|---|
| Moisture | 6.5 |
| Ash | 5.5 |
| Crude fibre | 1.5 |
| Ether extract | 6.25 |
| Crude protein | 7.71 |
| Nitrogen free extracts | 72.56 |

### Nutrient Digestibility of Finisher Broilers Given Garlic and Ginger Extract

Table 4 shows the result of the apparent nutrient digestibility. The result revealed that giving broiler birds garlic extract orally had a significant effect ($P>0.05$) on the digestibility.

**Table 4: Apparent Nutrient Digestibility of Broiler Birds Administered Garlic and Ginger Extract at Finisher Phase**

| Parameter | T1 | T2 | T3 | T4 | T5 | SEM | LS |
|---|---|---|---|---|---|---|---|
| | **0%** | **2%** | **2%** | **2%** | **2%** | | |
| Dry matter | $88.67^{d}$ | $96.35^{e}$ | $81.11^{a}$ | $92.22^{b}$ | $96.52^{c}$ | 2.86 | * |
| Crude fibre | $96.62^{d}$ | $94.74^{e}$ | $93.73^{a}$ | $90.7^{b}$ | $96.88^{c}$ | 1.12 | * |
| Ether extract | $82.4^{c}$ | $79.57^{c}$ | $75.92^{a}$ | $91.08^{d}$ | $85.02^{b}$ | 2.56 | * |
| Ash | $80.75^{e}$ | $79.75^{d}$ | $79.94^{e}$ | $82.66^{a}$ | $85.58^{b}$ | 1.09 | * |
| Crude protein | $86.28^{c}$ | $83.22^{d}$ | $85.58^{d}$ | $92.35^{b}$ | $89.57^{a}$ | 1.6 | * |
| Nitrogen free extract | $57.45^{c}$ | $60.25^{e}$ | $42.1^{a}$ | $60.38^{b}$ | $65.98^{d}$ | 4.02 | * |

**: Significant at ($p<0.05$), SEM: standard error mean, LS: level of significance, T1: control (no treatment given), T2: ( 2% ginger treatment twice weekly),T3: ( 2% garlic treatment twice weekly),T4: ( 2% ginger treatment daily),T5: ( 2% garlic treatment daily).

**Carcass Characteristics of Broiler Birds Administered Garlic and Ginger Extract**

Table 5 shows the result of carcass characteristics broiler chicken given garlic and ginger extract orally. The result revealed that there was significant effect (P >0.05) both on the parameters and cut parts except for the shank which has no major effect (P > 0.05).

**Table 5: Carcass characteristic of broiler birds given garlic and ginger extract at finisher phase**

| Parameters | T1 | T2 | T3 | T4 | T5 | SEM | LS |
|---|---|---|---|---|---|---|---|
| Live weight (g) | 2200 | 2800 | 2800 | 2400 | 2600 | 116.61 | * |
| Slaughter weight (%) | 94.72 | 86.53 | 94.71 | 94.95 | 85.92 | 2.1 | * |
| Plucked weight (%) | 90.36 | 83.89 | 90 | 87.91 | 84.53 | 1.34 | * |
| Eviscerated weight (%) | 81.84 | 77.82 | 82.2 | 81.4 | 75.21 | 1.36 | * |
| Dressed weight (g) | 1614 | 1851.4 | 2112.9 | 1820.6 | 1819.9 | 79.49 | * |
| Dressed weight (%) | 73.36 | 66.12 | 75.46 | 75.85 | 69.96 | 1.83 | * |
| CUT PARTS | | | | | | | |
| Dressed weight (%) | 73.36 | 66.12 | 75.46 | 75.85 | 69.96 | 1.83 | * |
| Back | 15.89 | 17.77 | 12.88 | 14.42 | 12.03 | 1.03 | * |
| Breast | 40.79 | 39.08 | 31.74 | 42.37 | 39.54 | 1.83 | * |
| Head | 3.71 | 3.17 | 2.65 | 2.65 | 2.56 | 0.21 | * |
| Drum stick | 17.24 | 6.37 | 14.59 | 13.07 | 13.31 | 1.79 | * |
| Neck | 8.16 | 8.63 | 7.14 | 6.12 | 7.7 | 0.43 | * |
| Shank | 7.83 | 15.49 | 6.28 | 4.65 | 4.89 | 1.99 | NS |
| Thigh | 18.01 | 17.12 | 16.26 | 13.79 | 15.06 | 0.74 | * |
| Wings | 15.67 | 15.58 | 14.85 | 12.51 | 13.45 | 0.61 | * |

**:** LS: level of significance, NS: no significance, ** Significant at ($P<0.05$), SEM: standard error mean, T1: control (no treatment given), T2: (2% ginger treatment twice weekly), T3: ( 2% garlic treatment twice weekly), T4: ( 2% ginger treatment daily), T5: ( 2% garlic treatment daily).

The crude protein and crude fibre content of garlic obtained in this study was lower than the 16.55% and 3.05% earlier reported by [14] as the respective protein and fibre content of garlic (*Allium sativum*). The nitrogen free extract 62.22% recorded was in close range with the authors. While the crude protein and crude fibre content of ginger (*Zingiber officinale*) is 7.71% and 1.5% and the nitrogen free extract 72.56%. The variation observed in the protein and fibre values of garlic and ginger might be as a result of differences in the status of the growing medium, stage and time of harvest and type and extent of processing. The protein content of the experiment diets used in this study was within the recommended level for broiler finisher. [15] recommended 18-20% as the protein requirement for growers to finishers under temperate conditions, while [16] put the protein requirement of broiler finishers raised in the tropic at 21%. The carcass characteristics was high in T2 and T3 ($P<0.05$) which was given ginger and garlic extract twice in a week than T4 and T5 which was given ginger and garlic extract every day. The treatment given ginger extract (T2 and T4) had a higher breast yield than the other treatments served garlic extract ($P<0.05$).T2 which was given garlic and ginger extract shows more effect compared to the control, the breast weight in T4 and T5 which was given ginger and garlic daily has more effect compared to those given ginger and garlic extract twice in a week and the control, there was a decrease in the weight of the head in the treatment given garlic and ginger extract daily compared to dose given twice a week and the control. There was also a decrease in the drum stick compared to the control. The birds which were given garlic and ginger extract twice a week has more effect in the neck, shank, thigh and wings compared to those given daily. The concentration of garlic and ginger extract (2%) used in this study was adequate enough to cause a marked effect on the nutrient digestibility of the broilers. [17] who, contemplated the impacts of ginger and garlic fundamental oils on development execution announced that all organ loads and carcass attributes were not influenced by the medicines, aside from a decline ($P< 0.05$) in relative liver load of birds on garlic oil treatment contrasted with those given ginger oil and control. These outcomes negate with the consequences of the current examination which may be because of lower stock density, ideal and disinfectant states of ascending in current investigation. [18] recommended that allicin in garlic advances the exhibition of the intestinal flora in this manner further developing absorption and upgrading the usage of energy, prompting further body development. [19] additionally recommended that garlic additive improves the movement of pancreatic compounds and gives an atmosphere to better retention of supplements. Infusing the test in powder and through implantation, recorded a huge significance difference ($P < 0.05$). The present examination shows that the test fixings altogether ($P < 0.05$) affected the carcass portions of the broilers. However, as opposed to [17] and [18] who announced that carcass parts were not influenced by ginger and garlic, it is anyway in consonance with [20] who revealed a critical impact on the remains portions of broilers taken care of with garlic. This suggests that their utilization can be prescribed to farmers in the spot of anti-biotics agents.

## CONCLUSION AND RECOMMENDATION

In conclusion, garlic and ginger extract can be incorporated through inclusion in drinking water of broiler up to 2% daily or twice a week without any significant deleterious effect on carcass characteristics and growth performance of the birds. From the findings of the study, it is recommended that Garlic and Ginger extract could be included in the drinking water of broiler finisher up to 2%. Further studies on carcass characteristics and nutrient digestibility should be carried out with higher concentration of garlic and ginger extract

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# EVALUATION OF AIR-DRIED LEAF OF AFRICAN ALMOND (*TERMINALIA CATAPPA)* AS A SOURCE OF NATURAL ANTIOXIDANT

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**ABSTRACT**

Terminalia catappa possesses several phyto-constituents associated with its antimicrobial, anti-inflammatory, antioxidant and hepatoprotective activities. This research was carried out to determine the antioxidant activity of air-dried African Almond leaves by using ascorbic acid as standard, and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) as a free radical. The results of the study showed the notable antioxidant potential of air-dried Almond leaves, as evidenced by their scavenging activity, which ranged from 29.74 % to 75.48 %, exhibiting a dose-dependent relationship, with increased inhibition activity observed at higher extract concentrations from 0.2 mg/ml to 1.0 mg/ml, respectively. The findings of this study show that Almond leaves are a promising natural source of antioxidants, offering a sustainable alternative to the synthetic antioxidants widely used in foods and livestock feeds. Natural antioxidants like those found in Almond leaves are increasingly valued for their safety and potential health benefits, such as reducing the risk of chronic diseases associated with oxidative stress.

**Keywords:** African Almond leaf; feed additive; natural antioxidant; air-drying

## INTRODUCTION

Leaf meals from local plants are gaining attention as potential additives, given their nutritional and bioactive compounds that can enhance rabbit performance while replacing synthetic antioxidants with natural sources that are easily available and safe (Windisch *et al*., 2008). Among these alternative feed sources is the African Almond (*Terminalia catappa*), known for its abundance in the tropical and subtropical regions. The leaves of *Terminalia catappa* contain bioactive compounds such as tannins, flavonoids, and saponins, which have antioxidant and antimicrobial properties (Ayoola and Adeyeye, 2010). However, drying methods of leaf meals can influence their nutritional and bioactive composition, potentially affecting their efficacy as feed ingredients. Different drying techniques, such as air drying, sun drying, and oven drying, may impact the nutrient retention of the leaf meal and the bioavailability of its phytochemicals (Nadeem *et al*., 2015). There is a rising need for the replacement of synthetic antioxidants with natural sources that are easily available and safe. Therefore, the present research work was carried out to evaluate the antioxidant potential of the African Almond leaf meal and the possibility of its inclusion as a natural food and feed additive in livestock feed.

## MATERIALS AND METHODS

### Source of experimental test material

African Almond leaves were collected from Gidan Kwano area, Minna, Niger State. The leaves were air-dried under shade for 7 days, and stored in polythene bags for laboratory analysis.

### Preparation of the samples extract

The extract preparation of the samples was carried out by weighing (1g) of the grounded samples each into a separate conical flask. Afterwards, 100ml of ethanol was measured and added to the weighed samples in the conical flasks. The extraction was conducted for 40 minutes with the use of a digital 4-hole water bath (Model: E-Track England) at 70 degrees centigrade. The resultant extracts were allowed to cool at room temperature and filtered using a Whatman filter paper (No. 1).

**Determination of antioxidant activity of test samples using the free radical scavenging assay**

In the determination of the antioxidant potential of African Almond leaves, 2, 2-diphenyl-1picrylhydrazyl (DPPH) was used as the standard free radical using the method outlined by (Mukherjee *et al*., 2011) with minor adjustments (by utilizing different sample extract concentrations 0.0, .0.2, 0.4, 0.6, 0.8 and 1.0 mg/ml). Ascorbic acid (vitamin C) was used as the standard control antioxidant. The concentration of 100 µM of 2, 2-diphenyl-1-picrylhydrazyl was used to dissolve methanol to a final concentration of 0.03mM. Serial dilution was made to determine the IC50 inhibitory concentration value, which is the concentration of the sample to produce 50 % reduction of free radicals. Different concentrations (0.20, g/ml) of the test material extract and ascorbic acid (the standard antioxidant) was used. An ultraviolet spectrophotometer was used to determine the absorbance at 517nm. The percentage inhibition of the samples at the different doses was calculated using the formula below;

$$\% \text{ Inhibition} = \frac{Ac - As}{Ac} \times 100$$

Where Ac = absorbance of the control

As = absorbance of the test samples

## RESULTS AND DISCUSSION

Antioxidant activity of air-dried African Almond leaf is presented in Figure 1. This study highlights the prominent antioxidant potential of air-dried African almond leaves, as evidenced by their scavenging activity, which ranged from 29.74% to 75.49%. This activity is largely attributed to the presence of bioactive compounds, including phenolic acids, flavonoids, and tannins, which are well-recognized for their capacity to neutralize free radicals and alleviate oxidative stress (Balasundram *et al*., 2006). Variations in scavenging activity may be linked to differences in extract concentration and the availability of these compounds. The findings demonstrate a clear dose-dependent relationship, with increased inhibition activity observed at higher extract concentrations (0.2 mg/ml to 1.0 mg/ml). This pattern is consistent with prior studies showing that higher concentrations of plant extracts enhanced the availability of antioxidant compounds, thereby improving their free radical scavenging ability. For instance, Prior *et al.* (2005) reported similar dose-dependent responses when evaluating the antioxidant capacity of various fruits and plant extracts. Moreover, Rababah *et al*. (2011) identified high levels of flavonoids, such as quercetin and kaempferol, in Almond leaves, which might have contributed to this concentration-dependent increase in antioxidant activity. These findings suggest that African Almond leaves are a promising natural source of antioxidants, offering a sustainable alternative to the synthetic antioxidants widely used in the food and pharmaceutical industries. Comparable dose-dependent trends have been reported in studies on Olive and Grape leaves, where higher extract concentrations were linked to enhanced antioxidant activity, further supporting the potential applications of Almond leaves in similar contexts (Silva *et al*., 2021). Additionally, natural antioxidants like those found in almond leaves are increasingly valued for their safety and potential health benefits, such as reducing the risk of chronic diseases associated with oxidative stress.

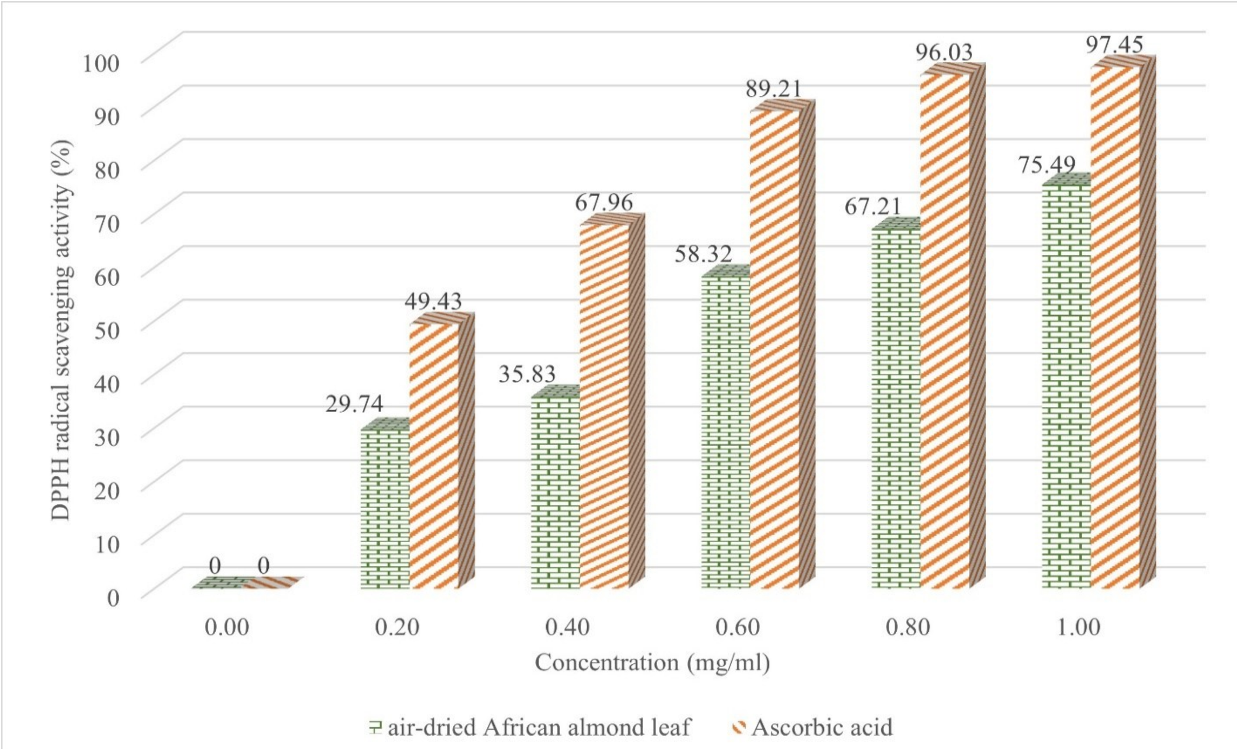


**Figure 1: Antioxidant activity of air-dried African Almond leaf**

## CONCLUSION AND RECOMMENDATIONS

The dose-dependent scavenging activity of African Almond leaf extracts, ranging from 29.74% to 75.49%, emphasizes their potential as a valuable antioxidant source. These findings show that air-dried African Almond leaves can be used as a natural source of antioxidants in animal feed and food preservation. Future research may be conducted on isolating and characterizing the specific compounds responsible for these effects, this could enhance their practical application in commercial products.

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# GROWTH PERFORMANCE OF TILAPIA, HYBRID AND AFRICAN CATFISH IN PONDS UNDER THE CAGES OF PULLETS FED CASSAVA PEEL AND SHEANUT CAKE BASED DIETS

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## ABSTRACT
The integration of poultry animal with fish farming leads to increased productivity per unit area, diversification of economic activities and a better use of on-farm biological and chemical energy. The study was aimed at evaluating the growth performance of Tilapia fish, Hybrid catfish and African catfish raised in ponds under the cages of layer chickens fed molasses-flavoured sundried cassava peel meal (MFSCPM) and molasses-flavoured sheanut cake meal (MFSNC) diets without supplementary feeding. A total number of 100 pieces each of hybrid, tilapia and African catfish, respectively, were used for the study, each of the treatments was replicated five times, with each pond containing 20 pieces of fish which amounted to using a total number of fifteen (0.6 m x1.2 m) sized earthen ponds. There was no significant impact from inclusion of 10% or 20% of molasses-flavoured sundried cassava peel meal or molasses-flavoured sundried sheanut cake in the feed on the growth or development of fishes raised in ponds under the cages without supplementary feed. More so, the weight gain of the fishes in the first four weeks of the experiment could be an indication that the continuous direct deposition of waste from the poultry cages into the fish ponds was favorable for fish growth at the early stage of production.

**Keywords: supplementary, waste, fish pond, Tilapia, Hybrid and African catfish,**

## INTRODUCTION
Feeding, accounts for about 70 % of the total expenditure in both animal and fish production, which has necessitated finding out ways to cut down on production price (Sani, 2015).Poultry production leaves large amount of manure, which poses a serious threat to environmental and human health if not properly managed (Goran *et al*., 2022), thus the need for a well-organized method for early disposal of wastes to obtain a healthy and profitable poultry farming activity becomes imperative (Purnima *et al*., 2018). There is paucity of informmation on the use of integrated farming system as a way of recycling poultry excreta with little or no environmentl pollution. The main linkages between poultry and fish production involve the direct use of poultry wastes, which function as fertilisers to stimulate natural food webs in fish ponds, allowing increased productivity and income while reducing the influence of the waste product on the environment (Singh *et al.,* 2014). Egg laying birds of constant weight that produces fairly constant levels of waste are easier to manage than broilers in which the amount of waste available cannot always be the same due to their short maturation period (Goran *et al.,* 2022). Approximately 60-70 % of the total nitrogen excreted in poultry manure occurs as uric acid and urea (Nahm, 2003), while its crude protein content can be more than 20 %, in addition, the chicken manure gives about 110-1400 kcal / kg energy content, and contains a high concentration of synthesised soluble vitamins, it is therefore, a complete fertilizer with characteristics of both

organic and inorganic fertilisers, which can be used without resorting to the addition of supplementary feed (FAO, 2003). There is tendency to; obtain fish and poultry meat as well as chicken eggs from the same farming system; not incur transportation cost for manure; that nutrients trapped in parts of the manure that gets consumed directly by the fish will be much higher than the dry poultry manure mixed with bedding materials, thus, more production of animal protein will be ensured from the same area of minimum land and overall increase in farm production and income (Bolorunduro, *et al*., 2013).

## METHODOLOGY

The study was conducted at the Integrated Farm Unit, Research Operations Department, National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Niger State. New Bussa is located between latitude 9˚52'59.0"North and longitude 4˚30'40.2'' East in the southern guinea savanna zone of north central Nigeria, with the minimum and maximum temperatures of 39 ℃ and 42℃, respectively with a mean annual rainfall of about 1000 mm (Raji *et al.,* 2011).

A total number of 100 pieces each of hybrid catfish, tilapia fish and African catfish of known weight, were bought from NIFFR hatchery unit, and stocked at juvenile stage, in the ponds provided beneath the pullet cages, the fishes were left to suvive on the waste product from poultry unit that passed directly into the ponds. A total number of fifteen (0.6 m x1.2 m) sized mini earthen ponds, each of which had separate inlet and outlet channels were made available for the purpose of this study. Flow through system was used through out the study period. On a weekly basis, five pieces of fish were picked at random from each replicate, for weight measurment using a KERRO BL50001 electronic compact digital scale, and also the total length measurement using a meter rule from tip of the snout to the tip end of the tail. At the end of the experimental period, the weight gain (WG) and specific growth rate (SGR) were calculated using the formula;

WG = final weight – initial weight

Specific growth rate (SGR) = $\frac{\text{(final weigth – initial weight) x 100}}{\text{Number of days}}$

Data collected were analyzed using one-way analysis of variance (ANOVA) at 0.05 significant level, using statistical package for social sciences SPSS (version 23). Where means were significant, they were separated using the Duncan multiple range test as contained in the package.

## RESULTS AND DISCUSSION

### Growth performance of hybrid catfishes (*Heteroclarias* sp.) raised in ponds under the cages of pullets fed molasses- flavoured sundried cassava peel and sheanut cake meal diets

The same initial weight (IW) for all treatments, shows that the treatments started with similar average weights. Inclusion of 10% or 20% of MCP or MSN in the feed of the pullets did not have a significant impact on the growth or development of fishes raised in ponds under the cages without supplementary feed. More so, the weight gains of the fishes in the first four weeks of the experiment (0.12 kg -0.16 kg) indicates that the continuous direct deposition of waste from the poultry cages into the fish ponds was favorable for fish growth and not detrimental to the hybrid catfishes at the early stage of production. This result agrees with the findings of Megerssa *et al.* (2016) who observed that the growth rate of both Tilapia and Common Carp fishes were faster in ponds under poultry integration than under goat manure pond fertilization.

**Growth performance of all male Tilapia fishes (*Oreochromis niloticus*) raised in ponds under the cages of pullets fed molasses- flavoured sundried cassava peel and sheanut cake meal diets**

All the treatments started with the same initial weight (0.01 kg) meaning that they were of similar weight at the onset of experiment. Although, there were differences in growth performance based on available feed composition, they were are not statistically significant according to the P-values. The results for all the parameters measured of all male Tilapia fishes raised under the ponds of pullets fed MFSCPM and MFSNC diets agrees with the findings of Megerssa *et al.* (2016) where it was observed that the growth rate of both Tilapia and Common Carp fishes were faster in ponds under poultry integration than under goat manure pond fertilization.

**Growth performance of African Cat Fishes *Clarias gariepinus* raised in ponds under the cages of pullets fed molasses- flavoured sundried cassava peel and sheanut cake meal diets**

The same initial weight of 0.01 kg for all the treatments, is an assurance that any observed differences in growth parameters are not due to differences in starting weights. Final weight was higher in 20% MCP group (0.15 kg), and lowest for both 10% MCP and 10% MSN groups, however, the P-value of 0.48 indicates that these differences are not statistically significant. Weight gain and SGR followed a similar trend to final weight. Length measurements were significantly higher for 20% MCP group has the highest length (18.47 cm), and the P-value of 0.03 indicates that the difference is statistically significant, and this could probably be due to upcoming shooters in the pond.

**Table 1: Growth performance of hybrid catfish raised in ponds under the cages of pullets fed molasses-flavoured sundried cassava peel and sheanut cake meal diets**

| Parameter | Control | 10% MCP | 20% MCP | 10% MSN | 20% MSN | SEM | P-value | L/SIG |
|---|---|---|---|---|---|---|---|---|
| IW (kg) | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.75 | NS |
| FW (kg) | 0.17 | 0.14 | 0.13 | 0.13 | 0.13 | 0.03 | 0.51 | NS |
| WG (kg) | 0.16 | 0.13 | 0.13 | 0.13 | 0.12 | 0.14 | 0.51 | NS |
| SGR (%) | 0.36 | 0.29 | 0.27 | 0.28 | 0.27 | 0.02 | 0.51 | NS |
| L (cm) | 18.9 | 18.3 | 17.2 | 17.5 | 17.4 | 17.3 | 0.57 | NS |

**Table2: Growth performance of all male tilapia fish (Oreochromis niloticus) raised in ponds under the cages of pullets fed molasses-flavoured sundried cassava peel and sheanut cake meal diets**

| Parameter | Control | 10%MCP | 20%MCP | 10%MSN | 20%MSN | SEM | P-value | L/SIG |
|---|---|---|---|---|---|---|---|---|
| IW (kg) | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.93 | NS |
| FW (kg) | 0.11 | 0.07 | 0.11 | 0.07 | 0.08 | 0.01 | 0.33 | NS |
| WG (kg) | 0.11 | 0.06 | 0.10 | 0.06 | 0.07 | 0.01 | 0.34 | NS |
| SGR (%) | 0.24 | 0.14 | 0.23 | 0.14 | 0.16 | 0.02 | 0.34 | NS |
| L (cm) | 4.00 | 2.67 | 8.83 | 6.50 | 4.00 | 1.54 | 0.79 | NS |

**Table 3: Growth performance of African cat fish Clarias gariepinus raised in ponds under the cages of pullets fed molasses-flavoured sundried cassava peel and sheanut cake meal diets**

| Parameter | Control | 10% MCP | 20% MCP | 10% MSN | 20% MSN | SEM | P-value | L/SIG |
|---|---|---|---|---|---|---|---|---|
| IW (kg) | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.18 | **NS** |
| FW (kg) | 0.12 | 0.10 | 0.15 | 0.10 | 0.13 | 0.01 | 0.48 | **NS** |
| WG (kg) | 0.12 | 0.09 | 0.14 | 0.10 | 0.12 | 0.01 | 0.48 | **NS** |
| SGR (%) | 0.26 | 0.20 | 0.31 | 0.22 | 0.27 | 0.02 | 0.48 | **NS** |
| L (cm) | $18.13^{ab}$ | $13.50^{c}$ | $18.47^{a}$ | $14.70^{bc}$ | $14.40^{c}$ | 0.69 | 0.03 | * |

NS: means not significant, * significant, 10%MCP = 10% inclusion of molasses-flavoured cassava peel meal, 20%MCP = 20% inclusion of molasses-flavoured cassava peel meal**,** 10%MSN = 10% inclusion of molasses-flavoured sheanut cake, 20%MSN = 20% inclusion of molasses-flavoured sheanut cake, IW = initial weight, FW = final weight, WG = weight gain, SGR = specific growth rate, L = length.

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# IMPACT OF PROCESSING METHOD ON THE PROXIMATE COMPOSITION AND COST EFFICIENCY RATIO OF MODIFIED BAMBARA NUT BASED READY TO USE THERAPEUTIC FOOD (RUTF)

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## ABSTRACT
Nigeria has one of the highest rates of childhood stunting globally, with 40% of children affected. However, only 20% of these children receive the necessary treatment. Ready-to-Use Therapeutic Food (RUTF) is a critical tool in addressing severe acute malnutrition. This study developed four Bambara nut-based RUTF samples by incorporating local ingredients like groundnut, dates, crayfish, fennel seeds, vegetable oil, and micronutrient powder, the Bambara nut was modified using four different processing methods (roasted, fermented/boiled, germinated/boiled, and steamed). The proximate composition was analyzed and the cost efficiency ratio determined using standard procedures. The energy content of all samples exceeded the UNICEF-recommended 520-550 kcal, ranging from 583 to 637 kcal. The total protein content of the roasted (12.00%) within, and fermented/boiled samples (12.30%), slightly above the recommended value of 10-12% of total energy for the standard RUTF, while germinated/boiled (15.82%), and steamed samples (15.20%) had higher protein content. The Fat content ranged from 66.60 % to 72, this values exceed 40–60% recommended by WHO. All the values for the carbohydrate; 14.90%, 16.50 and 18.20 for samples B, C, and D respectively are within the <20% of total energy recommended by WHO, except sample A (20.70%), which is slightly above. Moisture content was lowest in the roasted sample (2.25%) and all moisture levels are closely around the recommended values of 2.5, except sample D (5.25%). Additionally, the Bambara nut-based RUTF proved more cost-effective than imported versions, suggesting its potential for economic viability and local adoption in addressing malnutrition.
Key words: RUTF: Ready to use therapeutic foods, MN: Malnutrition, SAM: severe acute malnutrition, MUAC: mid upper arm circumference, world food programme, MNP: micronutrient powder, & ANRIN: accelerating nutrition results in Nigeria.

## INTRODUCTION
Malnutrition, which refers to both insufficient and excessive nutrition, is often termed "bad nutrition" and is viewed as "under-nutrition" in the context of developing countries (WHO 2024). It is a condition where an individual's physical functions are severely impaired, preventing essential processes such as growth, pregnancy, lactation, physical work, and the ability to recover from illness. (Ibrahim *et al.,* 2023). For children, a healthy diet is crucial for proper growth, learning, and participation in daily activities. Malnutrition remains a leading cause of death in children in many low- and middle-income countries, particularly affecting those under five years old (Ibrahim *et al.,* 2023). This initiative focuses on addressing

underweight, stunting, wasting (with or without oedema), and malnutrition-related mortality in children under five. Globally, malnutrition is responsible for 50% of child deaths, and an estimated 59 million children under five are chronically malnourished. Reducing childhood malnutrition continues to be a critical public health goal in developing). countries (UNICEF, 2022)
Bambara groundnut (*Vigna subterranean* L.) is a highly nutritious legume that is particularly important in sub-Saharan Africa, where it is commonly grown and consumed (Majola *et al.,* 2021). Bambara groundnut is a rich source of plant-based protein, healthy fats, and essential micronutrients, such as iron, zinc, calcium, and magnesium. These nutrients are crucial for infant growth, cognitive development, and immune function. However, the beany flavor, hard-to-cook property, and high antinutrients have contributed to its low applicability in food formulations (James *et al*., 2018). Bambara groundnut is an excellent source of protein, providing about 20 – 30% protein by weight, which supports growth and tissue repair in infants (Majola *et al.,* 2021).

Nigeria has the second-highest rate of stunted children in the world and loses more than 1.5 billion US dollars in GDP each year due to malnutrition. Only two out of ten children suffering from malnutrition receive treatment at this time, and it is estimated that one out of every thirteen Nigerian babies born passes away before turning one-year-old (UNICEF 2024). According to UNICEF (2024), Nigeria is unduly reliant on imported Ready-to-Use Therapeutic Food (RUTF), which is expensive (＄56.15 per carton) and hard to find because of low local production, high importation costs, and logistical difficulties (UNICEF 2023). The nutritionally dense Bambara nut, which is sometimes referred to as a complete food because of its balanced macronutrient composition, is underutilized, even though Nigeria is the world's largest producer of the nutrient-rich legume which if used effectively, can treat malnutrition (Mulugeta *et al*., 2020).

The date palm (*Phoenix dactylifera*) is a flowering plant grown primarily for its edible fruit. These trees can reach heights of 21-23 m, with leaves up to 6 m long, typically featuring around 150 leaves. Date palms grow either individually or in clusters from a single root. With over 100 million trees cultivated globally, they are predominantly found in the Middle East, but also in regions such as Mexico, Australia, South America, southern Africa, and the US (Al-shwyeh *et al.,* 2019). Date fruits contain protein levels ranging from 1.22% to 3.30%, and fat content between 0.11% and 7.33% and other minerals and bioactive compounds (Aimahmoud *et al*., 2023).

Although Nigeria is the world's largest producer of Bambara nuts and other locally available yet underutilized crops, there is a critical need to develop a locally modified Ready-to-Use Therapeutic Food (RUTF) using nutrient-dense Bambara nuts. Severe acute malnutrition in children under five remains a major public health issue, with devastating health consequences and significant financial, economic, and social costs. One effective way to address this problem is by producing RUTF using ingredients sourced locally, like Bambara nuts, to ensure a sustainable and cost-effective solution. Utilizing homegrown ingredients not only reduces production costs but also makes RUTF more accessible to a larger number of children suffering from malnutrition. This approach would alleviate reliance on expensive imported RUTF, which often faces challenges like high shipping costs, delays, and donor fatigue. By tapping into local resources, Nigeria can improve the availability, affordability, and sustainability of malnutrition treatment, ultimately supporting more children and reducing the strain on international aid.

## MATERIALS AND METHODS

### Materials

The production and formulation of Ready to Use Therapeutic Food (RUFT) involved a variety of raw materials, including Bambara nut (*Vigna subterranea*), dates (*Phoenix dactylifera*), groundnut (*Arachis hypogea*), fennel seeds (*Foeniculum vulgare*), crayfish, vegetable oil, and micronutrient powder. These ingredients were selected for their nutritional properties and their potential to contribute to the efficacy of the therapeutic food. The micronutrient powder was obtained from the Accelerating Nutrition Results in Nigeria (ANRIN) project office located on Okada Road in Minna. In contrast, all other raw materials utilized in the process were procured from Kure Market, also situated in Minna, within Niger State.

### Roasting

Two kilograms of dried Bambara nuts were subjected to roasting following the procedure outlined by Okafor *et al*. (2014). The seeds were uniformly distributed on a tray and roasted in an electric oven (Crown Star, model MC - 4011) at a temperature of 140 ℃ for a duration of 60 minutes. After roasting, the nuts were allowed to cool before being milled with an electric blender. The resulting mixture was then sieved through a mesh with a size of 72 µm, subsequently packed, and stored in a polyethylene ziplock bag for future use.

### Fermentation and Boiling

Two kilograms of thoroughly cleaned Bambara nuts were subjected to fermentation following the methodology outlined by Chude *et al*. (2020). Prior to fermentation, the nuts underwent a rinsing and soaking process in tap water for a duration of 12 h. Once the soaking was complete, the water was drained, and the nuts were submerged in 15 L of fresh tap water, where they were allowed to ferment for 72 h. Subsequently, the nuts were rinsed again and boiled for three and a half hours, after which they were cooled and placed in a solar dryer to ensure complete drying. Following the boiling, drying, and fermentation processes, the nuts were ground into flour using a Silver Crest electric blender (Model SC-9880) and passed through a sieve with a mesh size of 72 µm. The resulting flour was then sealed in a Ziplock bag, appropriately labeled, and stored for future use.

### Germination and Boiling

According to Chinma *et al*. (2023), a total of 2.5 kg of Bambara nut seeds underwent an initial process of sorting and washing, followed by a soaking period of 12 h in water. Subsequently, the seeds were placed in a jute bag to facilitate germination, which occurred over a span of 72 h, at ambient temperature (approximately 28 ℃), resulting in the emergence of small green shoots. Upon completion of the germination phase, the seeds were extracted from the jute bag, thoroughly washed, and subjected to boiling for 30 minutes, in accordance with the procedure outlined by Uche *et al*. (2014), to halt further germination and render the seeds suitable for consumption. The final step involved drying the germinated and boiled seeds using a solar dryer until they were entirely desiccated, after which they were milled with a Silver Crest electric blender, model SC-9880, and sieved through a 72 µm mesh to produce flour, which was subsequently packaged in a labeled ziplock bag.

**Steaming**

According to the modifications made by Yahaya *et al.* (2022), the process of preparing cleaned Bambara nuts involved milling them with a Silver Crest electric blender, specifically model SC-9880. Following the milling, the resulting flour underwent steaming for a duration of 1 h and 30 minutes utilizing a Russell Hobbs electric steamer, model number 13888. Subsequently, the flour was dried for 40 minutes at a temperature of 105 ℃ in a Crown Star electric oven, model MC-4011, and was then subjected to sieving through a laboratory sieve with a mesh size of 72 µm.

**Date powder:** Dried dates underwent a meticulous sorting process before being crushed with a mortar and pestle to extract the seeds. Subsequently, the date flesh was processed in a Kenwood blender and passed through a sieve with a mesh size of 72 µm to produce date flour, as reported by Ashgan *et al.* (2024).

**Groundnut paste**: Prior to their utilization, the groundnuts underwent a thorough washing process, which included rinsing with tap water to eliminate any residual debris or damaged nuts. Subsequently, a sun dryer was employed to ensure the groundnuts were completely dried. The roasting process was carried out using the Crown Star electric oven, model MC-4011, at a temperature of 180°C for a duration of 30 minutes. Following this, the groundnuts were processed into a paste in accordance with the methodologies outlined by Joseph *et al*. (2023).

**Crayfish powder:** The crayfish underwent a meticulous cleaning process, which involved the manual removal of dirt, followed by winnowing and washing in a bucket of water. Subsequently, it was placed in a solar dryer where it was allowed to dry for three hours. After this drying period, the crayfish was roasted for five minutes at a temperature of 15 ℃, utilizing a Crown Star electric oven, model MC - 4011. The final steps included pulverizing the dried crayfish in a blender, sieving the resulting powder through a 72 mm sieve, and securely packaging it in a Ziplock bag, as detailed by Ibironke *et al*. (2018).

**Fennel Seed powder:** The fennel seeds were carefully cleaned through a process that included the manual elimination of dirt, followed by rinsing with tap water. After draining, the seeds were sun-dried for 30 minutes and then roasted for 5 minutes at a temperature of 15℃. Once roasted, the seeds were milled and sifted through a 72 mm mesh sieve, in line with the modified method described by Susinggih *et al.* (2023)

**Ingredients Blend Formulation for the production of modified Bambara nut based RUTF**

The composition of the ingredient blend for the samples that were roasted, fermented or boiled, germinated or boiled, and steamed is presented in Table 1. To ensure a consistent mixture, the samples underwent a comprehensive mixing process to achieve uniformity in the blending of the ingredients.

**Table 1: Bambara nut Based RUTF Samples Ingredients Blends Formulation.**

| Ingredients (%) | Roasted (A) | Fermented/Boiled (B) | Germinated/Boiled | Steamed |
|---|---|---|---|---|
| **Bambara nut flour** | 24.5 | 24.5 | 24.5 | 24.5 |
| **Peanut paste** | 37 | 37 | 37 | 37 |
| **Date powder** | 20 | 20 | 20 | 20 |
| **Vegetable oil** | 15 | 15 | 15 | 15 |
| **Crayfish powder** | 2 | 2 | 2 | 2 |
| **Fennel seed powder** | 1 | 1 | 1 | 1 |
| **Micronutrient powder** | 0.5 | 0.5 | 0.5 | 0.5 |
| **Total** | 100 | 100 | 100 | 100 |

Source: Sosanya *et al.* (2017) modified.

## METHODS

### Determination of proximate composition

The moisture contents of the samples were determined after drying at 105ºC. micro kjeldahi method was employed in determining the crude protein. Fat was extracted with petroleum ether, using a Soxhlet apparatus. Ash contents (gravimetric) was also determined all as described by Uche *et al* (2014). While the carbohydrate content was determined by difference.

Carbohydrate (%) =100% - [ (moisture (%) + Fat (%) + Crude protein (%) + ash (%) + Crude fiber (%)]

The energy content was calculated by multiplying the mean values of carbohydrate, crude protein, and crude fat by Atwater factors of 4, 4, and 9 respectively.

Energy value (kcal/100g) = {(carbohydrates (%) X 4) + (Crude Fats (%) x9) + (Crude Protein (%) x 4)}.

### Determination of the cost efficiency ratio

The cost efficiency ratio of the RUTF produced in this study was assessed by comparing it to the cost of the RUTF imported by UNICEF. The imported RUTF is priced at over 56 US dollars per carton, which contains 150 sachets of 92 g each, excluding shipping costs but including discounts provided to UNICEF by the supplier. When this price is converted to Nigerian naira, a carton amounts to approximately 85,000 naira. According to the methodology outlined by Shekar *et al*. (2017).

Cost Efficiency Ratio (CER) = Total Cost / Total Output

Total Cost of producing modified Bambara nut based RUTF (excluding expenses related to equipment, labor, and electricity) = 50,000 naira.

Total Output = 150 sachets

CER =150.50,000/ 150 = 333 Naira/ Sachet.

## RESULTS AND DISCUSSION

### Proximate composition of modified Bambara nut based RUTF

The moisture content of the four samples showed considerable variation with the WHO recommendation of 2.5% maximum. Sample A had a moisture level of 2.25%, which is within the acceptable range, 3.20% and 3.10% moisture content for samples B and C respectively, slightly exceeding the recommended limits, while Sample D had the highest moisture content of 5.25%. Maintaining low moisture levels is essential to minimize microbial growth and extend the shelf life of RUTF (WHO 2022). The World Health Organization (WHO) recommend that 40–60% of the energy in RUTF should come from fat. The fat content of the four samples varied significantly, with values 45.10%, 51.60%, 45.60% and 43.20% which correspond to 67%, 72.9%, 67.7%, and 66.6% of the energy for samples A, B, C, and D, respectively. These values not only surpassed the standard RUTF guidelines but were also higher than those reported by Sosanya *et al.* (2017), although they remained comparable. The incorporation of polyunsaturated oils in RUTF production is crucial for providing essential fatty acids. Fat plays a key role in addressing severe acute malnutrition (SAM), which involves extreme wasting and loss of subcutaneous fat. In addition to supporting tissue regeneration, fat is vital for immune function and overall health, helping to prevent illnesses in malnourished children as highlighted by Saaka *et al*. (2015).

According to WHO recommendations, protein should constitute 10–12% of the total energy content in RUTF. In this study, the protein content of the Bambara nut-based samples was 18.24%, 19.62%, 23.98%, 22.20% which corresponds to 12%, 12.3%,15.82% and 15.20% of total energy value for all the samples respectively, with sample B having 12.3%, slightly above the recommended range for sample A (12%). Samples C and D exceeded the recommended protein range of 15.82% and 15.20%, respectively. The ash content varied significantly across the samples. Sample B (1.61%) had the lowest ash content, followed by sample C (2.11%), and sample D (2.61%). Sample A, however, exhibited the highest ash content at 2.90%. Ash content represents the residual minerals left after the complete combustion of a food sample. A low ash content (<1%) indicates minimal mineral presence, while a higher ash content (>3%) suggests a higher concentration of minerals Ismail *et al.* (2017). The fiber content in samples B (0.30%), C (0.30%), and D (0.25%) showed little variation, while sample A had a noticeably lower fiber content of 0.23%. Carbohydrates are essential not only as a key energy source but also for enhancing the palatability of Ready-to-Use Therapeutic Food (RUTF). In this study, sample A had the highest carbohydrate concentration of 31.33%, with notable differences compared to samples B, C, and D, which had 23.77%, 24.97%, and 26.54% carbohydrates, respectively. The energy values of the Bambara nut-based Ready-to-Use Therapeutic Food (RUTF) samples A, B, C, and D in this study exceeded the recommended range of 520–550 kcal, with respective values of A (604.09 kcal), B (637.71 kcal), C (606.20 kcal) and D (583.60 kcal) (Table 2). Notably, sample B had the highest energy content of 637.71 kcal, while sample D (583.60 kcal) was closest to the recommended range. These findings revealed significant variability in energy content across the samples, which is consistent with the results of Sosanya *et al*. (2017), which also showed slightly higher energy levels than the guidelines. The variation in fats may be attributed to the inclusion of vegetable oil and groundnuts, both of which are rich in fat. Overall, the roasted sample A appeared to be the most closely with the WHO recommended values for most of the measured parameters, making it the preferred choice for adoption. Additionally, the steaming process used for sample D proved to be a valuable method, highlighting its potential benefits.

According to recommendations, protein should constitute 10–12% of the total energy content in RUTF. In this study, the protein content of the Bambara nut-based samples ranged from 12% to 15.82%, with sample B having 12.3%, slightly above the recommended range for sample A (12%). Samples C and D exceeded the recommended protein range, with contents of 15.82% and 15.20%, respectively.

The World Health Organization (WHO) guidelines suggest that 40–60% of the energy in RUTF should come from fat. The fat content of the four samples varied significantly, with values of 67.00%, 72.90%, 67.70%, and 66.60% for samples A, B, C, and D, respectively. These values not only surpassed the standard RUTF guidelines but were also higher than those reported by Sosanya *et al*. (2018), although they remained comparable. The incorporation of polyunsaturated oils in RUTF production is crucial for providing essential fatty acids. Fat plays a key role in addressing severe acute malnutrition (SAM), which involves extreme wasting and loss of subcutaneous fat. In addition to supporting tissue regeneration, fat is vital for immune function and overall health, helping to prevent illnesses in malnourished children, as highlighted by Saaka *et al*. (2015).

Regarding moisture content, the four samples showed considerable variation but generally stayed within the UNICEF maximum threshold of 2.5%. Sample A had a moisture level of 2.2%, which is within the acceptable range, while samples B and C had 3.20% and 3.10% moisture, respectively, both exceeding the recommended limits. Sample D had the highest moisture content at 5.25%. Maintaining low moisture levels is essential to minimize microbial growth and extend the shelf life of RUTF.

**Table 2: Proximate Composition of Bambara nut Based Ready to Use Therapeutic Food.**

| Parameters (%) | A | B | C | D |
|---|---|---|---|---|
| **Energy (kcal)** | $604.09^{c}\pm0.45$ | $637.71^{a}\pm0.10$ | $606.20^{b}\pm0.21$ | $583.60^{d}\pm0.30$ |
| **Total protein** | $12.00^{d}\pm0.01$ | $12.30^{c}\pm0.00$ | $15.82^{a}\pm0.01$ | $15.20^{b}\pm0.01$ |
| **Total Fat** | $87.00^{c}\pm0.01$ | $72.90^{a}\pm0.01$ | $67.70^{b}\pm0.01$ | $66.60^{d}\pm0.00$ |
| **Carbohydrate** | $20.70^{a}\pm0.12$ | $14.90^{d}\pm0.01$ | $16.50^{c}\pm0.10$ | $18.20^{b}\pm0.10$ |
| **Moisture** | $2.25^{c}\pm0.11$ | $3.20^{b}\pm0.03$ | $3.10^{b}\pm0.10$ | $5.25^{a}\pm0.10$ |
| **Crude fibre** | $0.23^{c}\pm0.01$ | $0.30^{b}\pm0.00$ | $0.30^{b}\pm0.01$ | $0.25^{b}\pm0.01$ |
| **Ash** | $2.90^{a}\pm0.02$ | $1.61^{d}\pm0.01$ | $2.11^{c}\pm0.01$ | $2.61^{b}\pm0.01$ |

Result are expressed as the Mean values ±standard deviation (SD) with different superscript along the same column are statistically significantly different (P<0.05).

A=Roasted Bambara based RUTF sample; B=Fermented /Boiled Bambara based RUTF sample; C=Germinated / Boiled Bambara based RUTF sample and D=Steamed Bambara based RUTF sample (Control)

**Cost Efficiency Ratio**

To date, the financial burden of procuring RUTF has largely been borne by international non-governmental organizations such as Médecins Sans Frontières (MSF) and various United Nations agencies, as highlighted by UNICEF in 2024. Replacing milk, a costly protein source, with Bambara nuts of which Nigeria is believed to be the largest producer has significantly reduced the cost of RUTF while improving its micronutrient profile, as reported by Mulugeta *et al*. (2020). Additionally, dates have been used in place of sugar due to their natural sweetness, which helps sustain energy levels, as well as their antioxidant properties and other nutritional benefits. Research indicates that locally sourced RUTF made with Bambara nuts is more cost-effective than imported alternatives, with total production costs amounting to around 50,000 naira (300 naira per 100 g sachet, or 60,000 naira per carton of 150 sachets) (Table 3).

Despite efforts by UNICEF and other international organizations to import RUTF, the incidence of Severe Acute Malnutrition (SAM) among children in Africa, particularly in Nigeria, remains alarmingly high. The use of locally available ingredients, such as Bambara nuts, groundnuts, crayfish, and dates common in northern Nigeria for the production of RUTF in regions with high rates of malnutrition could play a critical role in reducing the prevalence of SAM, as suggested by Sosanya *et al*. (2017).

**Table 3: Cost efficiency ratio of the Imported and the Bambara nut based RUTF**

| Naira #/ Quantity | Imported RUTF | Bambara nut Based RUTF |
|---|---|---|
| Cost (Naira) | 85,000 | 50,000 |
| Output (Sachet) | 150 | 150 |

## CONCLUSION

This study sought to tackle the challenges of high costs and frequent shortages of imported Ready-to-Use Therapeutic Foods (RUTF), which contribute to malnutrition. By exploring the impact of different processing methods on the macronutrient composition of Bambara nut-based RUTF, the research demonstrated that locally produced RUTF is both a cost-effective alternative and meets the required nutritional standards.

## RECOMMENDATION

To reduce dependence on imported Ready-to-Use Therapeutic Foods (RUTF), it is crucial to conduct *in-vivo* studies and other relevant research. The ongoing use of local ingredients, such as replacing milk and sugar with locally sourced alternatives, is recommended in RUTF production. Additionally, incorporating this approach into national nutrition programs targeting regions with high malnutrition rates will improve its effectiveness and long-term sustainability.

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# ESSENTIAL AMINO ACID PROFILE OF BAMBARA AND GROUNDNUT BASED READY-TO-USE THERAPEUTIC FOOD (RUTF)

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## ABSTRACT

Childhood malnutrition remains a public health issue, especially in developing countries like Nigeria. Unfortunately, only a few malnourished children have access to conventional ready-to-use therapeutic foods. This study focuses on assessing the essential amino acid profile of locally made ready-to-use therapeutic foods. The ready-to-use therapeutic food was made from a blend of ingredients including processed Bambara nuts (roasted, fermented/boiled, germinated/boiled, and steamed), groundnut, dates flesh, crayfish, fennel seed, vegetable oil, and micronutrient powder. Four samples (A, B, C, and D) of locally made ready-to-use therapeutic foods were produced, and essential amino acid analysis was conducted on each sample. The samples A, B, C, and D represent roasted, fermented/boiled, germinated/boiled, and steamed samples, respectively. The findings revealed significant differences ($p<0.05$) in the amounts (1.95±0.01, 2.15±0.01, 1.21±0.01, and 0.82±0.01 g/100 g) of tryptophan present in the samples. Sample B had the highest Leucine content (7.84±0.01 g/100 g), while the lowest amount (3.83±0.01 g/100 g) was found in sample A. Similarly, sample B had the highest amounts of Isoleucine (6.02±0.02 g/100 g), (Phenylalanine 6.78±0.01 g/100 g), and Valine (5.87±0.01 g/100 g). The study also showed that the amounts of Threonine in samples B, C, and D (3.70±0.00, 3.53±0.01, and 3.90±0.01 g/100 g) were not significantly different ($p>0.05$). However, the level of Threonine in sample A (5.43±0.60 g/100 g) differed significantly ($p<0.05$) compared to samples B, C, and D. Overall, the study deduced that the ready-to-use therapeutic food made using fermented/boiled Bambara nuts (sample B) contained more essential amino acids than the other processed samples.

**Key words:** RUTF: ready to-use therapeutic food, SAM: severe acute malnutrition, LMICs: low and middle income countries, EAA: essential amino acids, ANRIN: accelerating nutrition results in Nigeria & MNP: micronutrient powder.

## INTRODUCTION

Malnutrition, specifically undernutrition, is a critical issue among children, with infants and children aged 6–59 months particularly susceptible to Severe Acute Malnutrition (SAM) (Moustiès et al., 2022). The prevention and management of SAM are crucial for improving child survival rates (Ghimire et al., 2020). However, treating children with SAM in Low- and Middle-Income Countries (LMICs) presents challenges, leading the World Health Organization (WHO) to recommend Ready-to-Use Therapeutic Food (RUTF) for SAM treatment (Tsurayya et al., 2024).

RUTFs are an effective treatment for SAM in children under five years old, focusing on weight gain and recovery compared to other dietary approaches (Schoonees et al., 2019). Developed in the 1990s and widely implemented in the early 2000s, RUTFs now play a crucial role in the community-based management of SAM (Nikièma et al., 2022). They are easy to handle, require no home preparation, and provide caregivers with additional time. Different types of RUTF have been created in various countries, tailored to align with local tastes, culture, and food habits (Marchini et al., 2022). The peanut flavor and paste texture are more popular in Africa than in Asia (Bahwere et al., 2017). In the past decade, RUTF formulations and associated costs have been optimized using linear programming to make better use of local resources like Bambara nut (Akinmoladun et al., 2023).

Amino acids are essential for metabolism and play a crucial role in protein and energy processes within the body (Ling *et al.,* 2023). In children, they are necessary for synthesizing proteins that require dietary intake. Higher concentrations of Essential Amino Acids (EAAs) in plasma lead to increased protein synthesis in human muscles (Church *et al.,* 2020). Children suffering from oedematous malnutrition (kwashiorkor) often exhibit reduced antioxidant capacity and may need amino acids to enhance their antioxidant capacity and mitigate oxidative stress (Visternicu *et al.,* 2024).

The Bambara nut is believed to originate from the region between West and Central Africa (Majola *et al.,* 2021). It is extensively cultivated throughout sub-Saharan Africa and is also found in small quantities in Thailand, Malaysia, and Indonesia (Halimi *et al.,* 2019). There is a higher preference for Bambara nut in dry, drought- prone areas, likely due to its capability to yield reasonably well under such conditions, thus providing a reliable source of food for farmers (Maphosa *et al.,* 2022; Musah *et al.,* 2021). In Africa, the annual production of Bambara nut is approximately 0.3 million tons with an average yield of 0.85 t/ha, although its yield potential can exceed 3 t/ha. Nigeria is the largest producer, with an average output of 0.1 million tons, followed by Burkina Faso with 44,712 tons, and Niger with 30,000 tons (Tan *et al.,* 2020).

Groundnut farming is predominantly carried out by smallholder farmers. Despite its potential, challenges such as climate variability, pest infestation, and limited access to improved seeds hinder optimal production (Ijarotimi *et al.,* 2021). In recent years, increased emphasis on research, improved agricultural practices, and government initiatives to boost the sector have led to resurgence in groundnut production (Odoemelam *et al.,* 2020; Muhammad and Sulaiman, 2023). Micronutrient powders (MNPs) are single-dose sachets of vitamins and minerals in powder form that can be added to semi-solid food to address micronutrient deficiencies, particularly in young children (Suchdev *et al.,* 2020). Malnutrition, particularly among children under the age of five, continues to be a pressing global public health issue, with a negative impact in developing countries

Millions of children in developing countries suffer from Severe Acute Malnutrition (SAM), and relying on imported, commercially manufactured Ready-to-Use Therapeutic Food (RUTF) presents significant financial and logistical challenges for many low-income countries. Therefore, there is a pressing need to produce RUTF using locally available foods. This justifies the exploration of locally sourced, affordable alternatives to traditional RUTF. The food ingredients (Bambara nuts, groundnuts, crayfish, date flesh, and fennel seeds) used in this study is rich sources of nutrients such as protein, fiber, and essential micronutrients, which can address the nutritional needs of malnourished children. Additionally, these ingredients are readily available and affordable in many rural communities. Moreover, a modified RUTF could reduce dependency on imported products, thus easing the financial burden on the state and the country as a whole, while also enhancing food security. This aligns with Sustainable Development Goal 2, which aims to eradicate hunger in all its forms, making this research a critical area of study with the potential for significant public health impact.

## MATERIALS AND METHODS

### Materials

The food based materials used in this study include Bambara nut (*Vigna subterranea*), dates (*Phoenix dactylifera*), groundnut (*Arachis hypogea*), fennel seeds (*Foeniculum vulgare*), crayfish, vegetable oil, and micronutrient powder. These ingredients were selected for their nutritional properties and their potential to contribute to the efficacy of the therapeutic food. The micronutrient powder was obtained from the Accelerating Nutrition Results in Nigeria (ANRIN) project office located on Okada Road in Minna. In contrast, all other raw materials utilized in the process were procured from Kure Market, Minna, Niger State.

### Processing Methods

#### Roasting

Two kilograms of dried Bambara nuts were roasted according to the procedure outlined by Okafor et al. (2014). The seeds were evenly spread on a tray and roasted in an electric oven (Crown Star, model MC-4011) at a temperature of 140°C for 60 minutes. After roasting, the nuts were cooled before being ground with an electric blender. The resulting mixture was then sifted through a 72 µm mesh, packed, and stored in a polyethylene ziplock bag for later use.

#### Fermentation and Boiling

Two kilograms of thoroughly cleaned Bambara nuts were subjected to fermentation following the methodology outlined by Chude et al. (2020). Before fermentation, the nuts were rinsed and soaked in tap water for 12 hours. After soaking, the water was drained, and the nuts were placed in 15 liters of fresh tap water to ferment for 72 hours. After fermentation, the nuts were rinsed again and boiled for three and a half hours. They were then cooled and placed in a solar dryer to ensure complete drying. Once dried, the nuts were ground into flour using a Silver Crest electric blender (Model SC-9880) and sifted through a sieve with a mesh size of 72 µm. The resulting flour was sealed in a Ziplock bag, labeled appropriately, and stored for future use.

#### Germination and Boiling

This process was conducted according to the guidelines outlined in a study by Chinma et al. (2021). Initially, 2.5 kg of Bambara nut seeds were sorted and washed, then soaked in water for 12 hours. The seeds were then placed in a jute bag to promote germination, which took place over 72 hours at an ambient temperature of approximately 28 ℃, resulting in the growth of small green shoots. After germination was complete, the seeds were removed from the jute bag, washed thoroughly, and boiled for 30 minutes following the method described by Ndidi et al. (2014). This boiling process was done to stop further germination and make the seeds suitable for consumption. The final step involved drying the germinated and boiled seeds in a solar dryer until completely desiccated. The dried seeds were then ground into flour using a Silver Crest electric blender, model SC-9880, and sieved through a 72 µm mesh. The flour was then packaged in a labeled ziplock bag.

**Steaming**

This was done using the method of Yahaya *et al.* (2022) with modification. The Cleaned Bambara nuts were steamed for 1 hour 30 minutes using an electric steamer, and they were cooled and allowed to dry, it was then milled and the flour was obtained by sieving using a 72mm mesh size laboratory sieve. Figure 1 shows the pictures of Bambara nuts, Crayfish, Fennel seeds, and Groundnuts.

**Table 1: Bambara nut Based RUTF Samples Ingredients Blends Formulation**

| Ingredients (%) | Roasted (A) | Fermented/Boiled (B) | Germinated/ Boiled | Steamed |
|---|---|---|---|---|
| Bambara nut flour | 24.5 | 24.5 | 24.5 | 24.5 |
| Peanut paste | 37 | 37 | 37 | 37 |
| Date powder | 20 | 20 | 20 | 20 |
| Vegetable oil | 15 | 15 | 15 | 15 |
| Crayfish powder | 2 | 2 | 2 | 2 |
| Fennel seed powder | 1 | 1 | 1 | 1 |
| Micronutrient powder | 0.5 | 0.5 | 0.5 | 0.5 |
| **Total** | 100 | 100 | 100 | 100 |

**Statistical Analysis**

The data obtained were in triplicates and the results were subjected to one-way analysis of variance and expressed as mean with standard deviation. The differences between means were separated by Duncan's Multiple Range Test using IBM SPSS Statistics Programme, Version 19.0 (Illinois, USA). Significant differences were expressed at 5% level.

**RESULTS AND DISCUSSION**

The analysis of amino acid composition across the samples revealed differences in the concentrations of essential amino acids. Sample B consistently showed higher levels of key amino acids such as leucine (7.84 g/100 g), isoleucine (6.02 g/100 g), and phenylalanine (6.78 g/100 g) compared to the other samples (Table 2). Essential amino acids are crucial for protein synthesis and muscle repair, making Sample B potentially more beneficial for promoting muscle growth and recovery, particularly in children, who have high protein needs. The importance of these amino acids in growth and development cannot be overemphasized (Wessels *et al*., 2016; Luiking *et al*., 2014). Since tryptophan is a precursor for serotonin, which influences mood, and methionine is critical for metabolism and detoxification (Höglund *et al*., 2019), the lower levels in Sample D suggest it might be less effective in supporting these specific biological processes compared to the other samples.

**Table 1: Essential Amino Acid Profile of Bambara nut Based Ready to Use Therapeutic food**

| | Samples | | | |
|---|---|---|---|---|
| Amino acid (g/100 g) | **A** | **B** | **C** | **D** |
| Tryptophan | 1.95±0.01[b] | 2.15±0.01[a] | 1.21±0.01[c] | 0.82±0.01[d] |
| Histidine | 2.60±0.01[d] | 3.34±0.01[a] | 3.10±0.02[c] | 3.13±0.01[b] |
| Leucine | 3.83±0.01[d] | 7.84±0.01[a] | 6.75±0.01[b] | 6.30±0.00[c] |
| Isoleucine | 5.08±0.01[b] | 6.02±0.02[a] | 3.00±0.00[c] | 2.85±0.01[d] |
| Phenylalanine | 4.81±0.01[d] | 6.78±0.01[a] | 4.95±0.01[c] | 5.34±0.01[b] |
| Valine | 4.84±0.06[b] | 5.87±0.01[a] | 3.85±0.00[d] | 4.34±0.01[c] |
| Lysine | 5.72±0.01[a] | 3.64±0.01[d] | 3.89±0.01[c] | 4.01±0.01[b] |
| Methionine | 4.00±0.01[b] | 3.21±0.01[c] | 3.22±0.00[c] | 4.20±0.01[a] |
| Threonine | 5.43±0.60[a] | 3.70±0.00[b] | 3.53±0.01[b] | 3.90±0.01[b] |

Values are expressed as Mean ± standard deviation (SD). Values along the group (horizontal) having different superscript differ significantly (P<0.05).

## CONCLUSION

In conclusion, the amino acid composition of the four samples shows variations in the concentrations of amino acids. Sample B had higher concentrations of tryptophan, histidine, leucine, isoleucine, phenylalanine, and valine. This suggests that a ready-to-use therapeutic food (RUTF) formulation using fermented and boiled Bambara nuts could provide a valuable source of essential amino acids necessary for a child's growth and development.

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# FAECAL MICROBIAL GROWTH OF WEANER RABBITS (*Oryctolagus cunniculus*) FED GARLIC AND GINGER SUPPLEMENTED BASAL DIETS

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## ABSTRACT
This study was carried out to investigate the faecal microbial growth of rabbits fed diets supplemented with garlic and ginger. Thirty-six female Dutch weaner rabbits weighing between 714.33 g to 730.60 g were randomly allotted into four dietary treatments of nine rabbits and three replicates with three rabbits per replicate in a completely randomized design. The dietary treatments were designated as follows; control containing 0 g garlic and ginger (T1), 100 g garlic per 100 kg feed (T2), 100 g ginger per 100 kg feed (T3) and 50 g garlic + 50 g ginger per 100 kg feed (T4). Data obtained were subjected to analysis of variance and significant differences were separated using Duncan Multiple Range Test. The result showed that there were significant ($p<0.05$) differences in initial bacteria count, final bacteria count, average bacteria count and growth in bacteria. The initial bacteria count of rabbits in T3 were significantly higher ($p<0.05$) than rabbits in T2 and T4. However, the value ($2.11\times10^6$) obtained was similar ($p>0.05$) to the control ($1.79\times10^6$). The final bacteria count and growth in bacteria of T2 had higher values ($7.17\times10^6$ and $5.90\times10^6$) than the control ($3.31\times10^6$ and $2.6333\times10^6$) and T3 ($1.54\times10^6$ and $5.70\times10^6$), although similar ($p<0.05$) values were obtained in T4 ($5.2\times10^6$ and $4.17\times10^6$). Similarly, average bacteria count was superior ($p<0.05$) in T2 and T4 than in T3 and TI. In conclusion, garlic and ginger supplemented up to 0.1 % inclusion levels can be incorporated into the diet of rabbits.
**Keywords**: Faecal microbial growth, weaner rabbit, ginger, garlic.

## INTRODUCTION
Livestock agriculture apart from providing animal protein to man, has also played an important role in the standard of living of humans (Bettencourt *et al.,* 2015). Animal protein is an important necessity in human nutrition due to its balanced amino acid profile (Jon, 2018). In Nigeria, the production and availability of meat produced by some conventional sources like, cattle, poultry, sheep and goat to meet the growing demand for animal protein is insufficient for the growing population. Hence the use of recognized micro herbivores and unconventional species of livestock such as rabbit (*Oryctolagus cuniculus*) may be a promising source of animal protein to mitigate protein shortage due to high cost of chicken, beef and pork for the growing population in Nigeria (Mohammed *et al.,* 2018), thus making it emerge as a viable livestock specie. In previous years, much attention has been given to rabbit farming in order to facilitate the increase of productions without adversely affecting meat quality and animal wellness. Antibiotics were the most common feed additives used in time past, however, the use of synthetic antibiotics is being regulated because of the development of resistant microorganisms and their effect on human health (Joseph *et al*., 2015). This has prompted the need for new initiatives in the livestock and pharmaceutical industries to seek and promote the use of alternative materials that

combine the effects of nutritional and medicinal properties, simultaneously (Esiegwu *et al*., 2014) and to carry out studies on the addition of natural antioxidants as nutritional supplements in animal feeding to improve health, performance, meat quality and shelf-life of raw or cooked meat products (Jiang and Xiong, 2016). Safe supplements such as garlic and ginger which are natural growth promoters can be used as potential alternatives for common artificial growth promoters like antibiotics (Demir *et al.,* 2003). Garlic and ginger powder and their extracts have been studied for their antioxidant and antimicrobial properties both in dietary supplementation and in food preservation (Zomrawi *et al.,* 2012). These natural antioxidants have been recognized to be better than synthetic antioxidants due to their lower cytotoxicity and tissue residue (Sen *et al*., 2010), ability to mitigate or prevent generation of free radicals or reactive oxygen species (Ali *et al*., 2008). Hence, garlic and ginger could play an important role in rabbit feeding strategy. Therefore, the main aim of this study is to determine the faecal microbial growth of weaner rabbits fed garlic and ginger supplemented basal diets.

## MATERIALS AND METHODS

### Experimental site

The experiment was conducted at the Rabbit Research Unit of the Department of Animal Production, Teaching and Research Farm, School of Agriculture and Agricultural Technology of the Federal University of Technology Minna, Niger State, Nigeria. Minna is located within latitude $9^0$ 30’ and $6^0$ 45’ North and longitude $6^0$ 30’ N and $6^0$ 45’ East of the equator. It falls within the Southern Guinea Savanna agro-ecological zone of Nigeria. It is characterized by a mean annual temperature which lies between $21^0$C and $35^0$C and mean annual rainfall varying from 1100 to 1600 mm (FMSN, 2015).

### Sources and Processing of Feed Ingredients

Methionine, Lysine, Fish meal, Vitamin premix, Salt, Bone meal, Limestone, Soybean meal and Wheat offal were purchased from Animal care retailer shop Gidan Matasa, Okada Road, Minna, Niger State, dried ginger and garlic were purchased from Kure Ultra-Modern Market, Minna, Niger State, while Maize was purchased from Garatu market, Niger State. Dried garlic and ginger were ground into powder and incorporated into rabbit diets.

### Experimental Diets

The feed ingredients were weighed and ground to rabbit’s particle size of 1mm and mixed for proper circulation of micro and macro nutrients. Four diets were formulated and designated as follows; Treatment 1 = diet without garlic and ginger supplement, treatment 2= diet containing 100 g garlic supplement per 100 kg feed, treatment 3= diet containing 100 g ginger supplement per 100 kg feed and treatment 4= diet containing 50 g garlic and 50 g ginger supplement per 100 kg feed.

### Experimental Animals and Management

Thirty-six (36) female Dutch weaner rabbits were used for the experiment. Before the arrival of the rabbits, the experimental house and rabbit hutches were properly washed and fully disinfected. The rabbits were randomly shared into four (4) nutritional treatments in a Completely Randomized Design (CRD). Each treatment had three replicates with three (3) rabbits per replicate. Rabbits were reared in hutches measuring 0.6 m × 0.5 m × 0.4 m, for 42 days. Medications were given as at when due. The rabbits were fed 5 % of their body weight of the experimental diets in the morning at 8:00, 100 g roughage (groundnut haulms) in the evening at 5:00 pm to aid proper digestion and water was given *ad-libitum*. The experiment lasted for a period of eight weeks.

**Table 1: Gross composition and calculated nutrient values of the experimental diets (%)**

| | Dietary treatments (kg) | | | |
|---|---|---|---|---|
| **Ingredients** | T1 (control) | T2 (100 g garlic) | T3 (100 g ginger) | T4 (50 g garlic+ 50 g ginger) |
| **Maize** | 49.00 | 49.00 | 49.00 | 49.00 |
| **Groundnut cake** | 12.00 | 12.00 | 12.00 | 12.00 |
| **Fishmeal** | 03.00 | 03.00 | 03.00 | 03.00 |
| **Rice bran** | 18.00 | 17.90 | 17.90 | 17.90 |
| **Wheat offal** | 14.00 | 14.00 | 14.00 | 14.00 |
| **Limestone** | 01.00 | 01.00 | 01.00 | 01.00 |
| **Garlic** | - | 00.10 | - | - |
| **Ginger** | - | - | 00.10 | - |
| **Garlic + ginger** | - | - | - | 00.10 |
| **Bonemeal** | 02.00 | 02.00 | 02.00 | 02.00 |
| **Salt** | 00.25 | 00.25 | 00.25 | 00.25 |
| **Lysine** | 00.25 | 00.25 | 00.25 | 00.25 |
| **Methionine** | 00.25 | 00.25 | 00.25 | 00.25 |
| **Vitamin premix** | 00.25 | 00.25 | 00.25 | 00.25 |
| **Total** | 100.00 | 100.00 | 100.00 | 100.00 |
| **Calculated content** | | | | |
| **Crude fibre** | 10.70 | 10.65 | 10.66 | 10.65 |
| **Crude protein (%)** | 16.08 | 16.11 | 16.10 | 16.10 |
| **ME (kcal/kg)** | 2526.10 | 2526.05 | 2526.08 | 2526.07 |

Premix supplied per Kg of diet: Vit. A, 10,000iu; Vit D3, 2000iu; Vit E, 23mg; Vit. K, 2mg; Vit, B1, 1.8mg; Vit B2, 5.5mg; pantothenic acid, 7.5mg; Vit. B12, 0.015mg; Folic acid, 0.75mg; Biotin, 0.06mg; Choline chloride, 300mg; Cobalt, 0.2mg; Copper,3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Zinc, 30mg; Antioxidant, 1.25mg.

## Data Analysis

Data were collected on faecal microbial growth, differences between parameters were analyzed by one-way ANOVA (analysis of variance) and statistical assessment of result was carried out using SSPS software 15 version and means were separated using the Duncan multiple range test, where there were statistically significant differences ($P<0.05$).

**Table 2: Effect of garlic and ginger supplemented diets on the faecal microbial growth of rabbits.**

| Parameters | T1 | T2 | T3 | T4 | SEM | P-Value |
|---|---|---|---|---|---|---|
| **Initial bacteria count ($\times10^6$)** | $1.79^{ab}$ | $1.26^{bc}$ | $2.11^{a}$ | $1.03^{c}$ | 1.46 | 0.01 |
| **Final bacteria count ($\times10^6$)** | $3.31^{bc}$ | $7.17^{a}$ | $1.55^{c}$ | $5.20^{ab}$ | 7.75 | 0.03 |
| **Average bacteria Count ($\times10^6$)** | $1.90^{b}$ | $3.45^{a}$ | $1.79^{b}$ | $4.60^{a}$ | 3.89 | 0.01 |
| **Increase in bacteria ($\times10^6$)** | $2.63^{bc}$ | $5.90^{a}$ | $5.70^{c}$ | $4.17^{ab}$ | 7.12 | 0.02 |
| **Initial fungi count ($\times10^6$)** | 2.60 | 1.00 | 1.63 | 0.73 | 3.17 | 0.47 |
| **Final fungi count ($\times10^6$)** | 0.00 | 0.33 | 3.367 | 1.33 | 7.80 | 0.47 |
| **Average fungi count ($\times10^6$)** | 1.21 | 1.61 | 1.14 | 0.91 | 1.56 | 0.52 |
| **Growth in fungi ($\times10^6$)** | 2.60 | 4.37 | 1.30 | 1.33 | 6.62 | 0.35 |

$^{abc}$: means with along the rows with different superscript is significantly ($P<0.05$) different, SEM: Standard Mean Error, P-Value: Probability value

## RESULTS AND DISCUSSION

Table 2 shows the faecal microbial growth of rabbits fed diets containing garlic and ginger supplementation. There were significant ($p<0.05$) differences in initial bacteria count, final bacterial count, average bacteria count and increase in bacteria count. However, there were no difference ($P>0.05$) in initial fungi count, final fungi count, average fungi count and growth in fungi across the treatment groups. Initial bacteria count of rabbits fed T3 were higher ($p<0.05$) than rabbits fed T2 and T4. However, the value ($2.11\times10^6$) (T3) obtained was similar ($p<0.05$) to T1 ($1.79\times10^6$). The final bacteria count and increase in bacteria growth of rabbits fed T2 ($7.17\times10^6$ and $5.90\times10^6$) were higher ($p<0.05$) than those fed T1 ($3.31\times10^6$ and $2.6333\times10^6$) and rabbits fed T3 ($1.54\times10^6$ and $5.70\times10^6$), although the value was similar ($P<0.05$) to the values obtained for rabbits fed T4 ($5.2\times10^6$ and $4.17\times10^6$). Similarly, average bacteria count was superior ($p<0.05$) in rabbits fed T2 and T4 than rabbits fed T3 and T1. The increased final bacteria count in rabbits fed 100 g garlic supplemented diet could be attributed to the probiotic and prebiotic promoting substances contained in garlic. Lim *et al.* (2003) in their study reported that garlic are believed to stimulate the growth of Bifido bacterium and Lactobacillus bacteria, which are beneficial for the host. Probiotics have been shown to have a positive effect on the gut microbiota of rabbits in research on ginger by Bónai *et al.* (2012). Similarly, the average bacteria count of rabbits fed 100 g garlic supplemented diet and rabbits fed 50 g garlic + 50 g ginger supplemented diet correlate with the findings of Wlazlo *et al.* (2021) who reported that in the upper part of the duodenum to the jejunum and ileum, the number of bacteria steadily increases, until it reaches a value ranging from 1011 to 1012 cfu/g of faeces in the colon and caecum.

**CONCLUSION AND APPLICATION**

It can be concluded from the results obtained that the inclusion of garlic and ginger supplementation in the diet of rabbits up to the level of 0.1 % can be tolerated by rabbits and does not pose any negative effect on rabbits in terms of their performance. This was established from the results obtained in the initial bacteria count, final bacterial count, average bacteria count and increase in bacteria count. Thus, garlic and ginger supplemented up to 0.1 % inclusion levels can be incorporated into the diet of rabbits.

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# SURVEY ON AGROCHEMICAL USAGE PATTERN IN SIX DENSELY POPULATED IRRIGATION VILLAGES AROUND TIGA RESERVOIR KANO STATE – NIGERIA

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## ABSTRACT

The recent upsurge in rejection of Nigeria's agro-commodities in the international market is attributed to improper and excessive usage of agrochemical during production, processing, storage, and transport. In this survey study, sixty farmers were selected from six villages around *Tiga Reservoir* from August, 2021 to January, 2022. The questionnaire used was designed to assess the farmer's general knowledge, attitude and practice on agrochemical usage patterns. Simple frequency distribution and percentage were used to analyze the data. The results indicated that agrochemicals were readily available and widely used for crop cultivation. Synthetic pyrethroid with various trade names was found to be the most commonly used class of toxic agrochemical. Cereals and vegetables were the dominant crops cultivated in the study area. Respondent's sociodemographic features indicated that (46.6%) are traders, (30.00%) are civil servants and (23.3%) depend on agriculture for a living. Farmer's knowledge of agrochemical shows that 51.66% know that endosulfan and monocrotophos are banned for use on vegetables, and 98.33% hear about food poisoning due to agrochemical residues in food. Farmer's attitude shows that 58.33% apply agrochemical regularly, while 98.33% contact agrochemical dealers¸ 86.66% contact agricultural officers and 38.33% contact scientists for agrochemical recommendations. Farmer's practice shows that all farmers used sticks to mix agrochemical, and 90% used agrochemical caps to measure the required chemicals. Also, 68.33% stored their agrochemical inside the house, 31.66% at the farm and 30% outside the house with farm equipment. All the respondents sprayed at weekly intervals and used first aid methods like washing the affected area with water and soap. Most of the farmers (40%) are using empty agrochemical containers for house or farm purposes. The level of illiteracy and poor awareness campaign contributed to the poor agrochemical usage among farmers. Policymakers should improve farmers' literacy by increasing extension workers and outreach programs in the study area.

**Keywords**: *Tiga*, Pesticide, Respondent, Synthetic, Pyrethroid.

## INTRODUCTION

Safe agricultural practices are paramount to any economy and society, without good agricultural practices, the economy will not thrive. The recent increase in the rejection of agro-commodities in the international market is attributed to poor agricultural practices such as excessive usage of agrochemicals during production, processing, storage, transport, and marketing (Indira, 2010). Agrochemicals enters the human body via the food chain and humans are exposed due to poor usage of pesticides or agrochemicals and their residues via water and air (Radha *et al.,* 2015). A recent increase in agricultural activities around Tiga Reservoir has led to an excessive use of agrochemicals for the treatment of various pests to maximize the yield of the agricultural produce and reduce the intensive labor.

The irrigation site around Tiga Reservoir is very vital for the economic development of Kano State, as it provides food and improves the nutritional and economic security of the State. The productivity of Nigeria is low compared to other countries due to yield losses caused by insect pests, diseases and nematodes (Abdulsalam *et al.,* 2021). The crops are attacked by several insect pests, and infestation is observed from the seedling to the harvest stage. Farmers cannot tolerate any loss in the farm produce either by insects or diseases and resort to chemical control. The widespread use of agrochemical increases their residues in various environmental components and agro-commodities. Indiscriminate and improper application of agrochemicals and negligence to follow proper waiting periods make the marketed farm produce very often contaminated with agrochemical (Honnakerappa and Udikeri, 2018). Many researchers have shown that many farm produce samples showed the presence of pesticides/agrochemicals residues, which led to produce rejection at the international market (Singh *et al.,* 1999). Literature reveals that agricultural produce, which contains the residues of pesticides/agrochemicals above their respective maximum residue limit may pose health hazards to consumers (Mukherjee and Gopal, 2013). Thus, contamination of agricultural produce is sometimes more than the prescribed tolerance limits. Hence, the survey on agrochemicals usage pattern in six densely populated irrigation villages around *Tiga Reservoir* is necessary to study the pattern of agrochemicals usage among farmers to promote the production of standard farm produce for local sales and export and prevent environmental damages.

## MATERIALS AND METHODS

A survey on agrochemicals usage pattern was carried out from August, 2021 to January, 2022 in six densely populated irrigation villages around Tiga Reservoir, Kano State, to assess the socio demographic characteristics of farmers, general knowledge, attitude, and practices on agrochemicals application and draw out farmers' views on plant protection approaches. A questionnaire was prepared to collect the data scientifically for a statistical analysis on various parameters such as types of crops grown, types of agrochemicals used, toxicity class, farmers socio demographic features, general knowledge, attitude, and practices on agrochemicals application.

### Study site

Six densely populated irrigation villages were selected for field survey based on considerable agricultural activities around Tiga Reservoir. The details of the locations for the field study were presented in Figure 1 and Table 1. From each village, 10 farmers were selected randomly and interviewed.

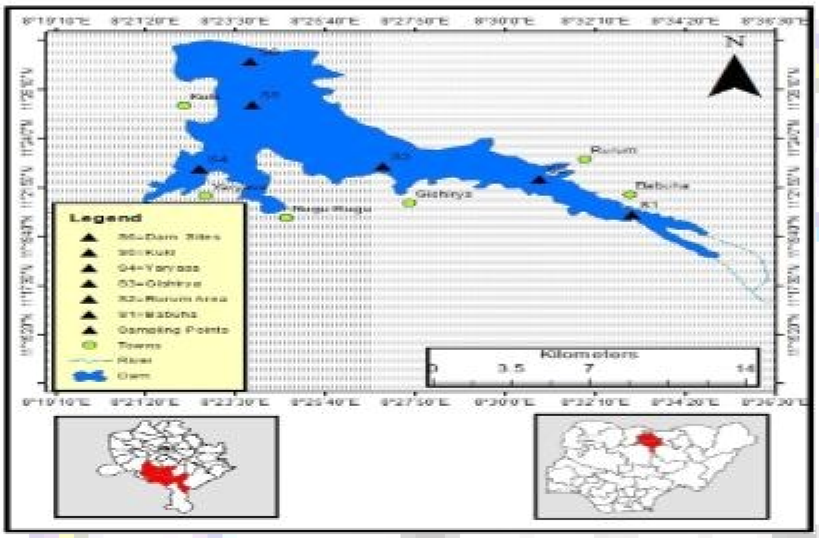


**Figure 1: Tiga Reservoir map**

(Indira, 2010). (Radha *et al.,* 2015). (Honnakerappa and Udikeri, 2018). (Singh *et al.,* 1999) (Mukherjee and Gopal, 2013).

**Table 1: Sampling stations coordinate**

| s/no | Villages | L.G.A Kano | Longitude/latitude | No of respondent farmers |
|---|---|---|---|---|
| 1 | Babuha | Rano | 8.658143/11.214684 | 10 |
| 2 | Rurum | Rano | 8.609364/11.305104 | 10 |
| 3 | Gishirya | Tudun wada | 8.473735/11.365780 | 10 |
| 4 | Yaryasa | Tudun wada | 8.379746/11.370539 | 10 |
| 5 | Kuki | Bebeji | 8.353572/11.389574 | 10 |
| 6 | Dam Site | Rano | 8.386884/11.460958 | 10 |

**Data Analysis**

A survey studies was conducted at farmer's fields from six villages around Tiga Reservoir, sixty farmers were interviewed personally using a structured questionnaire to appraise the farmers' socio demographic characteristics, general knowledge, attitude and practices on agrochemicals application. The data collected from the respondents representing Babuha, Rurum, Gishirya, Yaryasa, Kuki and Dam Site was subjected to statistical tools and techniques to draw meaningful conclusions. Simple statistical tools like frequency distribution, and percentage were used for data analysis.

## RESULTS AND DISCUSSION

### Socio-demographic characteristics of farmers

Table 2, shows that, all the 60 farmers who participated in this appraisal study had 451 members in their households. Among the participants surveyed, 83.33% were male and 16.66% were female. Furthermore, 55% were heads of their families, and the mean age of the study participants was 24.9 with a minimum age of 25 years and a maximum of 46 years. The educational status of the participants showed that 28.33% could not read or write, 10% attended primary schools, 23.3% attended secondary schools and 38.3% attended tertiary institutions. The result of the study shows that most of the farmers surveyed were literate and can easily adopt a good agricultural practice around the Reservoir. This finding is contrary to Olaoye *et al.* (2012) who opined that most farmers in Nigeria are illiterate or semi-literates. The farm locations of the participants showed that 83.3% have their farms near Tiga Reservoir and 16.6% have their farms far from Tiga Reservoir. The majority (96.6%) of participants tilled hectares and 3.3% tilled acres. The-results also showed that agrochemicals enter into the Reservoir by seepage.

**Table 2: Socio-demographic characteristics of farmers**

| S/N | Variables | Frequency | Percentage |
|---|---|---|---|
| 1 | Sex | | |
| | 5. Male | 50 | 83.33 |
| | 6. Female | 10 | 16.66 |
| 2 | Age of the respondent | | |
| | 1. ≤25 years | 15 | 25.00 |
| | 2. ≤35 years | 16 | 26.66 |
| | 3. ≤45 years | 12 | 20.00 |
| | 4. ≥46 | 17 | 28.33 |
| 3 | Marital Status | | |
| | • Single | 14 | 23.33 |
| | • Married | 40 | 66.66 |
| | • Divorced | 2 | 3.33 |
| | • Widowed | 4 | 6.66 |
| 4 | Head of The Household | 33 | 55.00 |
| 5 | Educational status | | |
| | v. None | 17 | 28.33 |
| | vi. Primary | 6 | 10.00 |
| | vii. secondary | 14 | 23.33 |
| | viii. Tertiary | 23 | 38.33 |
| 6 | Farm location | | |
| | 1. Near Tiga Reservoir | 50 | 83.33 |
| | 2. Far from Tiga Reservoir | 10 | 16.66 |
| 7 | Size of the farm tilled | | |
| | 1. Acres | 2 | 3.33 |
| | 2. Hectares | 58 | 96.66 |

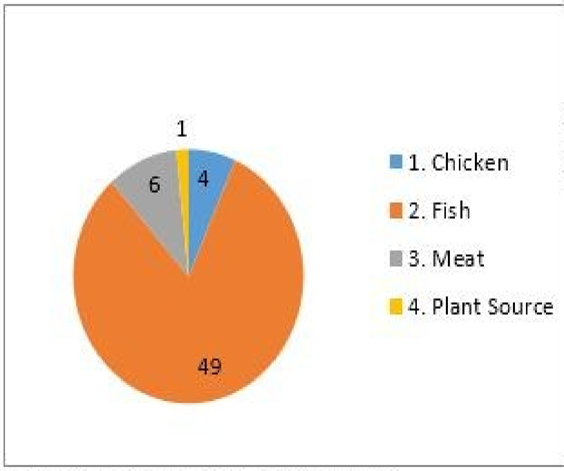


Figure 2: Major source of protein

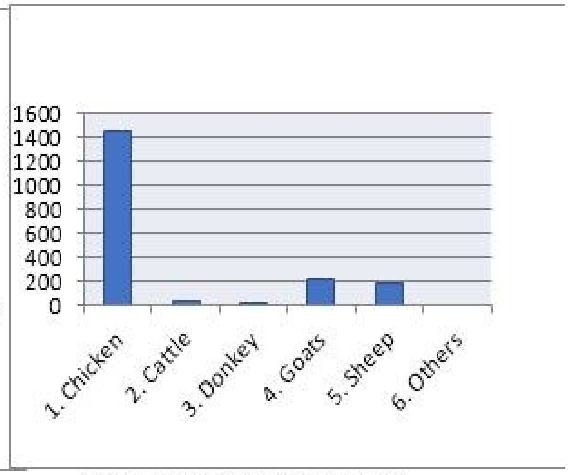


Figure 3: Types of livestock

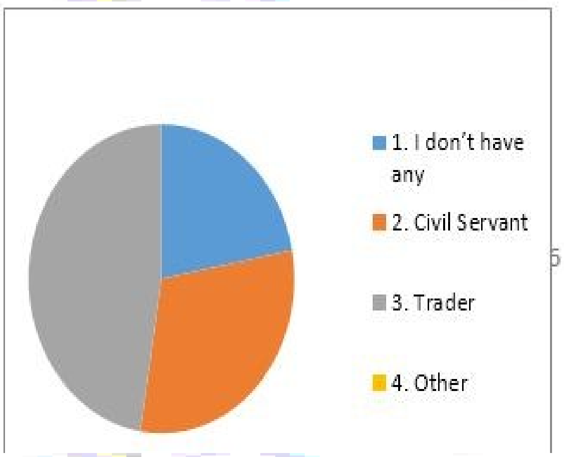


Figure 4: Occupation besides farming

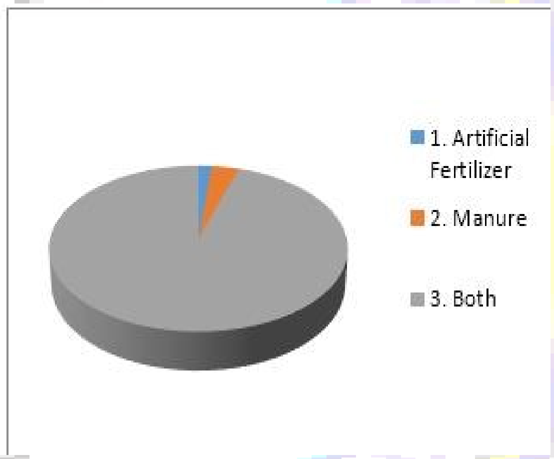


Figure 5: Types of fertilizer used

The source of protein, as shown in the Figure 2, (81.66%) of the study participants depend on fish as the source of protein, (10.0%) meat, (6.6%) chicken, and only (1.66%) depend on plant as the source of protein. This is in line with the findings of Omorinkoba *et al.* (2011), who stated that most rural household have access to fish protein than any other source of animal protein. The livestock, as shown in Figure 3, chickens with 76% were the dominant livestock, followed by goats (11.2%), sheep (9.9%), cattle (1.9%), and donkeys (0.52%) among the study participants. Occupation besides farming, as shown in Figure 4 above, indicated that 46.6% were traders, 30.0% were civil servants and 23.3% depended on agriculture for a living. The fertilizer used, as shown in Figure 5, showed that 95% of the participants used both manure and artificial fertilizer, while 3.33% used manure, and only 1.66% used artificial fertilizer alone.

**Types of crops grown and agrochemicals used**

Table 3, shows that, among the crops produced in the area, maize, rice, cowpeas, and vegetables were the dominant crops cultivated. However, the pesticide used in the study area belongs to nine major toxicity classes and synthetic pyrethroid is the most commonly used class as shown in Table 4.

**Table 3: Types of crops grown**

| s/no | Villages | Dominant crops | Other host crops |
|---|---|---|---|
| 1 | S1-Babuha | Maize, Millet, Rice, Cowpea | Tubers, Vegetables, Chili, Groundnut, Sorghum |
| 2 | S2-Rurum | Maize, Rice, Millet, Cowpea | Tubers, Vegetables, Groundnut, Chili, Sorghum |
| 3 | S3-Gishirya | Rice, Maize, Millet, Vegetables | Cowpea, Sorghum, Groundnut, Tubers, Chili |
| 4 | S4-Yaryasa | Cowpea, Rice, Vegetables, Maize | Chili, Sorghum, Millet, Tubers, Groundnut |
| 5 | S5-Kuki | Rice, Vegetables, Cowpea, Vegetables | Sorghum, Groundnut, Millet, Tubers, Chili |
| 6 | S6-Dam Site | Maize, Cowpea, Rice, Chili, Vegetables | Sorghum, Groundnut, Millet, Tubers |

**Table 4: Types of pesticides used in the study area and their toxicity class**

| S/N | Pesticide category and their common names | Chemical family | Toxicity class |
|---|---|---|---|
| | Herbicide | | |
| 1 | Butachlor/Butaforce/ Chlormebuform/ Butashi | Chloroacetanilide | III |
| 2 | Glysate/ Glyphosate/ Vinash/ Glyspring/ Gobara | Phosphonomethyl Glycine | III |
| 3 | Paraforce/ Paraquat/ Gramazon/ Dragon/ | Bipyridinium quaternary ammonium | II |
| 4 | Force top/ Pendimethalin | Dinitroaniline | II |
| | Insecticides | | |
| 5 | Cypergreen/Cypermethrin/ Karate/ Cypermethrin/ Lambda cyhalothrin | Synthetic pyrethroid | II |
| 6 | Imi/ Imidacloprid | Chloronicotinyl nitro guanidine | II |
| 7 | Gamalin 20 | Gamma-HCH, Lindane | II |
| 8 | Sniper | Dicholorovinyl dimethyl phosphate | Ib |
| 9 | Rocket/Chlorpyrifos | Organophosphate | II |

**(**Source: * Toxicity class of pesticides - classified by the World Health Organization (WHO, 2019 Ia = Extremely hazardous; Ib = Highly hazardous; II =Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use; FM =Fumigant, not classified; O = Obsolete as pesticide, not classified.**)**

**Farmers general knowledge on agrochemicals application**

Table 5, shows that, among the study participants, (98%) knows the recommended pesticides against different pests and only (41.66%) knows pesticide classification based on toxicity, which could be due to illiteracy and a lack of public awareness campaign about proper pesticide applications and negligence of farmers. This was in agreement with the findings of Gupta (2004) who discovered that most rural farmers have less knowledge on agrochemicals toxicity classification. Data pertaining the general awareness of farmers in using pesticides is presented in Table 2. About 78.33% observed the effects of pesticides on the health of the men spraying during spraying activities. The most common health problems observed during spray included skin irritation (100%), cough (100%), breathlessness (100%), eye irritation (100%) and headache (80%). About 51.66% knew that endosulfan and monocrotophos were banned for use on vegetables. More than half of the farmers were aware of the endosulfan and monocrotophos ban in agriculture. About 66.66% farmers know the recommended pre-harvest intervals required after using pesticides, while 90% knew that pesticide residues are found in vegetables, and only 80% knows that pesticides enter the food chain and bioaccumulate. Many farmers knew the decontamination method of pesticides. In this case, 95% had the knowledge of pesticide decontamination methods when they come in contact with them. In the same vein, 76.66% of the respondents were aware of agro-commodities rejection at the international markets due to pesticide residues. Also, about 98.33% respondents were aware of food poisoning as a result of pesticide residues in food, 55% have heard about cancer, 73.3% have heard about physical impairments and only 3.33% have not heard anything about pesticide effects.

**Table 5: General knowledge of farmers on pesticide application**

| S/N | Questions | N=60 Frequency | Percentage |
|---|---|---|---|
| 1 | Are you aware about recommended pesticides against different pests | 59 | 98.33 |
| 2 | Are you aware about the pesticide classification based on toxicity | 25 | 41.66 |
| 3 | Do you observe pesticide effect on health of spray men during spray | 47 | 78.33 |
| 4 | Most common health problem observed during spray | | |
| | xiii. Skin irritation | 60 | 100 |
| | xiv. Cough | 60 | 100 |
| | xv. Breathlessness | 60 | 100 |
| | xvi. Eye irritation | 60 | 100 |
| | xvii. Headache | 48 | 80 |
| 5 | Are you aware that endosulfan is banned for use | 31 | 51.66 |
| 6 | Are you aware that monocrotophos is banned for use on vegetables | 31 | 51.66 |
| 7 | Are you aware that for each pesticide, pre-harvest interval is recommended | 40 | 66.66 |
| 8 | Are you aware that pesticide residues are found in vegetables | 54 | 90 |
| 9 | Do you know that pesticide residues in food enter into body and accumulate | 48 | 80 |
| 10 | Are you aware about pesticide decontamination method | 57 | 95 |
| 11 | Are you aware that food exports are rejected due to pesticide residues | 46 | 76.66 |
| 12 | What types of effects did you heard due to pesticide residues in food | | |
| | iii. Poisoning | 59 | 98.33 |
| | iv. Cancer | 33 | 55 |
| | v. Physical impairments | 44 | 73.33 |
| | vi. Not heard about any bad effects | 2 | 3.33 |

Farmers attitudes on pesticide application, shows the frequency of pesticide usage and farmers perception on its use (Table 6). The result shows that about 58.33% of the respondents apply pesticides regularly, and 41.66% apply pesticides occasionally. Furthermore, 95% of the farmers stated that the quantity of pesticides used at their farm was adequate, while 95% of the farmers perceived that pesticides were helpful in getting good returns. Majority (95%) of the farmers observed that high pesticide doses give high yields. These results are in agreement with the findings of Mahantesh and Alka Singh (2009) who stated that most rural farmers are of the opinion that high yield is directly related to agrochemical input. The contact person for pesticide recommendations, as shown in Table 6, indicated that the majority of the farmers (98.33%) preferred to contact pesticide dealers, while 86.66% preferred the agricultural officers and 38.33% preferred to contact scientists for pesticide recommendations due to the ease and convenient accessibility of the dealers, followed by agricultural officers, and finally the agricultural magazines/scientists. This finding is in line with work done by Jamali *et al.* (2014) who reported that the major source of farmers's knowledge of agrochemicals was from the agrochemical dealers. The result of this study suggests that stakeholders should increase the number of extension workers to educate farmers on proper usage of agrochemicals around Tiga Reservoir to protect the Reservoir's aquatic biodiversity and prevent agro-commodity contamination.

**Table 6: Farmers attitude on pesticide application**

| S/N | Questions | N=60 | |
|---|---|---|---|
| | | Frequency | Percentage |
| 13 | How frequently do you apply pesticides | | |
| | 5. Regularly | 35 | 58.33 |
| | 6. Occasionally | 25 | 41.66 |
| 14 | Do you think the quantity of pesticides used is adequate | 57 | 95 |
| 15 | Do you think that pesticides are helpful in getting good returns | 60 | 100 |
| 16 | Do you think high pesticide dose gives higher yields | 57 | 95 |
| 17 | Whom do you contact for pesticide recommendations | | |
| | 1. Agricultural officer | 52 | 86.66 |
| | 2. Dealer | 59 | 98.33 |
| | 3. Scientist /Agricultural magazine | 23 | 38.33 |

Farmers practice on pesticide application is shown in Table 7. All the respondents used sticks to mix pesticides. This finding is similar to that of Kumar *et al.,* (2017) who reported in their study that 90% respondents used the pesticide cap to measure the required chemicals and 71.66% followed a safe method while storing, mixing, or spraying pesticides. All the respondents used pesticide mixtures (Kumar *et al*., 2017), About 68.33% stored their pesticides inside the house, 31.66% at the farm site away from the house and 30% outside house with farm equipment. All the respondents (100%) spray at a weekly interval and only 1.66% spray at a two-day interval.

Use of empty pesticide containers and their disposal, is presented in Table 7. About 40% of the farmers use empty pesticide containers for house or farm purposes, while 61.66% bury the containers inside soil, 40% sale empty containers and no single farmer throws the containers into the trash, poor management of pesticide container could reach Tiga Reservoir, which may harm Fish, Plants, and other Aquatic Biodiversity because the empty pesticide container is hazardous due to the residues left inside. Similar finding has been reported by Srivastava *et al.,* (2011) who observed that majority of the rural farmers never manage empty agrochemical containers properly. Proper disposal of empty pesticide containers without using them for house or farm purposes is essential in order to avoid health hazards due to pesticides residues. The best first aid and decontamination method were shown in Table 7, where all farmers used first aid methods like washing the affected area with water and soap, and 71% induced vomiting if pesticide was swallowed. Farmers usually followed simple and easy first aid practices, which were helpful to the victim until he or she was taken to the hospital. All the respondents followed washing of vegetables with water, while 53% followed salt water washing as the decontamination methods to remove pesticide residues. Majority farmers were unaware of various decontamination methods but as a regular kitchen practice, they wash vegetables under tap water. All farmers follow–crop rotation and natural control as an alternative to pesticide use, while 81.66% implement–IPM (Integrated Pest Management) as an alternative for pesticide usage (Kumar *et al.,* 2002).

## CONCLUSION

The results of this survey study revealed that majority of the respondents were literate and follow most of the agrochemical application guidelines with poor management of agrochemical container and residues, Policymakers should increase extension workers and outreach programs around Tiga reservoir to sensitize farmers on good agricultural practices and proper management of agrochemicals containers to avert health hazards. The laboratory-based study is recommended to assess the residual concentration of agrochemicals in water, sediment, and fish in Tiga Reservoir to assess the level of agrochemical pollution.

**Table 7: Farmers practices on pesticide application**

| S/N | Questions | | N=60 | |
|---|---|---|---|---|
| | | | Frequency | Percentage |
| 1 | How do you mix the chemical | A= Bare hands | 0 | 100 |
| | | B= Stick | 60 | 100 |
| 2 | How do you measure the chemical | A= Pesticide container cap | 54 | 90 |
| | | B= Approximately | 6 | 10 |
| 3 | Do you follow safe methods while storing / mixing / spraying pesticides | | 43 | 71.66 |
| 4 | Do you use pesticide mixtures | | 60 | 100 |
| 5 | Pesticide Storage method | | | |
| | 1. Inside the house | | 41 | 68.33 |
| | 2. At farm site, away from house | | 19 | 31.66 |
| | 3. Outside the house with farm equipment | | 18 | 30 |
| 6 | Common waiting period you follow after pesticide spray | | | |
| | 1 Day | | 0 | 0.00 |
| | 2 Day | | 1 | 1.66 |
| | 4 Day | | 0 | 0.00 |
| | Week | | 60 | 100 |
| 7 | Use of empty pesticide containers for house / farm purpose | | 24 | 40 |
| 8 | What method do you follow to dispose empty pesticide containers | | | |
| | • Bury in soil | | 37 | 61.66 |
| | • Sell | | 24 | 40.00 |
| | • Throw into trash | | 0 | 0.00 |
| 9 | Best first aid you follow | | | |
| | 4. Induce vomiting if swallowed | | 43 | 71 |
| | 5. Washing the affected area with water | | 60 | 100 |
| | 6. Washing the affected area with soap water | | 60 | 100 |
| 10 | Common method of decontamination followed | | | |
| | 1. Salt water wash | | 32 | 53 |
| | 2. Water wash | | 60 | 100 |
| 11 | Best alternative for pesticide use | | | |
| | **2.** Crop rotation | | 60 | 100 |
| | **3.** Natural control | | 60 | 100 |
| | **4.** Integrated pest management | | 49 | 81.66 |

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# GROWTH PERFORMANCE, FEED EFFICIENCY, AND SURVIVAL OF AFRICAN BONYTONGUE (*Heterotis niloticus*) FED DIETS WITH VARYING CRUDE PROTEIN LEVELS IN EARTHEN PONDS

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## ABSTRACT
This study evaluates the growth performance, feed efficiency, and survival of *Heterotis niloticus* fed diets containing varying crude protein (CP) levels (25, 30, 35, and 40 % respectively) in earthen ponds over a 12-week period. Juvenile *H. niloticus* were stocked at a density of 20 fish/ pond of 2m x 2m dimension and fed twice daily with isonitrogenous diets formulated to the respective CP levels. Key growth parameters, including mean final weight (MFW), weight gain (WG), specific growth rate (SGR), and feed conversion ratio (FCR), as well as survival rates, were assessed. The results showed that fish fed 35 percent CP diet exhibited the highest MFW (105.00 ± 2.00 g), WG (102.50 ± 2.30 g), and SGR (4.65 ± 0.01 %), indicating superior growth performance. Feed efficiency was highest at 25 percent and 30 percent CP levels, reflected in lower FCR values (1.57 ± 0.02 and 1.58 ± 0.01, respectively). Survival rates ranged from 56.6 percent to 71.66 percent, with no significant differences among treatments. These findings suggest that a 35 percent CP diet optimizes growth performance in *H. niloticus* cultured in earthen ponds, balancing growth and feed efficiency. The study provides a framework for diet formulation to enhance sustainability and profitability in tropical aquaculture systems.
**Keywords**: *Heterotis niloticus*, Crude protein, Feeding, Earthen pond, Aquaculture

## INTRODUCTION
The African bonytongue (*Heterotis niloticus*), a freshwater fish species widely distributed across West and Central Africa, is of significant economic and ecological importance. Its adaptability to various aquaculture systems, high market demand, and suitability for polyculture (Monentcham, *et al*., 2010) make it a promising candidate for sustainable fish farming in tropical regions. Despite these advantages, research on the optimal dietary requirements for this species, particularly crude protein (CP) levels, remains limited compared to other aquaculture species like *Clarias gariepinus* and *Oreochromis niloticus* (Monentcham *et al*., 2010; FAO, 2021). Protein is a vital macronutrient in fish diets, influencing growth performance, feed efficiency, and overall health. However, excessive protein levels can increase feed costs and nitrogen excretion, while inadequate protein limits growth and production (Monentcham *et al*., 2010). Thus, determining the optimal dietary CP level is essential for maximizing growth and feed utilization efficiency

while minimizing environmental and economic impacts. Studies have shown that optimal protein levels vary among fish species based on their feeding habits, life stages, and culture environments (Tacon *et al*., 2020). For *Heterotis niloticus*, protein requirements may differ from carnivorous or herbivorous species, necessitating tailored nutritional studies (Obasa & Faturoti, 2001; Monentcham *et al*., 2010) . In this context, earthen pond systems provide a semi-natural environment that can support fish growth through a combination of natural productivity and supplemental feeding. Evaluating the growth performance, feed efficiency, and survival of Heterotis *niloticus* fed diets with varying CP levels in this system is critical to understanding the species' nutritional needs under practical aquaculture conditions. This study, therefore, aims to fill existing knowledge gaps, providing insights for optimizing diets to enhance productivity and sustainability in *Heterotis niloticus* aquaculture.

## MATERIALS AND METHODS

### Study area

The experiment was conducted at the integrated fish farm unit of the National Institute for Freshwater Fisheries Research, New Bussa. The experiment was carried out in a period of three months (July to September 2024) as part of an undergoing research.

### Experimental setup and design

A total of 240 samples of *H. niloticus* were distributed into twelve earthen ponds of 2m x 2m each, at the integrated farm, with 20 fish per pond, assigned into four treatments set up in a completely randomized design (CRD) with three replicates per treatment. The treatments were based on the crude protein (CP) levels tested on the fish specimens at 25 percent CP as Treatment 1; 30 percent CP as Treatment 2; 35 percent CP as Treatment 3; and 40 % percent CP as Treatment 4. The experimental fish were fed to apparent satiation twice daily at around 09:00am and around 05:00pm.

### Assessment of growth and survival

The body weight of the experimental fish specimens was recorded every two weeks by weighing all the fish in each experimental unit on an electric top loading weighing balance, to assess their growth and survival. Feeding rate was adjusted after every sampling. The following growth performance parameters were recorded.

Weight Gain of the fish

Weight Gain (g): $W_1 – W_0$ (Bagenal & Tesch, 1978)

Where $W_1$ = Final weight; $W_0$ = Initial weight

Mean Daily Weight Gain (g/day): (Bagenal & Tesch, 1978)

Where: $W_1$ = Mean Final body weight (g); $W_0$ = Mean Initial body weight (g); t = culture period (days).

Specific Growth Rate (%/day): $(InW_1 – InW_0)/t \times 100$ (Stickney, 1979)

Where: Ln = Natural Logarithm; $W_1$ = Mean Final body weight of fish (g); $W_0$ = Mean Initial body weight of fish (g); t = culture period (days)

Survival Rate (%): (Bagenal & Tesch, 1978)

Where: $N_1$ = Number of fish at the end of experiment; $N_0$ = Number of fish at the start of experiment.

vii. Feed Conversion Ratio (FCR): (Hepher, 1988).

**Data analysis**

Data collected on the growth performance studies was subjected to one-way analysis of variance (ANOVA). Means were separated using Duncan multiple range test (DMRT) where significant differences (P<0.05) exist. The analysis was carried out using SPSS software for windows.

**Plate 1: *Heterotis niloticus* juveniles being sampled**

## RESULTS

**Table 1: Growth response parameters of *Heterotis niloticus* fed diets containing different CP levels in earthen pond**

| | Treatments (percent CP) | | | |
|---|---|---|---|---|
| **Parameters** | **1** | **2** | **3** | **4** |
| Initial mean weight (g) | 2.50±0.20[a] | 2.33±0.5[a] | 2.50±0.30[a] | 2.50±0.45[a] |
| Mean final weight (g) | 90.00±1.00[a] | 90.20±0.20[a] | 105.00±2.00[c] | 101.00±1.00[b] |
| Mean weight gain (g) | 87.50±0.80[a] | 67.86±0.65[a] | 102.50±2.30[c] | 98.50±0.95[b] |
| Mean daily weight gain (g) | 1.04±0.01[a] | 1.04±0.01[a] | 1.22±0.02[c] | 1.17±0.01[b] |
| FCR | 1.57±0.02[a] | 1.58±0.01[a] | 1.77±0.01[b] | 1.76±0.02[b] |
| SGR (%) | 4.49±0.01[a] | 4.50±0.00[a] | 4.65±0.01[c] | 4.61±0.01[b] |
| Survival rate (%) | 58.33[a] | 63.33[a] | 71.66[a] | 56.66[a] |

Means with similar superscripts on the same row are not significantly different

Treatment 1 (25 percent CP), Treatment 2 (30 percent CP), Treatment 3 (35 percent CP), and Treatment 4 (40 percent CP)

The growth response of *Heterotis niloticus* to different crude protein (CP) levels reveals distinct trends across various parameters. The mean final weight of the fish was highest for the 35 percent CP treatment (105.00 ± 2.00 g), indicating superior growth compared to other treatments, followed by the 40% CP treatment (101.00 ± 1.00 g), while the 25 percent and 30 percent CP treatments showed similar but significantly lower final weights. In terms of mean weight gain, fish fed 35 percent CP exhibited the highest growth (102.50 ± 2.30 g), showing a marked improvement compared to the 40 percent CP treatment (98.50 ± 0.95 g), with the 25% and 30% CP treatments achieving much lower weight gains of 87.50 ± 0.80 g and 67.86 ± 0.65 g, respectively. Similarly, the mean daily weight gain followed the same trend, with the 35 percent CP treatment achieving the highest daily increment (1.22 ± 0.02 g), followed by the 40 percent CP treatment (1.17 ± 0.01 g), while fish on 25 percent and 30 percent CP diets grew at a significantly slower daily rate of 1.04 ± 0.01 g.

Feed conversion ratio (FCR), which measures feed efficiency, was best in the 25 percent and 30 percent CP treatments, with FCR values of 1.57 ± 0.02 and 1.58 ± 0.01, respectively. This indicates better feed utilization at these lower protein levels compared to the 35 percent and 40 percent CP treatments, which had higher FCR values of 1.77 ± 0.01 and 1.76 ± 0.02, showing slightly less efficient feed use. Specific growth rate (SGR), which reflects the percentage increase in weight over time, was highest for fish fed 35 percent CP (4.65 ± 0.01 percent), followed closely by those fed 40 percent CP (4.61 ± 0.01 percent). In contrast, the 25 percent and 30 percent CP treatments showed nearly identical but lower SGR values of 4.49 ± 0.01 percent and 4.50 ± 0.00 percent, respectively, indicating slower growth. The survival rates did not differ significantly across the dietary treatments, with the highest survival observed in the 35 percent CP treatment (71.66 percent) and the lowest in the 40 percent CP treatment (56.66 percent), while the 25 percent and 30 percent CP treatments showed intermediate survival rates of 58.33 percent and 63.33 percent, respectively. This suggests that protein level in the diet had no major impact on fish survival under the conditions of the study.

## DISCUSSION

The growth performance of *Heterotis niloticus* fed diets with varying crude protein (CP) levels highlights the critical importance of dietary protein optimization in aquaculture. Fish fed a 35 percent CP diet exhibited superior growth in terms of final weight, weight gain, and specific growth rate (SGR), indicating that this level satisfies the protein requirement for the species under the study conditions. Monentcham *et al*. (2010) reported similar findings, emphasizing that diets with approximately 35% CP maximize growth and feed utilization efficiency in African bonytongue fingerlings. The reduced growth observed at lower protein levels (25 and 30 percent CP respectively) suggests protein inadequacy, which aligns with studies by Obasa and Faturoti (2001), who found that diets below 31 percent CP compromise growth and yield in *Heterotis niloticus* due to insufficient amino acid availability for muscle development. Conversely, the slightly reduced performance at 40 percent CP supports the notion that excess dietary protein can lead to inefficiencies, such as increased nitrogen excretion and energy costs for deamination, as suggested by Monentcham *et al*. (2010).

Feed conversion ratio (FCR) was lowest at 25 percent and 30 percent CP, indicating better feed efficiency at these levels, though at the cost of slower growth. This observation aligns with findings by Obasa and Faturoti (2001), who noted that lower CP levels reduce metabolic waste but may not meet growth demands. The increase in FCR at higher protein levels corroborates findings by Monentcham *et al*. (2010), who attributed such trends to the diminishing returns of protein utilization efficiency. Survival rates showed no significant differences across treatments, suggesting that protein levels within the tested range do not critically impact the overall health and survival of the fish. This is consistent with previous studies indicating that factors such as water quality and environmental management have a more pronounced effect on survival than diet alone (Monentcham *et al*., 2010).

## CONCLUSION

In conclusion, a dietary protein level of 35 percent (105.00±2.00) appears to optimize growth and efficiency in *Heterotis niloticus* in earthen pond, balancing performance and economic viability. These findings are in line with global aquaculture standards advocating for species-specific diet formulation to enhance sustainability and profitability.

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# COMPARATIVE STUDY OF AMINO ACID PROFILE IN TRADITIONAL SMOKE *Clarias gariepinus* FROM WURNO AND TAMBUWAL SOKOTO STATE

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## ABSTRACT
African catfish (*Clarias gariepinus*) is very popular with fish farmers and consumers and commands a very high commercial value in Nigeria. The comparative analysis of amino acid composition in smoked *Clarias gariepinus* from Romo and Wurno Local Government Areas in Sokoto State, Nigeria were determined. The amino acids composition of the samples was determined using Gas Chromatography-Mass Spectrometry (G C-MS) Analysis. Wurno LGA showed higher levels of amino acids (P<0.05) such as valine, tryptopan, glycine, valine and histidine, while serline and arginine showed lower levels of amino acids (P>0.05). In Romo LGA, the smoked *Clarias gariepinus* exhibited higher levels of amino acids (P<0.05) such as isoleucine, serline and glycine, while valine, leucine, methionine, arginine and alanine exhibited lower levels of amino acids (P>0.05). This might be due to differences in environmental factors, feeding habits, and processing methods adopted by the traditional fish smokers in the locations. The freshwater fish was therefore found to be an important source of nutrient in both water bodies.
**Keywords**: Amino acid Smoke fish

## INTRODUCTION
Fish demand is increasing because of the increasing world population, higher living standards and the good overall image of fish among consumers (Cahu *et al*., 2004). In addition, the demand for fish is on the increase due to the health benefits of eating fish and due to increase in human population, the rinderpest disaster, and drought bane, which reduce the availability and affordability of red meat (Oshozekhai and Ngueku, 2014). Ojutiku *et al*. (2009) also highlighted that fish is rich in protein with amino acid composition very well suited to human dietary requirements comparing favorably with egg, milk and meat in the nutritional value of its protein. In Nigeria, fish is eaten fresh and smoked and form a much-cherished delicacy that cut across socio-economic, age, religions and educational barriers (Adebayo *et al*., 2008) and it is a rich source of protein commonly consumed due to the higher cost of meat and other sources of animal protein (Omolara and Omotayo, 2009). However, fish is highly perishable because it provides favourable medium for the growth of microorganisms after death (Aliya *et al*., 2012). An estimate of 40% postharvest losses of total fish landings have been reported in Nigeria (Akande, 1996) Fish spoilage in Nigeria is influenced primarily by high ambient temperatures, considerable distances of landing ports to points of utilization and poor as well as inadequate infrastructure for postharvest processing and landing (Saliu, 2008). Thus, it is imperative to process and preserve some of the fish caught in the period of abundance, to ensure an all-year-round supply. This will invariably reduce postharvest losses, increase the shelf-life of fish, and guarantee a sustainable supply of fish during off season with concomitant increase in the profit

of the fishermen (Eyo, 1997). Proper preservation starts the moment fish is harvested until reaches the consumer's table (Oluborode *et al*., 2010). Several processing techniques is in operation in Nigeria. These include chilling, freezing, salting, canning, drying and smoking. However, smoking is the most popular method of fish processing (Eyo, 2000) and among the several methods of long-term preservation of fish, smoking is perhaps the simplest method as it does not require sophisticated equipment or highly skilled workers (Olayemi *et al*., 2011). Smoked-dried fish is the most acceptable form of fish product in Nigeria (Stolyhiro and Sikorski, 2005; Yanar, 2007). Smoking is the oldest and most common method of fish preservation in many developing countries, Kumolu-Johnson *et al*., (2010). It is a method of preservation effected by combination of drying and decomposition of naturally produced chemical resulting from thermal breakdown of wood (Tobor, 2004). Fish also contains significant amounts of all essential amino acids, particularly lysine in which cereals are relatively poor. Fish protein can be used therefore to complement the amino acid pattern and improve the overall protein quality of a mixed diet (FAO, 2005).

## MATERIALS AND METHODS

Tarana water body, arba of barayar zaki village, kwargaba ward of Wurno Local Government Area in Sokoto State, Nigeria. It has an area of 685 km2 and a population of 162,307 at the 2006 census (HASC, 2006). The postal code of the area is 842 (NIPOST, 2009). A hot, oppressive rainy season with predominantly cloudy skies and a scorching, partly cloudy dry season with temperatures between 62°F and 105°F are both characteristics of the climate. It has a latitude / longitude of 10 00 8 00 E (weatherspark, 2023; NGCZ, 2023; CTV, 2023). Tsohon Romo, Romon sarki Local Government Area, this water body originated from Zamfara beside gumi town kebbe LGA, which passes to downstream. Tambuwal (Romon sarki) is located in the region of Sokoto. Sokoto's capital Sokoto (Sokoto) is approximately 116 km / 72 mi away from Romo Sarki. It has an area of 923,768.0 km2 and a population of 195,874,740 people. A latitude of 12°13'21.1"N (12.2225400°) and a longitude of 4°36'10.0"E (4.6027800°).

### Analysis of Amino Acid

All solvents and reagents used were of analytical grades. The GC–MS analysis was performed using a Varian 3800/4000 gas chromatograph / mass spectrometer. The samples were injected into the gas chromatograph on Agilent capillary column, 30m x 0.25mm, 0.25μm film thickness using a temperature program from $70^0$C, 2min, and 50C/min to $110^0$C, $10^0$C/min to $290^0$C, and $16^0$C/min to $300^0$C. The flow rate of nitrogen, the carrier gas, was 1mL/min. The following conditions were followed: transfer line temperature $250^0$C, injector temperature $200^0$C; ion source temperature $250^0$C, splitter: 10:1. The electron energy was 70eV and the emission current, 100mA. The 15N-methionine was used as the internal standard for quantitative determination (AOAC, 2005).

## RESULTS AND DISCUSSION

The results of the amino acid composition analysis of smoked *Clarias gariepinus* from Wurno LGA, Tarana water body, is presented in Table 1. It shows that the fish contains a total of 16 amino acids. The essential amino acids present in the highest concentrations were valine, phenylalanine, trypyopan and histidine, while the non-essential amino acids present in the highest concentration was glycine. Wurno LGA showed higher levels of amino acids such as valine, tryptopan, glycine, valine and histidine, while serline and arginine showed lower levels of amino acids. The results of the amino acid composition analysis of smoked *Clarias gariepinus* from Tambuwal LGA, Romon Sarki water body is presented in Table 2. It shows that the fish contains a total of 16 amino acids. The essential amino acids present in the highest concentrations was isoleucine, while the non-essential amino acids present in the highest concentrations was glycine. In Romo LGA, the smoked *Clarias gariepinus* exhibited higher levels of amino acids such as isoleucine, serline and glycine, while valine, leucine, methionine, arginine and alanine exhibited lower levels of amino acids. In September and October some amino acids were not detected.

The essential amino acids found in smoked *Clarias gariepinus* include histidine, isoleucine, tryptopan, leucine, methionine, phenylalanine, threonine, and valine. The non-essential amino acids such as alanine, glycine, asparagine, serline, proline, tyrosine, glutamic acid and arginine were also present in substantial amounts. Leucine promotes the healing of bones, skin and muscle tissue. Isoleucine is necessary for haemoglobin formation, stabilizing and regulating blood sugar and energy. Glycine, which is one of the major components of human skin collagen, together with other essential amino acids such as alanine form a polypeptide that will promote regrowth and tissue healing (Witte *et al.,* 2002). These amino acids are important for human nutrition and are essential for various physiological functions. Higher percentages of leucine, for example, are indicative of greater stimulation for protein synthesis (Etzel 2004). Higher amounts of threonine are indicative of better treatments for central nervous system disorders (Mohanty *et al.* 2014). Higher levels of methionine are indicative of better performance in treatments for liver diseases, healing, depression treatments, alcoholism, allergies, schizophrenia, and drug abstinence (Mischoulon and Fava 2002). This study was consistent with previous research on the amino acid composition of smoked fish. Other reports of similar nature provided valuable information on selecting fish and fish oils for nutritional purposes (Ackman and McLeod, 1988).

A study by Ayoola *et al*. (2017) having a slight difference in the amino acid profiles in smoked *Clarias gariepinus* from different locations in Nigeria. The major amino acids are glutamic acid, aspartic acid, lysine and leucine and ranged from 9.49% to 18.16% of total protein in the fish flesh. Levels of other amino acids ranged from 0.30% to 17.81% in *C. gariepinus* and 0.27% to 18.16% in *T. zillii*. However, the levels of certain amino acids may vary due to factors such as species, location, and processing methods adopted by the fishermen. The amino acid composition of smoked *Clarias gariepinus* is of great significance for human nutrition and health. The presence of essential amino acids in the fish makes it a valuable source of protein for communities in the study area. Amino acids are also important in healing processes and the composition of amino acids in fish is like that in man, people can acquire essential amino acids in abundance and proper balance by eating fish. The essential amino acids cannot be manufactured in human bodies but can be obtained from food. The present study indicated that the species from both water bodies had most of the essential amino acids. Deficiency in the essential amino acids may hinder healing recovery process (Mat, 1994).

Arginine is essential for people under certain conditions. With versatile physiological functions, it is nutritionally essential for neonates and adults with intestinal resection or dysfunction, burns, and renal dysfunction associated with NO (nitric oxide) deficiency. Moreover, essential roles were evidenced in reproduction, fetal formation, healing, immune system, tissue integrity, and a few benefits in obesity, diabetes, and metabolic syndrome treatments (Wu *et al.* 2009). Both

Wurno and Romo LGAs presented high content of essential amino acids, registering all values superior to the minimum recommendation standards determined by the Food and Agriculture Organization of the United Nations (45% FAO, 2013). However, the differences in amino acid content between the two locations highlight the need for further research to optimize processing methods and improve the nutritional value of smoked fish.

## CONCLUSION

This study provided valuable insights into the nutritional quality of traditional smoked fish in these two regions. The analysis revealed that the amino acid profile of the fish differed significantly between the two locations, with implications for the overall nutritional value and potential health benefits for consumers. Furthermore, the study also demonstrated the importance of proper smoking techniques in maintaining the nutritional integrity of the fish. Improper smoking methods can lead to the loss of essential amino acids and degradation of protein quality. Therefore, appropriate smoking practices should be emphasized to preserve the nutritional value of smoked fish.

**TABLE 1: Amino acid composition of smoke fish species from Wurno LGA.**

| Amino acids | Molecular formulas | Monthly (mg/100g) | | |
|---|---|---|---|---|
| | | August | September | October |
| Asn | $C_4H_8N_2O_3$ | $4.35\pm0.08^b$ | $2.52\pm0.15^a$ | $2.63\pm0.19^a$ |
| Thr | $C_4H_9NO_3$ | $1.01\pm0.01^a$ | $1.8\pm0.37^a$ | $3.09\pm0.53^b$ |
| Ser | $C_3H_7NO_3$ | $3.8\pm0.08^a$ | $3.99\pm0.05^a$ | $2.95\pm0.61^a$ |
| Gly | $C_2H_5NO_2$ | $6.36\pm0.02^c$ | $1.49\pm0.19^a$ | $3.69\pm0.87^b$ |
| Val | $C_5H_{11}NO_2$ | $2.56\pm0.08^a$ | $3.08\pm0.16^b$ | $3.68\pm0.13^c$ |
| Phe | $C_9H_{11}NO_2$ | $1.82\pm0.01^a$ | $2.25\pm0.35^{ab}$ | $2.82\pm0.36^b$ |
| Pro | $C_5H_9NO_2$ | $4.11\pm0.03^a$ | $4.77\pm0.40^{ab}$ | $5.16\pm0.04^b$ |
| Leu | $C_6H_{13}NO_2$ | $2.5\pm0.05^a$ | $4.06\pm0.75^{ab}$ | $4.51\pm0.66^b$ |
| Meth | $C_5H_{11}NO_2S$ | $1.13\pm0.01^a$ | $1.95\pm0.48^a$ | $3.33\pm0.30^b$ |
| Iso | $C_6H_{13}NO_2$ | $2.16\pm0.03^a$ | $2.35\pm0.64^a$ | $3.64\pm0.25^b$ |
| Tyr | $C_9H_{11}NO_3$ | $0.99\pm0.01^a$ | $3.94\pm0.31^b$ | $3.81\pm0.05^b$ |
| Try | $C_{11}H_{12}N_2O_2$ | $8.65\pm0.06^c$ | $3.05\pm0.05^b$ | $2.78\pm0.08^a$ |
| Lys | $C_6H_{14}N_2O_2$ | $0.37\pm0.02^a$ | $3.98\pm0.02^b$ | $4.11\pm0.19^b$ |
| His | $C_6H_9N_3O_2$ | $5.18\pm0.02^c$ | $1.44\pm0.08^a$ | $2.45\pm0.26^b$ |
| Arg | $C6H14N_4O_2$ | $1.5\pm0.02^a$ | $2.65\pm0.62^a$ | $2.68\pm0.33^a$ |
| Ala | $C_3H_7NO_2$ | $1.3\pm0.01^a$ | $1.69\pm0.16^{ab}$ | $2.08\pm0.20^b$ |

NOTE: Mean ± S.E.M with same superscripts on same row, shows no significant differences (P >0.05). (Asn=Asparagine, Arg=Arginine, Ala=Alanine, Gly=Glycine, Thr=Threonine, Ser=serine, Val=Valine, Leu=leucine, Ile=Isoleucine, Pro=Proline, Meth=Methionine, Phe=Phenylalanine, Lys=Lysine, His=Histidine, Try=Tryptopan and Tyr=Tyrosine).

**TABLE 2: Amino acid composition of smoke fish species from Romon sarki**

| Amino acids | Molecular formulas | Monthly (mg/100g) | | |
|---|---|---|---|---|
| | | August | September | October |
| Asn | $C_4H_8N_2O_3$ | $7.36\pm0.47^b$ | $2.82\pm0.22^b$ | $2.23\pm0.09^a$ |
| Thr | $C_4H_9NO_3$ | $2.59\pm0.17^b$ | $4.71\pm0.32^b$ | $1.26\pm0.38^a$ |
| Ser | $C_3H_7NO_3$ | $6.41\pm0.13^c$ | $1.57\pm0.21^a$ | $2.64\pm0.58^a$ |
| Gly | $C_2H_5NO_2$ | $9.61\pm0.18^c$ | $4.31\pm0.95^a$ | $3.29\pm0.33^b$ |
| Val | $C_5H_{11}NO_2$ | $2.99\pm0.04^a$ | $1.50\pm0.24^a$ | $2.20\pm0.76^a$ |
| Phe | $C_9H_{11}\ NO_2$ | $2.50\pm0.01^{ab}$ | $4.01\pm0.46^a$ | $3.09\pm0.63^b$ |
| Pro | $C_5H_9NO_2$ | $7.09\pm0.39^a$ | $3.47\pm1.12^a$ | $10.42\pm1.75^b$ |
| Leu | $C_6H_{13}NO_2$ | $4.12\pm0.77^a$ | ND | $5.74\pm1.27^a$ |
| Meth | $C_5H_{11}NO_2S$ | $4.44\pm0.63^a$ | $2.95\pm0.34^c$ | ND |
| Iso | $C_6H_{13}NO_2$ | $1.49\pm0.19^b$ | $3.91\pm0.04^b$ | $0.98\pm0.03^a$ |
| Tyr | $C_9H_{11}NO_3$ | $2.47\pm0.07^a$ | $2.40\pm0.61^a$ | $2.01\pm0.14^{ab}$ |
| Try | $C_{11}H_{12}N_2O_2$ | $0.69\pm0.12^b$ | $2.99\pm0.54^{ab}$ | $1.08\pm0.05^a$ |
| Lys | $C_6H_{14}N_2O_2$ | $0.86\pm0.06^a$ | $2.93\pm0.43^a$ | $7.65\pm3.00^b$ |
| His | $C_6H_9N_3O_2$ | $5.10\pm0.85^b$ | $1.65\pm0.02^a$ | $3.00\pm0.41^a$ |
| Arg | $C6H14N_4O_2$ | $0.67\pm0.16^a$ | $2.57\pm0.54^b$ | $1.91\pm0.75^a$ |
| Ala | $C_3H_7NO_2$ | $3.53\pm0.26^b$ | $2.52\pm0.05^a$ | ND |

NOTE: Mean ± S.E.M with same superscripts on same row, shows no significant differences (P >0.05), ND; not detected. (Asn=Asparagine, Arg=Arginine, Ala=Alanine, Gly=Glycine, Thr=Threonine, Ser=serine, Val=Valine, Leu=leucine, Ile=Isoleucine, Pro=Proline, Meth=Methionine, Phe=Phenylalanine, Lys=Lysine, His=Histidine, Try=Tryptopan and Tyr=Tyrosine).

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# PHYTOCHEMICAL PROPERTIES OF MODIFIED BAMBARA-GROUNDNUT BASED PASTE READY-TO-USE THERAPEUTIC FOOD

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## ABSTRACT
This study focused on the phytochemical properties of Modified Bambara-groundnut based paste ready- to use- therapeutic food. The ingredients used are bambaranut, groundnut, crayfish, fennel seeds, micronutrient powder, dates, and vegetable oil in calculated proportion. The Bambara nuts (2kg) were cleaned and were given four different treatments: roasting, germination, fermentation and lastly steaming giving four different samples of the formulation. The phytochemicals determined for each samples are tannins, saponins, alkaloids, phenols, flavonoids and carotenoids. The Phenolic compounds were found to be most abundant in Sample A (110.14 mg/100g), sample C was the lowest with (108 mg/100g) for flavonoids Sample A had the highest levels (34.47mg/100g) and sample C had the lowest with (32.9mg/100g) Tannin levels were also highest in the Sample A (73.38mg/g) while sample C was the lowest with (68.58mg/100g) Sample D showed the highest saponin concentration (89.82 mg/100g), sample C had the lowest (75.71mg/100g) different from the trend observed with flavonoids, phenols, and tannins. Carotenoid levels were highest in Sample B (62.24 µg/100g), and sample D with the lowest carotenoid content (52.02 µg/100g) while sample C has the amount of alkaloids present with (8.68 mg/100g) and sample B had the lowest alkaloid content (8.09 mg/100g). According to these results the modified Bambara groundnut Ready to use Therapeutic Food has high levels of phytochemicals which shows its therapeutic abilities and maybe be useful to combat SAM.
**Keywords**: SAM: severe acute malnutrition. RUTF: ready to use therapeutic food. ANRIN: accelerating nutrition results in Nigeria, WHO: world health organization, UNICEF: united nation children fund.

## INTRODUCTION
Good nutrition is the basic need for children to thrive, grow, learn, play, and participate in beneficial functions (WHO, 2019). Children who are not adequately fed or over fed become nutritionally impaired, a state of malnutrition. Malnutrition refers to deficiencies, imbalances, or excesses, in a person's intake of energy and/or nutrients, malnutrition is a health resulting from eating food that contains insufficient or too many calories, carbohydrates, vitamins, proteins, and minerals or a state of nutrition in which a person's diet does not provide adequate nutrients for optimal health or were the body has difficulty in absorbing or utilizing nutrients (WHO, 2022). Simply put, malnutrition is a state of under or over-nutrition (WHO, 2024). The prevalence of under-nutrition amongst under-five children is of great concern. Globally, 149 million children under the age of five are estimated to be stunted and 45 million are estimated to be wasted (UNICEF, 2022). Nigeria has the second highest burden of stunted children in the world with a

national prevalence state of 32%of children under five (UNICEF 2021). An estimated two million children in Nigeria suffer from severe acute malnutrition (SAM) but only two out of ten children is currently reached with treatment. The states in northern Nigeria are the most affected with malnutrition, especially wasting. Wasting is low weight for height and occurs when someone has not had enough food or adequate food quality. If not properly treated, wasting in children is associated with a higher risk of death (UNICEF, 2020). One of the conventional ways of treating malnutrition is through the use of Ready-to-Use Therapeutic Food (RUTF).

Ready-to-Use Therapeutic Food (RUT F) is a lifesaving essential supply item that treats wasting in children. It is a specially formulated, energy-dense, and nutrient-rich food product designed to treat severely acutely malnourished children under the age of five (UNICEF, 2021). RUTF is designed to be used instantly, requiring no further preparation; therefore, they fall into a category of food products specifically designed to be consumed without any further preparation. Many countries have developed locally formulated RUTF using indigenous ingredients. Nigeria has also developed locally formulated RUTF using indigenous ingredients including millet, sorghum, peanut paste, palm oil, sugar, milk powder, vegetable oil and micronutrient premix (Adegoke *et al.,* 2021). However, this study sought to use underutilized nutrients rich foods such as Bambara nut and dates.

Bambara nut *(Vigna subterranea)* is a legume crop predominantly grown in Africa especially in Nigeria, Bambara nut provides essential nutrients and improves dietary needs. The seeds contain 65% of carbohydrates, 18% protein, 6.5% oil and essential nutrients such as calcium, iron, potassium, and sodium (Nokuthula *et al*., 2021). Dates have been used in traditional medicine to treat fever and inflammation, they are commonly consumed by pregnant women pre and post-childbirth, thus serving as a comprehensive diet rich in secondary metabolites. They possess diverse pharmocological effect such as anticancer, ant-diabetic, anti-inflammatory, anti-microbial properties (Abdoussadeq *et al.,* 2024). Both Bambara nut and Dates are good sources of phytochemicals of important health benefits. Phytochemicals have been shown to have health benefits. Therefore, this study sought to determine the phytochemical properties, present in Bambara-groundnut-based RUTF.

## MATERIALS AND METHODS

### Sources of Raw Materials

The raw materials used in this study are Bambara nut *(Vigna subterranean*), Groundnut (*Arachis hypogea*), Dates *(Phoenix dactlifera*), Fennel seeds *(Foeniculum vulgare*), Cray fish, Vegetable oil, Micronutrient powder. The raw materials were purchased from Kure market Minna, Niger state, while the micronutrient powder was purchased from ANRIN (accelerating nutrition results in Nigeria) project office Okada road Minna, Niger State.

### Processing of Raw Materials

#### Date Processing

Dried dates underwent a meticulous sorting process before being crushed with a mortar and pestle to extract the seeds. Subsequently, the date flesh was processed in a Kenwood blender and passed through a sieve with a mesh size of 72 μm to produce date flour, as reported by Ashgan *et al.* (2024).

**Groundnut processing**:
Prior to their utilization, the groundnuts underwent a thorough washing process, which included rinsing with tap water to eliminate any residual debris or damaged nuts. Subsequently, a sun dryer was employed to ensure the groundnuts were completely dried. The roasting process was carried out using the Crown Star electric oven, model MC-4011, at a temperature of 180°C for a duration of 30 minutes. Following this, the groundnuts were processed into a paste in accordance with the methodologies outlined by Joseph *et al*. (2023).

**Crayfish Processing**
The crayfish underwent a meticulous cleaning process, which involved the manual removal of dirt, followed by winnowing and washing in a bucket of water. Subsequently, it was placed in a solar dryer where it was allowed to dry for three hours. After this drying period, the crayfish was toasted for five minutes at a temperature of 15℃, utilizing a Crown Star electric oven, model MC - 4011. The final steps included pulverizing the dried crayfish in a blender, sieving the resulting powder through a 72 μm sieve, and securely packaging it in a Ziplock bag, as detailed by Ibironke *et al*. (2018).

**Fennel Seed Processing**
The fennel seeds were carefully cleaned through a process that included the manual elimination of dirt, followed by rinsing with tap water. After draining, the seeds were sun-dried for 30 minutes and then toasted for 5 minutes at a temperature of 15℃. Once toasted, the seeds were milled and sifted through a 72 μm mesh sieve, in line with the modified method described by Susinggih *et al.* (2023)

**Bambara Nuts Processing**
*Roasted (Sample A)*
About 2 kg of cleaned Bambara nuts were sorted and roasted according to the method of Okafor *et al.* (2014). The Bambara nut seeds were spread evenly on a tray and roasted at 140ºC for 60 minutes in an electric oven (Crown Star, model MC - 4011), cooled, and milled using a blender and sieved to pass through 72 μm size mesh, packed and stored in a polyethylene zip lock bag till use.
***Fermentation and boiling (Sample B)***
Another 2kg of cleaned nuts was fermented according to the method of Chude *et al.* (2020). The nuts were rinsed and soaked in tap water for 12 hours before Fermentation. The water was decanted and the nuts were then put in 15 liters of tap water, the nuts were covered completely and left in the laboratory for 3 days. The nuts were rinsed and cooked for 3 hours and 30 minutes, allowed to cool, put in a solar drier, and left to dry completely. To obtain the flour, the fermented, boiled, and dried nuts were milled using a blender and sieved using a 72 μm mesh size sieve, the fine flour was then packed in a Ziploc bag, labeled, and kept until used.
***Germination and boiling (sample C)***
A 2Kg of cleaned Bambara nut was steeped for 12 hours before it was drained, the seeds were spread out on a jute bag, hydrated, and germinated for 72 hours at room temperature (28°C). The germinated seeds were picked, rinsed, and boiled for 30 minutes to soften according to the method of Ndidi *et al*. (2015) with modification. The germinated, boiled seeds were dried using a solar dryer until all seeds were completely dried. They were then milled using Ken wood blender and sieved using a 72 μm mesh size sieve to obtain fine flour which was packed in a labeled zip lock.

***Raw control and steaming (Sample D)***

This was done using the method of Yahaya *et al.* (2022) with modification, and cleaned 2 kg Bambara nuts were steamed for 1 hour 30 minutes using an electric steamer, and they were cooled and allowed to dry, it was then milled and the flour was obtained by sieving using a 72μm mesh size laboratory sieve.

**Table 1: Bambara nut Based RUTF Samples Ingredients Blends Formulation.**

| Ingredients (%) | Roasted (A) | Fermented/Boiled (B) | Germinated/ Boiled | Steamed |
|---|---|---|---|---|
| Bambara nut flour | 24.5 | 24.5 | 24.5 | 24.5 |
| Peanut paste | 37 | 37 | 37 | 37 |
| Date powder | 20 | 20 | 20 | 20 |
| Vegetable oil | 15 | 15 | 15 | 15 |
| Crayfish powder | 2 | 2 | 2 | 2 |
| Fennel seed powder | 1 | 1 | 1 | 1 |
| Micronutrient powder | 0.5 | 0.5 | 0.5 | 0.5 |
| Total | 100 | 100 | 100 | 100 |

Source: Sosanya *et al.* (2017) modified.

**A**=Roasted Bambara based RUTF sample; **B**=Fermented /Boiled Bambara based RUTF sample; **C**=Germinated / Boiled Bambara based RUTF sample and **D**=Steamed Bambara based RUTF sample (Control)

**Phytochemicals Determination**

The saponin content was determined according to the method described by Oloyede (2005). The tannin content was determined using the method of (AOAC, 2012). Singleton *et al.* (1999) method was used to determine total phenol content of the various samples. Total flavonoid content was determined using the method of (Chang *et al.*, 2002). Total alkaloid of the sample was determined using method of Oloyede (2005). Total carotenoids of the four different samples was estimated following the method of Rodrizguez-Amaya (2004).

**Statistical Analysis**

All analyses were performed in duplicate and the results were subjected to statistical analysis, using SPSS version 23.0. Statistical significance was established using One-Way Analysis of Variance (ANOVA) at 5% level of probability and differences between means were compared using Duncan Multiple range test.

**RESULTS AND DISCUSSION**

Analysis for selected phytochemicals was carried out they include tannins, phenols, flavonoids, saponins, alkaloids, and carotenoids. These are naturally occurring bioactive substances in plants which posses' disease protective and preventive abilities hence, their application in the medical and pharmacological field (Azwanida *et al.,* 2021). The various arrays of these phytochemicals exhibit a wide range of biological activities such as anti-inflammatory and antimicrobial effects making them highly valuable in the development of novel therapeutic agents (Patel *et al.,*2021). Phenolic compounds were found to be most abundant in Sample A (110.14 mg/100g). Phenols are widely distributed in plants and have gained attention due to their antioxidant properties. A study by Kumar *et al.* (2020) found that medicinal plants contain phenols and it contribute significantly to their therapeutic effect. Phenols are mostly beneficial at high concentration specific/acceptable limits are not standardized (Oppenheimer *et al.,* 2017).

**Table 2: Phytochemical composition of four different samples of the modified Bambara Groundnut ready to use therapeutic food.**

| **Samples** | **Phenols** (mg/100g) | **Flavonoids** (mg/100g) | **Tannins** (mg/100g) | **Saponins** (mg/100g) | **Alkaloids** (mg/100g) | **Carotenoids** (µg/100g) |
|---|---|---|---|---|---|---|
| A | $110.45\pm0.43^{a}$ | $34.47\pm0.24^{a}$ | $73.38\pm0.25^{a}$ | $85.21\pm0.33^{b}$ | $8.63\pm0.29^{a}$ | $56.02\pm1.11^{b}$ |
| B | $109.47\pm0.38^{ab}$ | $33.34\pm0.45^{b}$ | $70.23\pm0.10^{b}$ | $80.59\pm0.53^{c}$ | $8.09\pm0.17^{a}$ | $62.24\pm0.59^{a}$ |
| C | $108.44\pm0.45^{b}$ | $32.97\pm0.18^{b}$ | $68.58\pm0.37^{c}$ | $75.71\pm0.44^{d}$ | $8.68\pm0.35^{a}$ | $59.98\pm0.17^{a}$ |
| D | $109.16\pm0.22^{b}$ | $33.70\pm0.23^{ab}$ | $70.37\pm0.07^{b}$ | $89.82\pm0.55^{a}$ | $8.32\pm0.18^{a}$ | $52.99\pm1.15^{c}$ |

The value is mean of duplicate determination. Mean with different subscript in the same column are significantly different ($p<0.05$) while those with same super script are not significant ($p>0.05$)

**A**=Roasted Bambara based RUTF sample; **B**=Fermented /Boiled Bambara based RUTF sample; **C**=Germinated / Boiled Bambara based RUTF sample and **D**=Steamed Bambara based RUTF sample (Control)

Alkaloids concentrations were highest in sample C (8.68 mg/100g). Alkaloids are a group of diverse nitrogen containing compounds found in plant, they have been of interest in pharmacological and medicinal field for long due to their numerous biological activities some alkaloids have shown promising results in tumor inhibition and metastasis (Narula *et al.,* 2021). Tannin levels were highest in Sample A (73.38 mg/100g). Tannins have been used in recent years as natural preservatives due to antimicrobial properties. The presence of Tannins in a typical diets levels have been considered safe (Oppenheimer *et al.,* 2017). Saponins are characterized by their soap-like foaming properties. A recent research has highlighted their potential health benefits like anti-inflammatory and anti-cancer properties (Khoo *et al.,* 2020). Saponins have been effective in reducing cholesterol levels and improving immune function. Sample D had the highest level of saponin concentration (89.82 mg/100g). Saponins are considered generally safe in food, toxicity may occur at levels exceeding 150mg/kg body weight (Oppenheimer *et al.,* 2017). According to the European Food Safety Authority (EFSA) food supplement should contain about 100-200mg/kg. The US FDA has no specific limits but recommends monitoring. According to WHO/FAO maximum intake of saponin should be within 100- 200mg/kg

Sample A had the highest levels of flavonoids at 34.47 mg/100g. Flavonoids are wide range of polyphenol compounds widely distributed in plants. It has anti-oxidant and anti-inflammatory properties (Patel *et al.,* 2021). Flavonoids have also shown promise in cognitive health (Vauzour *et al.,* 2020). Carotenoids were highest in Sample B (62.24 µg/100g). Carotenoids have been extremely studied for their antioxidant properties and their potential role in eye health (Milani *et al.,* 2021). Some carotenoids like beta carotene serve as precursors to vitamin A, playing an important role in vision and immune function (Tanumihardjo *et al.,* 2020). The antioxidant properties of carotenoids help combat oxidative stress by neutralizing harmful free radicals which can lower the risk of chronic disease (Mortensen *et al.,* 2020).

## CONCLUSION

This study has shown that the modified Bambara groundnut based RUTF with four different (roasted, germinated, fermented and the raw control) have distinct phytochemical composition known for their therapeutic uses in the medical field. The roasted Bambara nut based RUTF (sample A) had the highest phenols, flavonoids, and tannins, suggesting more potent antioxidant properties. However, sample B had highest amount of carotenoids while sample C and D had the highest amount of alkaloids and saponin content respectively. This study shows that RUTF made from modified Bambara nut and local ingredients could be rich source of phytochemicals hence its ability in the treatment of SAM and other nutritional related non-communicable diseases.

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# EVALUATION OF TAMARIND SEED-BASED DIETS ON PRODUCTION OF NILE TILAPIA (*Oreochromis niloticus*) FINGERLINGSREARED IN PLASTIC BOWLS

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## ABSTRACT

A feeding study was conducted to assess the value of Tamarind, Tamarindus indica seed meal as dietary carbohydrate in the diets of Nile Tilapia, Oreochromis niloticus. Tamarind seeds were used to replace maize at 12.50%, 25%, 37.50% and 50% substitution levels for Treatments 1 to 5. Growth trial was conducted in cylindrical plastic bowls for 42 days. The fishes were fed at 5% body weight twice daily. There were significant ($p<0.05$) differences in the mean weight gain (MWG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER). There was significant ($p<0.05$) difference in mean weight gain with increasing inclusion levels of tamarind seed meal were observed. Diet 5 (100%) had the lowest mean weight gain. Diet 3 (50%) had the highest mean weight gain but significant between Diet 2, 4 and 1 (control). The highest survival rate was 100% (Diet 1) while the lowest survival rate was 90% (Diet 5). Diet 3 had the highest feed intake (28.48 g), protein intake (8.97 g) and protein efficiency ratio (2.44) while for Diet 5; feed conversion ratio (1.66) was recorded as the highest. There were no significant differences in diets 2, 3 and 1 (control) for the feed utilization by O. niloticus fingerlings. From above results, maize could therefore be replaced by tamarind seed meal at 25% inclusion level without affecting growth and nutrient utilization in the practical diet of Nile Tilapia, O. niloticus fingerlings. Based on the findings, partial replacement of maize meal with tamarind seed meal in the diets of O. niloticus fingerlings is recommended.

**Keywords*:*** Maize, Tamarind seed meal (TSM), Replacement, Oreochromis niloticus

## INTRODUCTION

Plant protein and carbohydrates feedstuffs, particularly soyabeans (*Glysine max*) and maize (*Zea mays*), have been extensively used in feeds with nutritional, environmental and economic benefits (Tacon, 1993). As the use soyabean and maize in human food and livestock feed increases, their cost has increased, and the economics of using them in fish feeds may become less favourable. Hence, evaluation of under-utilized indigenous plant protein/energy rich sources becomes imperative and remains a high research priority in Nigeria (NRC, 2011; Tacon *et al*, 2011). Vast quantities of forest seeds are discarded as wastes in Nigeria. There is strong economic justification for their use either as protein or carbohydrate/energy supplements in low cost diets for fish. A national feedstuff survey revealed that Tamarind (*Tamarindus indica*) represents a good source of digestible fish feed ingredient because of its low cost and availability (Balogun, 1990).

Tamarind (*Tamarindus indica*) is a multipurpose tropical fruit used primarily for its fruit which are eaten fresh or processed, used as a seasoning or spice or fruit and seeds are processed for non-food uses (Lewis *et al,* 2004). Tamarind contains about 18% crude protein, with amino acid profile comparable to maize, but with high methionine plus cystine (met+cys) value than maize (Nwanna *et al,* 2004). Nile tilapia (*Oreochromis niloticus*) is a fast growing and most preferred aquaculture species in Africa and is capable of utilizing plant materials in its diets.

Feed has been a major constraint to the growth of aquaculture because the price of conventional feedstuffs such as maize meal, guinea corn and millet meal which has continued to increase due to high demand for them and they are limited in supply (Fasakin *et al*., 1999). The unstable currency exchange also affects price of fish meal thereby resulting in the inclusion of locally and regionally grown crops and by-products into fish feed/diets (Olurin *et al*., 2006). Numerous by-products are produced in our country, Nigeria but usage is sometimes limited due to poor understanding of their nutritional and economic value, as well as their proper use in fish feed (Alatise *et al*., 2006). The primary goal in the aquaculture industry is reduce production costs, especially feeding expenses, while avoiding significant side effects. Commercial aquaculture relies heavily on a commercial fish diet, which is a crucial component and formulated for the optimum growth of particular fish species. Commercial fish feed usually includes fish meal and oil, corn grain, and soyabean meal to provide adequate amino acids and fatty acid profiles (NRC, 2011). Tamarind (*Tamarindus indica*) seed meal is a viable alternative carbohydrate source to maize meal in the diet of Nile Tilapia (*Oreochromis spp.*). Its utilization is expected to reduce feed cost drastically, thus leading to a viable and sustainable aquaculture industry. The aim and objective of this study is to evaluate tamarind (*Tamarindus indica*) seed meal as a substitute for maize meal and to evaluate the growth performance and nutrient utilization of Nile tilapia (*Oreochromis niloticus*) fingerlings fed tamarind based-diets.

## MATERIALS AND METHODS

### Experimental Site

The experiment was carried out at the Fisheries Technology Department's fish mill unit of the Federal College of Freshwater Fisheries Technology, New Bussa, Niger State, Nigeria.

### Experimental Fish

One hundred and fifty (150) fingerlings of Nile tilapia (*Oreochromis niloticus*) with average weight of 5.88±0.02 g were obtained from the College pond. The fish were acclimatized for three (3) days in the bowls during which they were fed on 35% crude protein feed before the commencement of the experiment.

### Collection of Tamarind (*Tamarindus indica*) seeds

The tamarind seeds were sourced from Abdulsalam Fish Farm, New Bussa, Niger State, Nigeria. The tamarind seeds collected were sun-dried and ground into fine powder using domestic grinding machine and analyzed for proximate composition at Laboratory of JaaGee Nigeria Limited, Ibadan, Oyo State on dry matter basis according to standard method of (AOAC, 2016).

### Source of Ingredients and Diet Preparation

The ingredients used in this study were purchased from Jasope feeds depot, Ibadan way, New Bussa, Niger State. These include yellow maize fish meal, soyabean meal, groundnut cake, along with the fixed ingredients such as vitamin premix, vegetable oil, bone meal, methionine, lysine and salt while the tamarind seeds were sourced from the premises of Abdulsalam Fish Farm, New Bussa, Niger State. The tamarind seeds were prepared by drying and grind into a fine powder with the hammer mill. The various feedstuffs were thoroughly mixed together in a bowl. Based on the proximate composition of the feedstuffs, five diets were formulated as presented on Table 1. The control diet (Diet 1) contained 40.25% of yellow maize meal which replaced with tamarind seed meal in diets 2, 3, 4 and 5 at 12.50%, 25%, 37.50% and 50% respectively. The resultant mixture was made into a dough and pelleted with Flat-die pelletizer of APF 150 model and then sun-dried at 30°C between 12 noon to 6 pm for two days and stored in an air tight polythene bag at ambient temperature (28°C). The proximate composition of the tamarind seed meal and the diets (moisture content, crude protein (N x 6.25), crude fat, crude fibre and total ash were determined in triplicate samples according to the methods of Association of Official Analytical Chemists (AOAC, 2016).

**Experimental Design**

The plastic bowls were used for this study which consists of five treatments replicated thrice in a completely randomized design. Ten fingerlings of *Oreochromis niloticus* of 5.88± 0.02 g were stock in each bowl. The fish were weighed with an electronic sensitive weighing balance (OHAUS – LS-200 model). The plastic bowls were washed, thoroughly rinsed and filled with water to 16cm high.

**Management of the experimental fingerlings**

Group of 10 fingerlings of Nile tilapia (*Oreochromis niloticus*) with average weight of 5.88±0.02 g having been acclimatized for three days were randomly stocked in to 15 plastic bowls containing 25 L of water for growth trials. Each of the diets was fed to fishes in triplicate plastic bowls at 5% body weight twice per day between 7 – 8am and 5 – 6 pm for 42 days. Fresh water was used to change the water in the experimental plastic bowls once in a week. Total weight of fishes in each plastic bowl was taken weekly to monitor growth responses and for feed adjustments.

**Growth Parameters**

Fish growth and feed utilization efficiency of this experiment were measured weekly and at the end of all experiments following Somsueb and Boonyaratpalin, (2001); Jantrarotai *et. al.*, (1996); Chuapoehuk, (1999) and Tinnungwatana and Viputhanumas, (2000).

Mean weight grain (g) = Mean final weight – Mean initial weight

$$\text{Daily growth rate (g/day)} = \frac{\text{(Mean final weight – Mean initial weight)}}{\text{Culture period (day)}}$$

$$\text{Specific growth rate (\%/day)} = \frac{\text{(In final weight – In initial weight)}}{\text{Culture period (days)}} \times 100$$

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Dry weight of feed fed}}{\text{Fish weight gain}}$$

Protein efficiency ratio (PER) = Fish weight gain (g)

Protein fed (g)

Survival rate (%) = (Final number of fish/Initial number of fish) × 100

**Statistical Analysis**

Data obtained from the experiment were analyzed using One-way Analysis of Variances (ANOVA) of the Statistical Package for Social Science (SPSS) Version 20.0. and Duncan's multiple range test (Zar, 1984) was used to compare the significant differences between treatment means at $P<0.05$.

**RESULTS AND DISCUSSION**

The proximate and energy composition (% dry matter) of tamarind seed and maize meal is presented in Table 2. The nutrient composition oftamarind seed showed that the tamarind seed meal contained high crude protein of 16.60% while maize meal contained 11.83% crude protein. The protein content of tamarind seed meal is higher than that of maize. The nutritional composition of experimental diets fed to *Oreochromis niloticus* fingerlings for 42 days is presented in Table 3. The growth performance and nutrient utilization of *Oreochromis niloticus* fed Tamarind seed meal diets for 42 days is presented in Table 4 while the mean weight of *Oreochromis niloticus* fed Tamarind seed meal-based diets is presented in Figure 1. The highest mean weight gain of 21.93±0.05 g was recorded in fish fed Diet 3 at 25%TSM containing. This was followed by 20.33±0.06 g on those fish fed Diet 2 containing 12.50%TSM with significant ($P<0.05$) difference between the fish fed Diet 1 (control), Diet 4 (37.50%TSM) and 5 (50%TSM) dietary treatments respectively. The mean weight gain decreased with increase in replacement of TSM for maize meal in the diets. It was lowest (13.73±0.21 g) in fish fed diet 5 containing 50%TSM with significant ($P<0.05$) difference in the mean weight gain of the diets 2 and 4 respectively. The specific growth rate (SGR) follows the same trend it as Table 4.3.

Food conversion ratio (FCR) ranged between 1.29±0.01 (Diet 1: 0%TSM) to 1.66±0.18 (Diet 5: 50%TSM). Fish fed diet 3 containing 25%TSM recorded the lowest feed conversion ratio of 1.29±0.01 with no significant ($P<0.05$) difference with Diet 1 (Control), while the poorest feed conversion ratio was obtained in fish fed Diet 5 containing (50%TSM). The protein efficiency ratio (PER) follows the same trend it as Table 4. However, there was no significant difference ($p<0.05$) in the food conversion ratio among diets 1, 2 and 3 respectively. The mean values of specific growth rate (SGR) and feed conversion ratio (FCR) obtained from this study was close to the mean values 1.53±0.05 and 2.05±0.07 for SGR and FCR reported for *Oreochromis niloticus* fingerlings fed cotton seed meal based diets Mbahinzireki *et al*., (2001). The high increase in the growth rate of *Oreochromis niloticus* in the first two weeks of culture in this work may be due to the initial starvation of the fish which made them more metabolically active. This observation was similar to that of Obasa and Faturoti, (2001) in juvenile *Heterotis niloticus*, where they recorded an increase in the growth of the fish as they were subjected to delay in feed administration.

**Table 1: Ingredients and percentage composition of experimental diets (g/100g/DM) fed to *Oreochromis niloticus* fingerlings**

| Ingredients | Diet 1 (0%) | Diet 2 (12.50%) | Diet 3 (25%) | Diet 4 (37.50%) | Diet 5 (50%) |
|---|---|---|---|---|---|
| Tamarind seedmeal | 0.00 | 5.03 | 10.06 | 15.09 | 20.13 |
| Yellow maize | 40.25 | 35.22 | 30.19 | 25.16 | 20.12 |
| Fish meal | 17.25 | 17.25 | 17.25 | 17.25 | 17.25 |
| Soyabean meal | 17.25 | 17.25 | 17.25 | 17.25 | 17.25 |
| Groundnut cake | 17.25 | 17.25 | 17.25 | 17.25 | 17.25 |
| Vitamin premix | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vegetable oil | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Bone meal | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Methionine | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Lysine | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| **Total** | **100.00** | **100.00** | **100.00** | **100.00** | **100.00** |

Table 2: Proximate and energy composition (% dry matter) of tamarind seed and maize meal

| Nutrients | Tamarind seedmeal | Maize meal |
|---|---|---|
| Moisture content (%) | 4.74 | 5.50 |
| Crude protein (%) | 16.60 | 11.83 |
| Crude fat (%) | 0.35 | 5.47 |
| Crude ash (%) | 2.70 | 1.48 |
| Crude fibre (%) | 5.82 | 15.14 |
| NFE (%) | 74.53 | 66.08 |
| GE (Kcal/100g) | 402.67 | 389.46 |
| ME (Kcal/100g) | 367.67 | 360.87 |

NFE (Nitrogen Free Extract) = 100 – (Crude protein + Crude fat + Crude fibre + Crude ash).
Gross energy = Caloric value of protein 5.65, NFE 4.1 and fat 9.45 kcal/g (NRC, 1993).
Metabolizable energy = Caloric value of protein 4.0, NFE 4.0 and fat 9 kcal/g (Atwater's calculation as described by Foster and Smith (1997).

Table 3: Nutritional composition of experimental diets fed to *Oreochromis niloticus* fingerlings

| Nutrients | Diet 1 (0%TSM) | Diet 2 (12.50% TSM) | Diet 3 (25% TSM) | Diet 4 (37.50% TSM) | Diet 5 (50% TSM) |
|---|---|---|---|---|---|
| Moisture content (%) | 1.65 | 1.56 | 1.58 | 1.48 | 1.56 |
| Crude protein (%) | 30.50 | 30.90 | 31.48 | 31.33 | 30.33 |
| Crude fat (%) | 2.32 | 3.12 | 2.14 | 2.34 | 2.56 |
| Crude ash (%) | 14.64 | 16.41 | 12.20 | 12.08 | 12.89 |
| Crude fibre (%) | 8.43 | 8.24 | 8.39 | 8.80 | 8.36 |
| NFE (%) | 44.11 | 41.33 | 45.79 | 45.45 | 54.14 |
| GE (Kcal/100g) | 375.10 | 373.52 | 385.82 | 385.47 | 417.53 |
| ME (Kcal/100g) | 319.32 | 317.00 | 328.34 | 328.18 | 360.92 |

Values in each row having the same superscripts are not significantly difference (p>0.05)

NFE (Nitrogen Free Extract) = 100 – (Crude protein + Crude fat + Crude fibre + Crude ash).
Gross energy = Caloric value of protein 5.65, NFE 4.1 and fat 9.45 kcal/g (NRC, 1993).
Metabolizable energy = Caloric value of protein 4.0, NFE 4.0 and fat 9 kcal/g (Atwater's calculation as described by Foster and Smith (1997).

Table 4: Growth and nutrient utilization of *Oreochromis niloticus* fed Tamarind seed meal diets for 42 days

| **Parameters** | **Diet 1 (0%TSM)** | **Diet 2 (12.50% TSM)** | **Diet 3 (25% TSM)** | **Diet 4 (37.50% TSM)** | **Diet 5 (50% TSM)** |
|---|---|---|---|---|---|
| Initial mean weight (g) | $5.89\pm0.01^{a}$ | $5.85\pm0.04^{a}$ | $5.89\pm0.02^{a}$ | $5.89\pm0.01^{a}$ | $5.88\pm0.01^{a}$ |
| Final mean weight (g) | $24.07\pm0.95^{c}$ | $26.18\pm0.49^{b}$ | $27.82\pm0.04^{a}$ | $22.17\pm0.18^{d}$ | $19.16\pm0.21^{e}$ |
| Mean weight gain (g) | $18.18\pm0.94^{c}$ | $20.33\pm0.46^{b}$ | $21.93\pm0.05^{a}$ | $16.28\pm0.18^{d}$ | $13.73\pm0.21^{e}$ |
| Specific growth rate (%/day) | $3.42\pm0.07^{b}$ | $3.57\pm0.04^{a}$ | $3.69\pm0.01^{a}$ | $3.15\pm0.02^{b}$ | $2.67\pm0.33^{c}$ |
| Feed intake (g) | $25.46\pm0.60^{b}$ | $28.72\pm0.09^{a}$ | $28.48\pm0.06^{a}$ | $26.05\pm0.08^{b}$ | $24.15\pm0.69^{c}$ |
| Food conversion ratio (FCR) | $1.40\pm0.05^{b}$ | $1.41\pm0.03^{b}$ | $1.29\pm0.01^{b}$ | $1.60\pm0.01^{a}$ | $1.66\pm0.18^{a}$ |
| Protein fed | $7.76\pm0.37^{c}$ | $8.78\pm0.08^{a}$ | $8.97\pm0.02^{a}$ | $8.16\pm0.17^{b}$ | $7.32\pm0.18^{d}$ |
| Protein efficiency ratio (PER) | $2.34\pm0.07^{b}$ | $2.32\pm0.06^{b}$ | $2.44\pm0.01^{a}$ | $2.00\pm0.04^{c}$ | $1.88\pm0.03^{d}$ |
| Survival rate | $100.00\pm0.00^{a}$ | $95.00\pm5.00^{ab}$ | $96.67\pm5.77^{ab}$ | $93.33\pm2.89^{ab}$ | $90.00\pm0.00^{b}$ |
| Total fish production (kg/m$^3$) | $2.41\pm0.10^{b}$ | $2.44\pm0.14^{b}$ | $2.69\pm0.16^{a}$ | $2.07\pm0.08^{c}$ | $1.77\pm0.02^{d}$ |
| Culture period | 42 | 42 | 42 | 42 | 42 |

Values in each row having the same superscripts are not significantly difference (p>0.05)

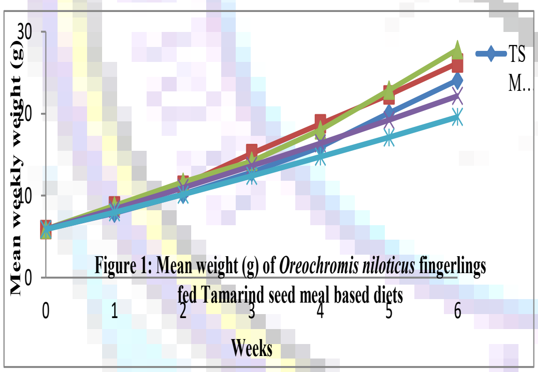


Figure 1: Mean weight (g) of *Oreochromis niloticus* fingerlings fed Tamarind seed meal based diets

**CONCLUSION AND RECOMMENDATION**

The results of the feeding trials showed no significant differences in the mean weight gain (MWG), specific growth rate, food conversion ratio and protein efficiency ratio among the fishes fed control diets and those fed diets partially replaced with tamarind seed meal at 12.50%, 25%, 37.50% and 50% inclusion levels of replacement. The growth performance and nutrient utilization can be achieved in intensively cultured *Oreochromis niloticus* fingerlings fed Diet 3, where maize meal has been replaced partially with tamarind seed meal at 37.50% level of inclusion. This study revealed that 37.50% tamarind seed meal diet would be best for the maximum growth of Nile tilapia, *Oreochromis niloticus* fingerlings. Furthermore, plant protein seed meal based diets are cheaper as compared to the conventional feeds, replacement of plant protein seeds in Nile tilapia, *Oreochromis niloticus* would also prove economically viable. Based on the results of the study, partial replacement of maize meal with tamarind seed meal in the diets of Nile tilapia, *Oreochromis niloticus* fingerlings is recommended.

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# ASSESSMENT OF CONTAGIOUS BOVINE PLEUROPNEUMONIA ANTIBODY TITRES AT THE TEACHING AND RESEARCH FARM FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

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## ABSTRACT
This study aimed to determine the seroprevalence and antibody titres of Contagious Bovine Pleuropneumonia (CBPP) in cattle at the Teaching and Research Farm, Department of Animal Production, Federal University of Technology, Minna, Niger State, Nigeria. A total of 75 blood samples were collected from 15 cattle over a 5-week period and analyzed using the Slide Agglutination Test (SAT). The degree of agglutination was quantified based on a percentage, with results recorded as a ratio (e.g., 1:65, 1:56, 1:125), where ratios ranging from 1:01 to 1:65 were considered negative, and those exceeding 1:66 were deemed positive. The results showed a low overall seroprevalence of 2.67% with a significant difference between male and female cattle (p-value = 0.02). Female cattle had higher antibody titres than male cattle (p-value = 0.03), indicating a better immune response. The study attributes the low seroprevalence to good veterinary services, access to quality vaccines, strict quarantine, and effective herd movement control. The study confirms the absence of CBPP at the farm, highlighting the importance of effective management practices in controlling the disease.
**Keywords:** Animal Health, Contagious Bovine Pleuropneumonia (CBPP), Slide Agglutination Test, Sero prevalence, Antibdy titres.

## INTRODUCTION

Nigeria, home to the largest cattle population in West Africa, with approximately 16.3 million heads (Ikhatua 2011), faces significant economic losses due to Contagious Bovine Pleuropneumonia (CBPP), a disease identified by the World Organization for Animal Health (OIE) as a major constraint to cattle productivity and economic value in northern Nigeria (Alhaji and Babalobi 2015). Globally, control measures focus on epidemic detection, livestock movement management, and stamping-out strategies. However, in Africa, management efforts primarily rely on vaccination programmes and antibacterial use (OIE 2008). CBPP persists in Nigeria, with frequent outbreaks in the northern region, facilitated by the nomadic Fulani herders' extensive migrations in search of grazing (Aliyu *et al*., 2000). Niger State is an endemic area, and the Federal University of Technology, Minna Teaching and Research Farm is at risk of outbreaks; hence, this study. aimed to ascertain the seroprevalence and antibody titres of cattle at the Teaching and Research Farm, and identify potential strategies to mitigate the prevalence of CBPP in the environment

## MATERIALS AND METHODS

### Study Location

The experiment was carried out at the Teaching and Research Farm, Department of Animal Production, Federal University of Technology, Minna, Gidan Kwano campus, Niger state. Geographically, Minna is located within latitude 09°31’ 18.2’’N, and longitude 6° 27’ 40 ‘E with an elevation ranging from 230-250 m. The study area lies within the Southern Guinea savanna of Nigeria. The location’s climate is sub-humid having a mean annual rainfall of 1338 mm, a dry season of about 5 months, and a mean temperature of about 30° C (FUT 2012).

### Study Population

A total of 105 cattle were found in the Teaching and Research Farm. Blood samples were collected aseptically from 15 cattle once a week, at random, and for 5 weeks, resulting in a total of 75 samples that were used for this study.

### Duration of the Study

The study lasted for 7 weeks (from March to April), encompassing both the blood sample collection and analysis stages.

### Experimental Method and Design

### Data Collection

Blood samples were collected weekly from 15 cattle for a period of five (5) weeks. The animals were retrained by the use of crush, and 5 mL blood was aseptically collected from the jugular vein into well-labelled Ethylene Diamine Tetra Acetate (EDTA) anticoagulant bottles using an 18 g needle and 10 mL syringe, following standard veterinary protocols. The blood samples were then stored in a cooler containing ice packs at 4° C to maintain sample integrity. The samples were transported to the Ministry of Livestock and Fisheries Development, Minna Niger State Veterinary Hospital, for subsequent analysis.

### Sampling Procedures

Samples collected from the cattle were taken to the laboratory for further analysis, where Slide Agglutination Test (SAT) was used to determine the levels of antibody titres among the samples collected. Prevalence rate was obtained using the formula below;

Prevalence rate formula =

$$\frac{\text{Number of positive sampled}}{\text{Total number of animals sampled}}$$

### Sera Collection from Sampled Blood Procedures

The serology method employed involved centrifuging the blood samples at 4000 revolutions per minute (r/min) for 5 minutes to separate the serum from the blood cells. This process yielded the sera, which was then used for further analysis.

### Titre Detection of Sera

Serum samples were placed on an open slide, followed by addition of the CBPP vaccine reagent, which had been previously diluted. The mixture was then thoroughly combined using an applicator stick. The slide was subsequently agitated by rotating it sideways (vice versa), facilitating the occurrence of agglutination between the antigen and antibody. The degree of agglutination was quantified based on a percentage, with results recorded as a ratio (e.g., 1:65, 1:56, 1:125), where ratios ranging from 1:01 to 1:65 were considered negative, while those exceeding 1:66 were deemed positive.

**Data Analysis**

All the data collected were imputed into a Microsoft Office Excel worksheet. The data were transformed and SPSS V16 was used to conduct a statistical analysis using descriptive statistics (means) and independent T-tests. The results underwent further analysis to determine the level of significance between male and female cattle in the herd, with the effect size being calculated using the Eta squared (η2) value (Cohen, 1998).

## RESULTS

Table 1 shows the seroprevalence of CBPP in the Teaching and Research Farm Federal, University of Technology Minna; out of the total of 75 animals sampled, 30 bulls were tested for CBPP antibodies, and none (0 %) were found to be positive. In contrast, 45 cows were tested, and 4.4 % of the total sampled were found to be positive for CBPP antibodies with a P-value (0.02). This indicates that there is a significant difference between the CPBB titre of male and female cattle in the herd.

**Table 1: Seroprevalence of CBPP in male and female cattle at the teaching and research farm**

| Sex | Number sampled | Number of positive | Prevalence Rate | P-value |
|---|---|---|---|---|
| **male** | 30 | 0 | 0% | |
| **female** | 45 | 2 | 4.44% | |
| **total** | 75 | 2 | 2.67% | 0.02 |

SAT=slide agglutinin test

Table 2 shows the CBPP antibody titres of male and female cattle in the Teaching and Research Farm. The results show that there is a significant difference based on antibody titres ($p<0.05$) of male and female cattle, with the p-value at (0.03); female cattle had higher scoring body titres than male antibody titres. The observed female antibody titre at (F=0.7666, SD=0.1095), and male at (M=0.0301, SD=0.0279) with an eta value of (0.81), and partial eta square (0.65) was considered to be large (eta squared =0.05).

**Table 2**: **Antibody titres for male and female cattle in Teaching and Research Farm (Eta value)**

| Parameter | Treatment | Mean | p-value | Eta value. | Partial eta sqaure |
|---|---|---|---|---|---|
| CBPP antibody Titter | Male | 0.7666 | 0.030 | 0.81 | 0.65 |
| | Female | 0.0301 | - | - | - |

## DISCUSSION

The overall seroprevalence of CBPP antibody using the SAT test in the study area was low at 2.61 % and this correlated with the findings of (Ansambou *et al*., 2018) who recorded similar low seroprevalence for CBPP in Angola, but is not in agreement with the findings of (Hussien *et al*., 2024) who reported high prevalence for CBPP in Sudan. The low seroprevalence observed in this study could be attributed to good veterinary services and management by workers at the Teaching and Research Farm. This observation agrees with (Ayinka 2020) who reported a correlation between higher healthcare and low incidence of CBPP outbreaks, implying that a higher prevalence is often due to healthcare breakdown. Furthermore, quick access to quality and well-preserved CBPP vaccines by the Ministry of Livestock and Fisheries Development, Minna, Niger State Veterinary Hospital, may also account for the low prevalence recorded in this study. This observation aligns with (Ayinka 2020) who reported a correlation between higher prevalence and vaccine source, as most CBPP vaccines were purchased from the open markets rather than the national veterinary research institute outstations within the region. The lower seroprevalence of CBPP may also be due to the strict quarantine and isolation programme carried out by skilled personnel at the Teaching and Research Farm (personal observation). Another reason may be the herd movement control, as animals are not allowed to graze with other animals which may predispose them to CBPP infection, making an outbreak unlikely in the Teaching and Research Farm. Although these observations contradict some researchers who reported higher prevalence of the disease in northern Nigeria, the reported higher prevalence reported by other authors may be due to breakdowns in management and wrong practices, such as indiscriminate antibiotic use, leading to chronic carriers of the disease and facilitating its spread to susceptible animals within the herd. In contrast, this study agrees with Olabode *et al*., 2013) and (Jasini *et al*., 2015) who reported lower CBPP prevalence rates in Kwara and Borno states, respectively.

The higher antibody titres observed in cows compared to bulls in this study, agrees with the findings of (Nwankpa *et al*., 2004: Billy 2014: Ayinka 2020), who reported that antibody titres in cows is higher than in bulls. This may be due to fewer bulls being kept in the herd; another reason could be due to female mothering and an indication of better immune response in contrast to bulls. Further analysis based on Eta value of 0.81 observed in this study, indicates a positive association for female cattle and thus, justifies that female possess better immune response to CBPP. This is in tandem with (Fink and Klein 2018) who reported better immune response for female cattle. (Klein and Flanagan 2016) also reported similar better immune responses in female cattle when compared to males. This study affirms that there is no presence of CBPP in the Teaching and Research Farm, Gidan Kwano, Minna, Niger State, Nigeria.

## CONCLUSION

This study found a low overall seroprevalence of CBPP at the Department of Animal Production Teaching and Research Farm, Gidan Kwano, Minna, Niger State, Nigeria. This was attributed to good veterinary services and management, access to quality CBPP vaccines, strict quarantine and isolation programmes, and effective herd movement control. The study also observed higher antibody titres in cows compared to bulls, and a positive association between female cattle and better immune response to CBPP. Overall, the study confirms the absence of CBPP at the farm, highlighting the importance of effective management practices in controlling the disease.

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# NUTRIENT DIGESTIBILITY OF BROILER CHICKENS FED DIET DIFFERENTLY PROCESSED DOUM PALM (*Hyphaene thebaica*) MEAL DIETS

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## ABSTRACT

The nutritional digestibility of broiler chickens fed diets supplemented with differently processed doum palm as a substitute for maize was assessed in an 8-week trial. Three dietary treatments were tested: a control diet (T1) 0% doum palm inclusion, a 10-hours soaked doum palm diet (T2) 12.5% inclusion, and an 80-minutes cooked doum palm diet (T3) 12% inclusion. A total of 117 Ross 308 broiler chicks were randomly assigned to the treatments, with each treatment consisting of 36 birds in a completely randomized design (CRD). The results showed significant differences ($p<0.05$) in nutrient digestibility during the starter phase for the soaked doum palm pulp meal (DPPM) diet, except for crude protein No significant differences ($p>0.05$) were observed during the finisher phase for any parameters. For the cooked doum palm pulp meal (DPPM) diet, significant differences in digestibility were found for dry matter, crude fiber, ash, and ether extract in the starter phase ($p<0.05$). In the finisher phase, only dry matter, ether extract, and ash showed significant differences ($p < 0.05$), while the experiment indicates that differently processed doum palm (soaked or cooked) affects nutrient digestibility in broiler chickens during the starter phase, with no significant effects observed in the finisher phase.

**Keywords:** Doum palm, Animal nutrition, Maize, Anti-nutritional factors, Nutrient digestibility.

## INTRODUCTION

The continuous rise in the cost of livestock feeds, coupled with the corresponding increase in the prices of animal products such as meat, eggs, and milk, underscores the need to explore the use of non-conventional feed ingredients in feeding domestic animals**.** **(**Alawa *et al.,* 1993; Ani *et al.,* 2007; Owen *et al.,* 2009 Owen *et al.,* 2010). A search for alternative feedstuffs that are readily available, cheap and nutritive becomes imperative in order to sustain the livestock industry particularly the fast growing and prolific monogastric species. Cereal grains especially maize which forms the bulk of energy in poultry feeds are in short supply as a result of industrial, livestock and human needs. This has resulted in competition between human and animal for available feed resources, and hence the high cost of animal production (Oluyemi *et al.,* 2000; Agbede *et al.,* 2002; Aderolu *et al.,* 2007). *Hyphaene hebaica* is commonly referred to as doum, and it is a type of palm tree with edible oval fruit which belongs to the mint family (Arecaceae). They have several vernacular names like doum palm, doom palm, gingerbread palm, zembaba, mkoma, arkobkobai and kambash Orwa *et al.,* (2009). Doum fruit (*Hyphaene thebaica*) is a good source of essential minerals such as potassium, sodium, calcium, magnesium and phosphorous. Furthermore, doum fruit has shown to provide essential B-complex vitamins, carbohydrate and fibers essential for good nutrition. Doum fruit possess good functional properties which can be used for various important applications in food industry Waleed *et al.,* (2014).

## MATERIALS AND METHODS

### Site of Experimental Study

The experiment was carried out at the Federal University of Technology Department of Animal Production, School of Agriculture and Agricultural Technology. Minna has land area of 6784 km and it is situated between latitude 9° 37 North and South equator and longitude 60 33 East with mean annual temperature of 28 - 40°C and mean annual rainfall of 1000 - 1500mm. Odegbenro *et al.,* (2022).

### Source of Experimental Material

The feed materials used in this study include maize, doum palm pulp meal, soybean meal, fishmeal, groundnut cake, maize offal, bone meal, limestone, common salt, palm oil, premix, L-lysine and Dl-methionine. All were purchased in Minna at Farida feed milling Industry, Gida Matasa, Minna Niger State. While the mature ripe doum palm (*Hyphaene thebaica*) fruits were sourced from Mashi Local Government of Katsina State.

### Experimental procedure

The experimental procedure involved two treatments for preparing doum palm (*Hyphaene thebaica*) fruits for inclusion in broiler chicken diets.

### Soaking

The matured doum palm fruits were soaked in portable tap water for 10 hours at the rate of 1 kilogram to 5 liters of water with the use of clean plastic drum at room temperature after which the water was drained and the soaked fruit mesocarps were removed with knife and air-dried at 25ºC for 72 hours the method described by Nafiseh *et al*. (2013). It was milled using 3mm hammer mill and incorporated in the broiler chickens' diets during the starter and finisher phases respectively.

### Cooking

The doum palm (*Hyphaene thebaica*) fruit were washed and poured into a pot containing boiled water at a temperature of 100ºC and cooked for 80 minutes at the rate of 1kg per 5 liters of portable water using the method described by Nafiseh *et al.* (2013). The water was drained and the cooked fruit mesocarps were removed with knife and air-dried at 25ºC for 72 hours. Sample were ground to pass through a 3 mm hammer mill and incorporated in the broiler chickens' diets during the starter and finisher phases respectively.

### Experimental diets

Three experimental broiler starter and finisher diets containing 0, 10 hours soaked and 80 minutes cooked doum palm pulp meal was formulated and designated as follows: T1, T2 and T3 respectively. T1 (Control) was 0 % of doum palm pulp meal diet, T2 was 12.5 % of 10 hours soaked doum palm pulp meal diet, T3 was 12.5 % of 80 minutes cooked doum palm pulp meal diet. Compositions of the experimental broiler starter and finisher diets are presented in Tables 1 and Table 2 respectively.

**Table 1. Ingredients (%) and calculated nutrient composition of the Experimental Broiler Starter diets**

| Ingredients (%) | T1 | T2 | T3 |
|---|---|---|---|
| Maize | 50.00 | 43.75 | 43.75 |
| Doum palm meal | 0.00 | 6.25 | 6.25 |
| Maize offal | 5.00 | 5.00 | 5.00 |
| GNC | 17.00 | 17.00 | 17.00 |
| Soya cake | 19.95 | 19.95 | 19.95 |
| Fish meal | 3.00 | 3.00 | 3.00 |
| Limestone | 1.00 | 1.00 | 1.00 |
| Bone meal | 2.00 | 2.00 | 2.00 |
| Palm oil | 1.00 | 1.00 | 1.00 |
| Common salt | 0.25 | 0.25 | 0.25 |
| *Vitamin Premix | 0.30 | 0.30 | 0.30 |
| L-lysine | 0.25 | 0.25 | 0.25 |
| Dl-methionine | 0.25 | 0.25 | 0.25 |
| **Total** | **100** | **100** | **100** |
| Calculated Nutrients | | | |
| ME(Kcal/kg) | 3131.85 | 3102.35 | 3068.43 |
| Crude protein (%) | 22.03 | 22.00 | 22.00 |
| Ether extract (%) | 7.78 | 7.79 | 7.79 |
| Crude fibre (%) | 3.69 | 4.51 | 4.51 |
| Calcium (%) | 1.34 | 1.34 | 1.34 |
| Phosphorus (%) | 0.67 | 0.72 | 0.76 |
| Lysine (%) | 1.12 | 1.12 | 1.12 |
| Methionine (%) | 0.65 | 0.65 | 0.65 |

Premix will provide the following per kilogram of feed: Vit. A, 10,000 i.u; Vit. $D_3$, 2000 i.u; Vit. E 23mg; Vit. K, 2 mg; Vit. $B_1$ (Thiamine), 1.8mg; Vit $B_2$ (Riboflavin), 5.5mg; Vit. $B_6$ (Pyridoxine), 3mg; Vit. $B_{12}$ 0.015mg; Pantothenic acid 7.5mg; Folic acid 0.75mg; Niacin 27.5mg; Biotin 0.6mg; Choline chloride 300mg; Cobalt 0.2mg; Copper 3mg; Iodine 1mg; Iron 20mg; Manganese 40mg; Selenium 0.2mg; Zinc 30mg; Antioxidant 1.25mg. ME= Metabolizable Energy.

**Table 2. Ingredients (%) and calculated nutrient composition of the Experimental broiler Finisher diets**

| Ingredients (%) | T1 | T2 | T3 |
|---|---|---|---|
| Maize | 57.00 | 49.87 | 49.87 |
| Doum palm meal | 0.00 | 7.13 | 7.13 |
| Maize offal | 5.00 | 5.00 | 5.00 |
| GNC | 15.00 | 15.00 | 15.00 |
| Soya cake | 16.00 | 16.00 | 16.00 |
| Fish meal | 2.00 | 2.00 | 2.00 |
| Limestone | 1.00 | 1.00 | 1.00 |
| Bone meal | 2.00 | 2.00 | 2.00 |
| Palm oil | 0.25 | 0.25 | 0.25 |
| Common salt | 0.25 | 0.25 | 0.25 |
| *Vitamin Premix | 0.25 | 0.25 | 0.25 |
| L-lysine | 0.25 | 0.25 | 0.25 |
| Dl-methionine | 0.25 | 0.25 | 0.25 |
| **Total** | **100** | **100** | **100** |

| | | | |
|---|---|---|---|
| Calculated Nutrients | | | |
| ME(Kcal/kg) | 3055.39 | 3018.81 | 3018.81 |
| Crude protein (%) | 20.09 | 20.08 | 20.05 |
| Ether extract (%) | 5.81 | 5.66 | 5.66 |
| Crude fibre (%) | 5.40 | 5.42 | 5.42 |
| Calcium (%) | 1.19 | 1.20 | 1.20 |
| Phosphorus (%) | 0.63 | 0.64 | 0.64 |
| Lysine (%) | 1.14 | 1.14 | 1.14 |
| Methionine (%) | 0.64 | 0.64 | 0.64 |

Premix will provide the following per kilogram of feed: Vit. A, 10,000 i.u; Vit. $D_3$, 2000 i.u; Vit. E 23mg; Vit. K, 2 mg; Vit. $B_1$ (Thiamine), 1.8mg; Vit $B_2$ (Riboflavin), 5.5mg; Vit. $B_6$ (Pyridoxine), 3mg; Vit. $B_{12}$ 0.015mg; Pantothenic acid 7.5mg; Folic acid 0.75mg; Niacin 27.5mg; Biotin 0.6mg; Choline chloride 300mg; Cobalt 0.2mg; Copper 3mg; Iodine 1mg; Iron 20mg; Manganese 40mg; Selenium 0.2mg; Zinc 30mg; Antioxidant 1.25mg. ME= Metabolisable Energy.

**Digestibility study**

Four birds from each of the six treatment groups were randomly selected and placed in metabolic cages for individual feeding and fecal collection, following Ayanwale *et al.,* (2006) method.
After a 3-day acclimatization period, total fecal collection was conducted over 4 days. Clean trays were placed under the cages to collect **faeces** which were then oven-dried at 60°C for 48 hours to constant weight. The dried fecal samples from each treatment group were bulked, ground, and analyzed for proximate compositions according to AOAC (2006) methods. The percentage digestibility of the following nutrients: dry matter, crude protein, crude fibre, ether extract, total ash and nitrogen free extract (NFE) were computed using the formula of Iyayi *et al.,* (2005), that is:

$$\text{Nutrient digestibility (\%)} = \frac{\text{Nutrient in feed ingested} - \text{Nutrient in faeces voided}}{\text{Nutrient in feed ingested}} \times 100$$

Where; Nutrient intake (g) = Dry feed intake × Nutrient in diet
Nutrient output (g) = Dry faecal output × Nutrient in faeces

**RESULTS AND DISCUSSION**

**Apparent nutrient digestibility of broiler chickens fed differently processed doum palm (*Hyphaene thebaica*) pulp meal diets at starter phase**

The results of apparent nutrient digestibility of broiler chickens fed differently processed doum palm (*Hyphaene thebaica*) pulp meal diets at starter phase are presented in Table 3. Significant ($P<0.05$) differences were observed across dietary treatments in the digestibility of dry matter, crude fiber, ash and ether extract. Broilers fed diet T3 (92.40%) exhibited significantly better dry matter digestibility than those fed diets T1 (the control diet) and T2 (91.87 and 91.80%, respectively), which had significantly similar levels of dry matter digestibility ($P>0.05$). When compared to birds fed diet T1 (81.82%), broilers fed diets containing doum palm pulp meal (T2 and T3) had considerably greater crude fiber digestibility ($P<0.05$) and similar values (89.60 and 88.88%, respectively). Ash digestibility also showed a significant trend ($P>0.05$).

Compared to birds fed diet T1 (the control diet), which had mean values of 85.21%, birds fed diets T2 and T3 (which contained doum palm pulp meal) had considerably higher and more similar values for ash digestibility (P>0.05). The dietary interventions had an impact on ether extract digestibility that was significant (p<0.05). When compared to the doum palm pulp meal diets (T2 and T3), which recorded mean values of 89.06 and 89.69%, respectively, diet T1 (the control diet) had the substantially higher value (p<0.05) of 93.28 percent. No significant differences (P > 0.05) were found in the digestibility of crude protein and nitrogen-free extract by broilers under various feeding conditions.

**Table 3. Apparent nutrient digestibility of broiler chickens fed differently processed doum palm (*Hyphaene thebaica*) pulp meal diets at starter phase**

| Parameters (%) | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| Dry matter | 91.87 | 91.80 | 92.40 | 0.028 | <.0001 |
| Crude protein | 89.07 | 85.67 | 87.90 | 1.906 | 0.2701 |
| Crude fibre | 81.82 | 89.60 | 88.88 | 0.529 | <.0001 |
| Ether extract | 93.28 | 89.06 | 89.69 | 0.625 | 0.0011 |
| Ash | 85.21 | 93.55 | 92.04 | 1.386 | 0.0021 |
| NFE | 86.25 | 82.80 | 83.48 | 1.759 | 0.1960 |

SEM= standard error of mean; P= Probability value; NFE=Nitrogen-Free Extract
abc Means on the same row with different superscripts are significantly (P<.0.05) different
$T_1$ = raw doum palm pulp meal
$T_2$= 10 hours soaked doum palm pulp meal,
$T_3$ = 80 minutes cooked doum palm pulp meal

**Apparent Nutrient Digestibility of Broiler Chickens Fed Differently Processed Doum Palm (*Hyphaene thebaica*) Pulp Meal Diets at Finisher Phase**

The results of apparent nutrients digestibility of broiler chickens fed differently processed doum palm (*Hyphaene thebaica*) pulp meal diets at finisher phase are presented in Table 4. Crude protein, crude fiber, and nitrogen free extract digestibility did not change significantly (P>0.05) among dietary treatments, however crude fiber digestibility was numerically higher in doum palm pulp meal diets (T2 and T3) with mean values of 87.53 and 86.86% respectively than diet T1 (85.42%). The digestibility of dry matter, ether extract, and ash content varied significantly (P<0.05) among treatment diets. Broilers fed diet T3 exhibited superior dry matter digestibility (92.40%) compared to those fed diets T1 (control) and T2, which had digestibility values of 91.87% and 91.80%, respectively. The digestibility of ether extract ranged from 89.06 to 93.28%. When compared to birds fed diets T2 and T3, which had similar (p>0.05) values (89.06 and 89.69%, respectively), diet T1 (the control diet) had the greatest value of ether extract digestibility (93.28%). Among dietary regimens, ash digestibility varied significantly (p<0.05). As comparison to diet T1 (85.94%), birds fed diets containing doum palm pulp meal (T2 and T3) had significantly greater percent ash digestibility (p>0.05) values (92.60 and 93.98%, respectively).

**Table 4. Apparent Nutrient Digestibility of Broiler Chickens Fed Differently Processed Doum Palm (*Hyphaene thebaica*) Pulp Meal Diets at Finisher Phase**

| Parameters (%) | T1 | T2 | T3 | SEM | P-value |
|---|---|---|---|---|---|
| Dry matter | 91.87 | 91.80 | 92.40 | 0.028 | <.0001 |
| Crude protein | 80.40 | 80.34 | 80.2400 | 0.194 | 0.7119 |
| Crude fibre | 85.42 | 87.57 | 86.86 | 1.687 | 0.4766 |
| Ether extract | 93.28 | 89.06 | 89.69 | 0.625 | 0.0011 |
| Ash | 85.94 | 92.60 | 93.98 | 1.696 | 0.0068 |
| NFE | 86.23 | 82.80 | 83.48 | 1.758 | 0.1960 |

SEM= standard error of mean; P= Probability value; NFE=Nitrogen-Free Extract
abc Means on the same row with different superscripts are significantly (P<.0.05) different
$T_1$ = raw doum palm pulp meal
$T_2$= 10 hours soaked doum palm pulp meal,
$T_3$ = 80 minutes cooked doum palm pulp meal

## CONCLUSION

Based on the research, feeding of processed doum palm meal-based diets at 6.25% and 7.13% in the starter and finisher respectively in broiler diets improved the digestibility of crude protein, crude fibre, ether extracts, nitrogen free extracts and ash with better nutrient availability without significant (P>0.05) difference in the values obtained. Broiler chicken fed differently processed doum palm shows improved nutrients digestibility, thus doum palm may proffers valuables options as alternative feed ingredient for poultry production.

## RECOMMENDATION

Based on the research, I recommend that raw and processed doum palm meal can be included in broiler diets without affecting digestibility, further research be conducted to assess its economic and production benefits in other animal classes, and it be considered as a substitute for conventional maize in broiler feed for cost-effective production.

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# PREVALENCE OF BLOOD PARASITES AMONG GOAT SOLD AT LIVESTOCK MARKETS IN NIGER STATE

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## ABSTRACT

Blood parasites, also known as haemoparasites are intracellular or intercellular microorganisms inhabiting in the blood cells of animals. They rely on the vector or carrier to transmit them to the host, it has been reported as a major constraint, causing high morbidities and mortalities and also preventing animals from expressing their full genetic potentials. The prevalence of blood parasites among goat sold at livestock markets at the three agricultural ecological zones of Niger State was determined. A total of ninety blood samples were aseptically collected from the jugular vein of goat sold at the livestock markets and were microscopically examined for the presence of haemoparasites. The laboratory results were subjected to statiscal analysis to determine the prevalence rate. The overall prevalence of haemoparasites infections was 22.2 % of all the samples examined. Five haemoparasites of goat with prevalence rates of 7.77 %, 5.55%, 3.33 %, 4.44% and 1.11 % for Microfilaria, Plasmodium, Anaplasma, Babesia and Theileria respectively were observed. Microfilaria had the highest prevalence rate (7.77 %) while Theileria had the least prevalence rate (1.11 %). The prevalence rate of the haemoparasites in relation to zones, revealed higher infection rate in Zone A (30.00%) than Zone B and C (20.00 and 16.66 %) respectively. The rate of prevalence of haemoparasites observed in this study were not significantly different (>0.05) across the three Agroecological Zones of the State. However, the result of this study indicates a prevalence of haemoparasite infections among goat sold at livestock markets in Niger state.

**Key words:** Prevalence, Haemoparasites, Goats, Parasites and Livestock markets

## INTRODUCTION

Urbanization, rising income and the increase in human population have all fueled livestock demand (including small ruminants). (Thornton, 2010). Long market chains are progressively forming in the livestock sector, which employs over 1.3 billion people globally and supports the livelihoods of 600 million poor smallholder farmers in developing nations directly. (Thornton,2010). Small ruminants play a significant role in the economies of millions of people throughout the world who make a living raising these animals in a variety of climates (Ben Salem, Silanikove *et al*., 2010; Gupta *et al*., 2013). Goat particularly in rural areas, play an important role in the survival of impoverished families (Ben Salem and Smith, 2008; Okoruwa, 2014) and are well-known for producing milk, meat, offal, skin, horn, wool dung for fire, and fibre, among other things. (Dwyer, 2009; Ben Salem, 2010). Goat also performs better than other domesticated ruminants in a variety of geographical and climatic settings, including harsh and extreme climates (Al-Haidary *et al*., 2012; Banerjee *et al*., 2014). However, one of the most important constraints of small and large scale goat production is the high prevalence of infectious diseases as well as a wide variety of parasite including blood Sucking Arthropod transmitted eukaryotic blood parasites (FAO, 2001; Bell-Sakyi *et al*., 2004). Goats can be infected with a variety of parasites in SubSaharan Africa, the most prevalent of which is gastrointestinal parasitic infection. (Ngole *et al*., 2001; Okaiyeto *et al*., 2008), as well as economically important prokaryotic and eukaryotic haemoparasites transmitted via vectors (Bell –Sakyi *et al*., 2004; Okaiyeto *et al*., 2008). Amongst the haemoparasitic infections, trypanosomosis, babesiosis and anaplasmosis are considered as major impediments to ruminant production (Marai *et al*., 2010). These diseases have been reported to cause severe destruction of red blood cells resulting in anaemia, high morbidity and mortality as well as infertility, jaundice and weight loss (Ademola and Onyiche,2013; Sharifi *et al*.,2016). Anaemia has been considered a reliable marker for the severity of haemoparasitic infection in goats (Adejinmi, *et al*., 2004). Several studies have reported the prevalence of *anaplasmosis, trypanosomosis, babesiosis* and theiler iosis from various breeds of goats in developing countries including Nigeria (Anyanwu, *et al*., 2016) but there is paucity of information about the parasites in Niger state.

## METHODOLOGY

### Study area

The experiment was conducted in the three agricultural ecological zones of Niger state (Zone A, B and C). Niger state is situated between latitude 9.6152 longitude 6.5478. The daylight temperature fluctuates between $38^0$C at the middle of wet season to over $42^0$C at the pinnacle of dry season, it has two distinct seasons; rainy season beginning between March and April and lasts till between September and October. The mean yearly precipitation is around 1200mm to 1300mm with August having the most noteworthy and dry season from November to March with the highest temperature in the month of March (Futminna students' hand book, 2019). The Zones are made up of several local government areas, Zone A include: Agaie, Bida, Edati, Gbako, Katcha, Lapai, Lavun and Mokwa local governments area. Zone B include: Bosso, Chanchaga, Gurara, Munya, Paikoro, Rafi, Shiroro, Suleja and Tafa local government areas while Zone C include: Agwara, Borgu, Kontagora, Magama, Mariga, Mashegu, Rijau, Wushishi and Zungeru local government areas.

### Experimental animal and sampling techniques

The local governments were numbered randomly and the first local government with the smallest odd number was selected from each zone (Cameroon, 1999). A total of three local government areas were selected, it includes; Bida (Zone A), Bosso (Zone B) and Zungeru (Zone c).

### Sample collection

Blood samples were collected randomly from the jugular veins of 90 apparently healthy goats of both sexes and various age groups at Baeji, Wuya and Zungeru livestock market squares in the three zones in Niger state (Bosso, Bida and Zungeru) respectively. From each sample, goat was manually restraint, 5ml of blood was aseptically collected from the jugular vein into a well labelled Ethylene Diamine Tetra Acetate (EDTA) anticoagulant bottles which were placed gently in ice pack for onward transportation to Niger State Veterinary Clinic, Bosso, Minna for analysis.

### Data analysis

The data was subjected to a variety of descriptive statistics, with the prevalence expressed as a percentage.

## RESULTS

**Table 1: Prevalence (%) of haemoparasites of goat sold at market square**

| Animal Examined | No Examined | Haemoparasite | No Positive | Prevalence (%) |
|---|---|---|---|---|
| | | *Anaplasma spp* | 3 | 3.33 |
| | | *Babesia spp* | 4 | 4.44 |
| Goat | 90 | *Microfilaria spp* | 7 | 7.77 |
| | | *Plasmodium spp* | 5 | 5.55 |
| | | *Theileria spp* | 1 | 1.11 |
| Total | 90 | | 20 | 22.2 |

Table 2.0: Prevalence of haemoparasites of goat in each zone of Niger state.

| Zone | No Examined | No Positive | Prevalence (%) |
|---|---|---|---|
| A | 30 | 9 | 30.00 |
| B | 30 | 6 | 20.00 |
| C | 30 | 5 | 16.66 |
| Total | 90 | 20 | 22.2 |

## DISCUSSION

The present study revealed 22.2% overall prevalence rate of haemoparasitic infections. Amongst the haemoparasites observed, Microfilaria had the highest prevalence rate of 7.77% followed by plasmodium with a 5.55% prevalence rate while *Anaplasma, Babesia* and *Theileria spp*. had 3.33%, 4.44% and 1.11% rate of prevalence respectively. This finding is similar to those of Jatau., *et al*., (2006) who in a similar study reported the same trend with *Anaplasma spp*. (11.34%), *Babesia spp*. (2.06%) and *Theileria spp*. (4.12%) populations from goats in Kano State. Anyanwu., *et al*. (2016) also reported a similar trend with *Anaplasma spp*. (20.70%), Babesia spp. (13.40%) and (2.81%) *Theileria spp*. from goats in Nassarawa State, Nigeria with varying prevalence rates. However, the finding of this present study contradict with those of Onaja, *et al*., (2013) and Opara., *et al*., (2016) who reported high prevalence of *Anaplasma spp*. compared to other haemoparasites genera in goats from Kano, Zaria and Lafia Nigeria respectively. Ukwueze and Kalu (2015) also reported higher prevalence of *Babesia spp*. (28.80%) against *Anaplasma spp*. (16.80%) in goats from Umuahia, Abia State, Nigeria.

The finding of *Babesia spp*. (4.44 %) and *Theileria spp*. (1.11 %) in the present study is not surprising; infections with these arthropod borne haemoparasites is likely to occur due to the grazing system practiced by the ruminant pastoralists, where the goats are usually grazed with other ruminants, which could possibly create opportunities for cross mechanical transmission of diseases amongst different species of ruminants during grazing especially where vectors such as the ticks are abundantly present. This observation buttresses similar suggestion by Useh, *et al*., (2006) who reported various species of haemoparasites in goats reared extensively in Zaria, Nigeria. From this present study, the relatively low prevalence of *Babesia spp*. could be attributed to the fact that animals that recovered from *babesiosis* become immune to re-infection (Adamu and Balarabe, 2012). Small ruminants such as the goats have been reported to be endemically unstable for *Babesia spp*. parasite (Jatau, *et al*., 2006). In this present study, trypanosomes were not recorded; this could signify absence of Glossina species in the study area. The finding of this present study is contradictory to Ohaeri (2010); Ukwueze and Kalu (2015), Josiah., *et al*., (2015) and Opara., *et al*., (2016) who have reported a low prevalence rates of 1.20, 1.60, 0.50 and 1.90% in goats from Umuahia, Abia, Kogi and Lafia in Nigeria respectively as well as Anyaebunam and Okafor (2013) who found a higher prevalence of 14.1% trypanosomes from goats in Nsukka Nigeria. None trypanosomes prevalence recorded in goats in the present study could be attributed to lower vector abundance with low infection rates in the zone as reported by Ohaeri (2005) and Ohaeri and Eluwa (2007) and Nwoha., *et al*., (2013) Moreover, small ruminants are not natural hosts for the mechanically trypanosomosis. The finding of this present study revealed a lower prevalence rates of haemoparasites in Zone C (16.66%) compared to Zones A and B (30.00 % and 20.00%) respectively. The low prevalence rates recorded in Zone C could be attributed to differences in atmospheric weather condition and lower vector abundance as reported by Ohaeri (2005) and Eluwa (2007).

## CONCLUSION

The result of this study clearly indicates the presence of haemoparasite in goat sold at livestock markets in the three agricultural ecological zones of Niger State. (Zone A had the higher prevalence rate (30.00%) followed by Zone B (20.00 %) and Zone C (16.6%) with the lowest rate. *Microfilaria spp*. had the highest prevalence rate (7.77%) with *plasmodium*, (5.55%) *Anaplasma,* (3.33%) while *Babesia* and *Theileria* (4.44% and 1.11% respectively). It revealed the existence of possible negative effect of the haemoparasites in blood of the goats infected in the study area.

## RECOMMENDATION

There is need for prevention and control programs against these parasites, which call for routine screening to reduce the pathophysiological effect of the parasites. Strategic measures should also be taken to control the vectors involved in their transmission. When these are adequately carried out it will improve the production potentials of small ruminants.

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# PREVALENCE OF HARD AND SOFT TICKS AMONG YOUNG AND ADULT CATTLE IN A RESEARCH FARM

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## ABSTRACT

Ticks attach to the skin of cattle and feed on their blood, causing direct damage and transmitting diseases with resultant economic losses. Understanding the tick type that affect cattle predominantly necessitate this study in order to know how best to minimize economic losses resulting from various tick infestation. This study investigated the prevelance of hard tick and soft tick infestation in cttle in the teaching and research farm of the federal university of technology, minna, Nigeria using a stratified random sampling procedure in a cohort. The study also evaluated tick infestation in both adult and young cattle on the farm. A total of 53 cattle were evaluated for tick infestation over a four-week period and ticks were identified using standard protocol. Data collected were analyse using descriptive statistics and t-test. The result shows that hard ticks were significantly most prevalent in cattle ($p<0.05$) with *Amblyoma* being the most prevalent spp (54%). adult cattle were most significantly infested ($p<0.05$). the study concluded that hard ticks affect cattle more than soft ticks and adult cattle were most infested. It was recommended that emphasis should be more towards ctrolling hard ticks with emphasis on diseases they transmit.

**Key words**: Cattle, Hard tick, Soft tick, Disease

## INTRODUCTION

Ruminant livestock, particularly cattle, play a critical role in Agribusiness and food security. They serve as primary source of meat, milk, leather, organic manure and source of livelihood. In many parts of the world, cattle farming serves as source of empowerment for rural and peri-urban communities (FAO, 2018). Cattle farming is central to trade, employment, and forms an integral part of Fulani culture where it is an index of wealth. However, cattle farming is threatened by diseases such as trypanosomiasis, babesiosis, anaplasmosis among other diseases which are commonly transmitted by parasites such as ticks. Ticks, are a major parasite of economic importance in cattle farming because of their direct and indirect impacts on health of cattle which could lead to death of the cattle if not controlled (Jongejan & Uilenberg, 2004). Tick control measures is related to risks associated with tick infestation in cattle farming and the indirect losses due to reduced animal performance and deaths caused by tick-borne diseases. (Walker *et al.,* 2003). It is estimated that tick-borne diseases cost the global livestock industry billions of dollars annually due to veterinary expenses, reduced productivity, and mortality (de Castro, 1997). Identification of a tick type plays a role in the choice and effectiveness of tick control measures. It also reduces the risk of the ticks developing resistance to acaricides (Abbas *et al.,* 2014).

**Tick types**

Ticks are blood-feeding arachnids that attach to the skin of cattle and feed on their blood, causing direct damage and transmitting diseases. Ticks can be divided into two main families: hard ticks (Ixodidae) and soft ticks (Argasidae). Hard ticks, such as *Rhipicephalus (Boophilus) microplus* and *Amblyomma* species, are more common in cattle and are known vectors for diseases like babesiosis and anaplasmosis (Jongejan & Uilenberg, 2004). Ticks generally attach to areas with thin skin, such as the ears, neck, and underbelly, and can cause substantial irritation and blood loss in addition to transmitting pathogens.

**Tick control**

A comprehensive understanding of the specific tick species in a given environment, their life cycles, and their interactions with both the host and the surrounding ecosystem is crucial for effective control and management of ticks. This is essential because different species of ticks have varying capacities to transmit diseases and can exhibit distinct behavioral patterns that influence their control especially in the choice of acaricide application. *Rhipicephalus (Boophilus) microplus)*, a one-host tick, is notorious for transmitting bovine *babesiosis*, while *Amblyomma* species are known vectors of heart water, a disease caused by *Ehrlichia ruminantium* (Jongejan & Uilenberg, 2004).

Significant impact of ticks on cattle farming underpins the need to study the types of ticks affecting cattle in the teaching and research farm so as to understand the best way to control them. There is often a lack of comprehensive studies focusing on the identification and characterization of tick species in specific settings, such as teaching and research farms. Most studies tend to focus on commercial or large-scale farming operations, neglecting the unique challenges faced by educational institutions. A detailed understanding of the tick species on these farms, coupled with insights into their prevalence, distribution, and resistance patterns, is necessary for implementing effective control measures that protect animal health and enhance research quality. The aim of this study is to identify and characterize the tick species affecting cattle on the teaching and research farm in Federal University of Technology, Minna, Gidan Kwano Campus, with the goal of informing and improving management strategies for tick control. To achieve this aim, the project will determine the prevalence and distribution of tick species infesting cattle on the farm.

## MATERIALS AND METHODS

**Study Area**

The study was conducted at the Teaching and Research Farm of Federal University of Technology Minna, Gidan Kwano Campus, Niger State. Geographically located within latitude 09°31' 18.2''N and longitude 6° 27' 40 'E with an elevation ranging from 230-250 m. The study area lies within the Southern guinea savanna of Nigeria. The location's climate is sub humid having a mean annual rainfall of 1338mm, dry season of about 5 months and mean temperature of about 30°C (Post Graduate School Prospectus, Federal University of Technology, Minna, 2012).

**Study Design**

A cross-sectional study design (transverse study in a cohort) was employed. The study was conducted over a period of 4 weeks, during which animals were systematically examined for the presence of ticks.

### Sampling Procedures

A stratified random sampling method was employed to select cattle for this study, ensuring that the sample represented the diversity within the herd in terms of age (adult and young). The farm's cattle population consisted of 53 cattle, including both local and cross-breed cattle, reared under a semi-intensive system. Ticks were collected from the selected cattle using manual method. The collection process was performed early in the morning when ticks are more likely to be attached to the host due to feeding habits. A systematic approach was used to ensure that ticks were collected from all parts of the animal, focusing on areas where ticks typically attach, such as the ears, neck, abdomen, and under the tail.

### Tick Identification Techniques

Visual Inspection, Morphological Examination using Walker *et al*. (2003) and Estrada-Peña *et al.* (2010) were used to ensure accurate identification of the tick species under the guide of an entomologist from the department of Animal Biology of the university.

### Data Analysis

Data were analyzed using descriptive statistics. T-test was used to compare mean tick infestation levels between young and adult cattle; hard tick and soft tick at $p < 0.05$. Effect sizes were calculated using Eta squared to assess the magnitude of differences. Analyses were performed using Microsoft Excel and statistical Package for Social Scientist software (SPSS 16.0)

## RESULTS

The result in Table 1 shows mean tick infestation for T1 was 5.50 (± 1.29), indicating a higher hard tick infestation compared to T2 which affirms the reports of Jongejan & Uilenberg (2004) which stated that hard ticks affect cattle predominantly more than soft ticks and the mean result of 3.50 (± 0.57) at $P<0.05$, suggesting a statistically significant difference between the two types of ticks. The result was further subjected to Eta ($n^2$) with a value of 0.65 indicating a large effect size. Based on the mean value obtained, the result indicates that T1 (hard tick) had a large difference when compared to T2. (soft tick)

**Table 1 Prevalence of Hard and Soft Tick in Teaching and Research Farm**

| Parameter | Treatment | Mean | Standard Deviation | P-Value | Eta-Value | Partial eta-value |
|---|---|---|---|---|---|---|
| TICK | T1 | 5.50 | 1.29 | 0.03 | 0.81 | 0.65 |
| | T2 | 3.50 | 0.57 | | | |

**T1= Hard Tick**
**T2= Soft Tick**

The prevalence of tick infestation in the cattle population was assessed in terms of the percentage of animals affected as shown in Figure 1

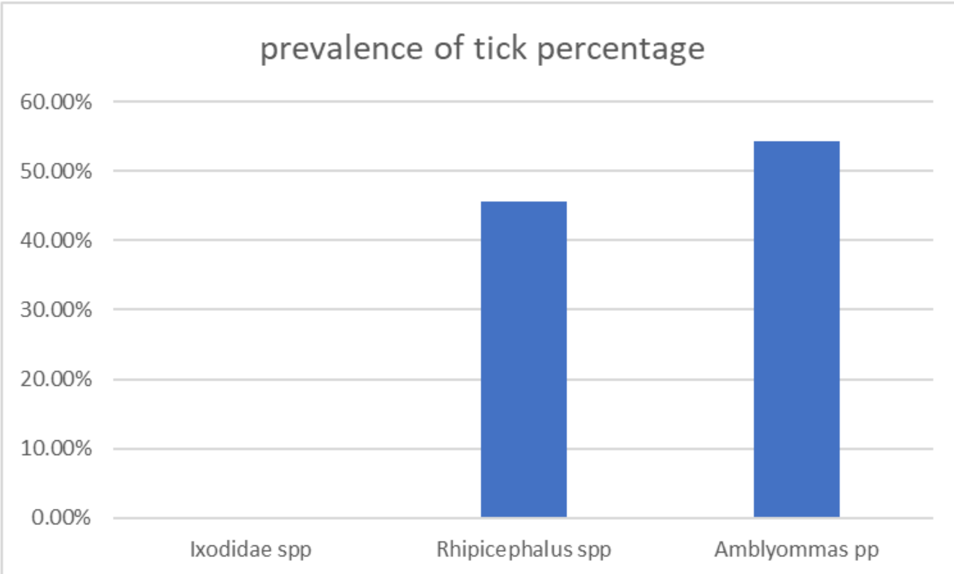


**Figure 1:** Prevalence of tick specie infestation in cattle on teaching and research farm

This result shows that 54% of the ticks was *Amblyommas spp* indicating the highest prevalence, followed by *Rhipicephalus spp* having 46% showing significantly higher prevalence and then *Ixodidae spp* having the lowest percentage.

The mean tick infestation presented in Table 2 shows that tick infestation for T1 (adult cattle) was 6.25 (± 2.06), indicating a higher infestation rate compared to T2 (young cattle), which had a mean infestation of 2.25 (± 1.29). The P-value for the comparison between T1 and T2 is $P<0.05$, suggesting a statistically significant difference in tick infestation between adult and young cattle groups. The Eta ($n^2$) of 0.73 indicates a large effect size, showing that age has a significant impact on infestation levels. Based on the mean value obtained, the result shows that T1 had a large difference when compared to T2.

**Table 2 Characterization of Tick between Adult Cattle and Young Cattle**

| Parameter | Treatment | Mean | Standard Deviation | P-Value | Eta-Value | Partial eta-value |
|---|---|---|---|---|---|---|
| Cattle | T1 | 6.25 | 2.06 | 0.02 | 0.86 | 0.73 |
| | T2 | 2.25 | 1.29 | | | |

**T1=Adult Cattle**

**T2=Young Cattle**

## DISCUSSION

This study focused on the prevalence, characterization, and impact of hard and soft tick infestations in cattle at the Teaching and Research Farm, Federal University of Technology, Minna, Niger State. The findings revealed significant differences between the types of ticks infesting cattle, with a higher prevalence of hard ticks compared to soft ticks. Furthermore, adult cattle exhibited a significantly higher tick burden than young cattle. These results align with previous studies that emphasize the predominance of hard ticks in livestock, particularly *Rhipicephalus* and *Amblyomma* species, which are known vectors for tick-borne diseases. It demonstrated that hard ticks (*Rhipicephalus spp.* and *Amblyomma spp.*) are more prevalent, with a mean infestation rate of 5.50 (± 1.29) compared to soft ticks, which had a mean rate of 3.50 (± 0.57). The P-value of 0.03 indicates a statistically significant difference between the two types of ticks, which suggests that hard ticks are more problematic for cattle on the farm. The high Eta square value (0.65) further supports this finding, indicating that hard ticks have a more substantial impact on cattle health. This is consistent with the work of Kasaija *et al.* (2021), who also reported higher infestation rates of hard ticks in cattle due to their longer feeding times and increased potential for transmitting diseases like babesiosis and anaplasmosis. Hard ticks, particularly *Rhipicephalus microplus*, have been well documented as primary vectors of cattle (Balinandi *et al.*, 2020) and this result is in line with my own study which shows hard ticks are more prevalent in cattle herds. Soft ticks, while less prevalent, are still significant due to their ability to feed on cattle intermittently, though their role in disease transmission is often considered less severe compared to hard ticks.

Table 4.2 shows that there is a prevalence of 54% *Amblyomma species* in teaching and research farm, followed by *Rhipicephalus species* at 46%, with *Ixodidae species* being. This high prevalence of *Amblyomma spp.* The study is in contrasts with earlier findings who reported that *Rhipicephalus spp are* dominated species with 56.59% and *Amblyomma species* with 43.35% of tick in his report (Eyo *et al*., 2014). This may be attributed to environmental factors, including vegetation density and humidity, which favor *Amblyomma* species. Age is an important consideration in tick infestation, with adult cattle (mean tick infestation of 6.25) being more heavily infested than young cattle (mean of 2.25). The Eta square value (0.73) suggests that age strongly influences tick burden, a finding supported by literature indicating that older cattle, due to their prolonged exposure to infested pastures, are more susceptible to tick infestation (Bianchi *et al.,* 2003). Additionally, adult cattle may have thicker skin, which facilitates tick attachment and feeding over extended periods, leading to higher tick burdens.

The high prevalence of hard ticks, especially in adult cattle, has serious implications for cattle health. Hard ticks, especially *Rhipicephalus microplus*, are known vectors of tick-borne diseases (TBDs) such as babesiosis and anaplasmosis. The heavy tick burden observed in adult cattle could lead to decreased productivity due to weight loss, anemia, and reduced milk yield. This high infestation of adult tick in this study aligns with the findings of Girma *et al.,* (2024). Who also reported similar high infestation in his studies, he further reported that adult ticks' ability to feed for long periods, leading to more severe health impacts compared to soft ticks, which feed for shorter durations.

## CONCLUSION

This study concludes that hard ticks, particularly *Rhipicephalus spp.* and *Amblyomma spp.*, are more prevalent in cattle at the Teaching and Research Farm compared to soft ticks.

## RECOMMENDATIONS

Based on the findings of this study, recommendations are made to manage and control tick (especially hard ticks) infestations in cattle. An integrated approach combining chemical acaricides with biological control methods should be implemented to manage the high prevalence of hard ticks. Also, frequent monitoring of tick populations should be conducted to detect changes in tick prevalence and species distribution, particularly for *Amblyomma spp.*, which had the highest prevalence in this study. Early detection of infestations can lead to timely intervention and prevent the spread of babesiosis and anaplasmosis. The study highlights the need for more effective tick control strategies to reduce the tick burden and prevent the spread of babesiosis and anaplasmosis.

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# NUTRITIONAL PROFILE OF COMMONLY CONSUMED INSECTS IN BIDA, NIGERIA

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## ABSTRACT

This study investigates the nutritional composition of three edible insects commonly consumed in Bida, Niger State, Nigeria: Shea butter caterpillar (Cirinabutyrospermi.), locusts (Schistocerca spp.), and termites (Macrotermesbellicosus). These insects are traditionally harvested and consumed as part of local diets and offer a potentially valuable source of nutrition. Insects were purchased from local markets and processed into powder. The proximate composition, mineral content and amino acid profiles were analyzed using standard methods. The results showed that all three insect species are rich in protein, with shea butter caterpillars, locusts and termites containing approximately 58g, 43g, and 65g of protein per 100g of dry weight, respectively. They also provided significant amounts of essential amino acids, such as leucine, lysine, and valine. The insects were high in fat content, particularly termites, which contained up to 38g of fat per 100g. Additionally, these insects are rich sources of iron, zinc, and calcium, which are vital for human health, particularly in regions facing micronutrient deficiencies. They offer sustainable food alternatives that enhance dietary diversity and have the potential to mitigate malnutrition. in resource-constrained environments, exemplified by Niger State, Nigeria.

**Keywords**: Edible insects, shea butter caterpillar, locusts, termites, food security, sustainable protein.

## INTRODUCTION

Edible insects have been an integral part of traditional diets in various parts of the world, particularly in Africa, where they serve as a vital source of nutrition and a sustainable food option (Cunha, Andrade, Ruivo and Pinto 2023; Ibitoye, Ebenebe, Oyediji, & Amobi 2021). In many rural communities, including those in Nigeria, insects are valued not only for their cultural significance but also for their high nutritional content, providing essential proteins, fats, and micronutrients (FAO, 2013; Oibiokpa, Akanya, Jigam & Saidu, 2017; Ibitoye, Ebenebe, Oyediji, & Amobi 2021; Okweche, Eyo, & Effa, 2022). They are a good source of bioactive compounds and have anti-inflammatory properties, they also contain unsaturated essential ω-3 and ω-6 fatty acids (Quah, Tong, Bojarska, Giller, Tan, Ziora, Esatbeyoglu, and Chai, 2023; Costa-Estrada, Reyes, Rosell, Rodrigo, Ibarra-Herrera 2021). The consumption of insects, often called entomophagy, has gained global attention as a potential solution to food insecurity and environmental sustainability (Van Huis et al., 2013; Cunha, Andrade, Ruivo and Pinto 2023).

In Bida, Niger State, Nigeria, edible insects such as shea butter caterpillar (*Cirinabutyrospermi*.), locusts (Schistocerca spp.), and termites (*Macrotermesbellicosus*) are commonly consumed, particularly during their peak seasons. These insects provide a cost-effective and accessible

source of nutrition, especially in areas where alternative protein sources such as meat and fish are limited or expensive (Kim *et al.* 2019; Ancha, Ikyaagba, & Kaor, 2021). Local communities harvest and prepare these insects in various ways, incorporating them into their daily diets to meet their nutritional needs (Ibitoye et al 2021; Aigbedion-Atalor *et al*. 2024). Studies have shown that edible insects are rich in high-quality protein, healthy fats, and essential micronutrients such as iron, zinc, and calcium, making them an important part of traditional diets (Rumpole& Schlüter 2013; Aigbedion-Atalor *et al.* 2024; Cunha *et al.* 2023).
The high protein, fat, and micronutrient content of shea butter caterpilar, winged termites, and locust underscore their importance as a sustainable and nutritious food source in Bida and the broader region. In areas where conventional protein sources such as meat and fish are expensive or scarce, these insects provide an affordable and culturally accepted alternative. Their nutritional value positions them as a potential tool for addressing malnutrition and micronutrient deficiencies in Nigeria and other parts of West Africa.

Similarly, studies across West Africa have demonstrated the critical role of edible insects in traditional diets and their potential for improving food security. For instance, Niaba *et al.* (2012), Oibiokpa *et al.* (2019), Ancha *et al.* (2021) and Okweche *et al.* (2022) found that insects consumed in Côte d'Ivoire and Nigeria respectively provided essential nutrients, particularly during the lean season and among the poor households when other protein sources were unavailable or unaffordable. The growing recognition of edible insects as a sustainable food source has led to increased research into their nutritional composition and potential role in combating malnutrition (Kim et al., 2019; Food and Agriculture Organization of the United Nations, 2013; Korean Society for Food Science of Animal Resources, 2020). This work focused on the nutritional profiles of three insects (shea butter caterpillar, winged termites and locusts) commonly consumed in Bida. Hence, this study would contribute to the broader discourse on the nutritional value of edible insects and their potential to enhance food security and dietary diversity in Nigeria and beyond.

## MATERIALS AND METHODS

### Study Area

The research was conducted in Bida, Niger State, Nigeria, a region known for the traditional consumption of edible insects such as Shea butter caterpillar (*Cirinabutyrospermi.),* locusts (*Schistocerca spp.),* termites (*Macrotermesbellicosus*). Locusts and shea butter caterpillars are collected during the dry season, and termites are harvested after the first rains. The laboratory analysis was carried out at the International Institute of Tropical Agriculture (IITA) central laboratory, Ibadan, Oyo State and the Science Laboratory Technology (SLT) Department, Federal Polytechnic Bida, Niger State.

Raw material procurement and handling

Insects were purchased from Old Market in Bida. Extraneous particles were removed by winnowing and sorting, followed by wet-cleaning to remove adhering debris and draining and sun-drying for 72 hours.

**Sample Preparation**

The dried insect samples were processed by further drying to constant moisture and then reduced to a fine powder using a Kenwood stainless warring blender. The powdered samples were stored in airtight containers at room temperature until they were analyzed.

**Proximate Composition Analysis**

The proximate composition of the powdered samples was determined according to standard methods as outlined by AOAC (2005) Essentially, the moisture content was determined by oven-drying the samples at 105°C until a constant weight was obtained and the crude protein was measured using the Kjeldahl method. The nitrogen content of the samples was converted to protein by multiplying with a conversion factor of 6.25. The crude fat was determined using the Soxhlet method, while ash content was determined using the principle of ashing at 550°C until a constant weight was obtained, and the acid-base digestion method was employed for the crude fibre determination. The carbohydrates was calculated by difference (CbD) (AOAC 2000).

Total Carbohydrate by difference (g/100g) = 100- (Protein (%) + Moisture (%) + Ash (%) + Fat (%)).

**Mineral Content Analysis:**

The mineral content was determined according to standard methods as outlined by AOAC (2005). The mineral content of the insect powder samples was analyzed using an atomic absorption spectrophotometer (AAS). The powdered samples were digested in a mixture of concentrated nitric acid and perchloric acid. The digest was then analyzed for iron, zinc, calcium, magnesium, and phosphorus. The AAS was calibrated with standard solutions of known mineral concentrations.

**Amino Acid Profiling:**

The Amino Acid profile was determined according to standard methods as outlined by AOAC (2005). Amino acid analysis was performed using high-performance liquid chromatography (HPLC), following acid hydrolysis of the insect proteins. The samples were hydrolyzed with 6N hydrochloric acid (HCl) at 110°C for 24 hours. After hydrolysis, amino acids were separated and quantified using a pre-column derivatization method with o-phthaldialdehyde (OPA) for fluorescence detection.

**Statistical Analysis**

All experiments were conducted in triplicate, and data were presented as mean ± standard deviation (SD). Statistical analysis was performed using SPSS version 22. Analysis of variance (ANOVA) was used to compare means between powder samples-at $p < 0.05$significance level.

## RESULTS AND DISCUSSION

### Nutritional composition of the edible insect

The proximate and mineral composition of the three edible insect species; Shea butter caterpillar (*Cirinabutyrospermi*.), locusts (*Schistocerca spp.),* and termites (*Macrotermesbellicosus*), is detailed in Table 1. The results revealed distinct differences and high composition of protein, fats, and essential minerals that could support their role as an important dietary resource in the region as indicatd by Nowakowski, Miller, Miller, Xiao, and Wu (2022). The results are consistent with the findings of Mishyna & Glumac (2021), Ancha, *et al.* 2021; Ibitoye *et al.* 2021 and Cunha, Andrade, Ruivo and Pinto (2023) which reported that edible insects are high in protein, fat and other essential nutrients, thus highlighting their potential to address food insecurity and malnutrition due to their nutrient density. The protein content of the studied insects were notably high, with values ranging from 43.54-65.75g per 100g of dry weight across the species which is similar to the findings of Oibiokpa *et al.* (2017) and Adepoju *et al.* (2014) who reported high protein content ranging from 43.8 to 71.0 % and (36.7g/100g) respectively. Shea butter caterpillar and locusts, in particular, demonstrated protein levels comparable to those reported by Stull, Finer, Bergmans, Febvre, Longhurst, Manter, Patz, & Weir (2019). Similarly, Banjo *et al.* (2006) and Aigbedion-Atalor, *et al.* (2024) found that locusts, shear butter caterpillar and termites which are commonly consumed in Nigeria contained between 50-65g of protein per 100g of dry weight, similar to the values found in this study. Winged termites also presented significant protein levels, aligning with reports of 38-45g/100g crude protein for winged termites in Nigeria (Fasoranti and Ajiboye 1993; Aigbedion-Atalor, *et al*. 2024). These findings suggest that edible insects can serve as a viable alternative to conventional animal proteins, especially in regions where access to meat and fish is limited.

**Table 1: Proximate and Mineral Composition of Edible Insects**

| g/100g | SBC | WT | Lc |
|---|---|---|---|
| Crude protein | 58.92±0.13 | 43.54±0.09 | 65.75±0.46 |
| Crude fat | 21.57±0.71 | 38.86±1.00 | 13.90±0.40 |
| Ash | 4.21±0.09 | 3.82±0.14 | 3.70±0.05 |
| Carbohydrates | 11.67±0.5 | 4.10±1.6 | 5.16±0.65 |
| Fibre | 5.53±0.09 | 5.28±0.28 | 3.24±0.06 |
| Moisture | 4.40±0.5 | 4.35±0.5 | 4.45±0.4 |
| **Mineral Composition (mg/100g)** | | | |
| Iron | 40 | 20 | 11 |
| Zinc | 11 | 8.8 | 6.8 |
| Calcium | 48 | 40 | 30 |
| Magnesium | 50 | 60 | 45 |
| Phosphorus | 110 | 100 | 95 |

SBC=Sheabutter caterpillar powder
WT=Winged termite powder
Lc=Locust powder

The fat content in the insects studied was particularly high in winged termites, with levels reaching 38.85g per 100g making them an excellent source of energy and unsaturated fatty acid. This is consistent with studies conducted by Ayieko et al. (2012), who reported similarly high fat levels (14.3- 30.4%) in termites consumed in Kenya and across West Africa. Termites are known to have high levels of polyunsaturated fats, which are beneficial for heart health, making them a valuable food source in regions where dietary fats are lacking. Locusts contained moderate amounts of fat (13.90±0.40 g/ 100g) primarily composed of unsaturated fatty acids. These findings are in line with research conducted by Rumpold and Schlüter (2013) which ranged between 10-30 g/ 100g. However, Rumpold and Schlüter (2013) and da Silva Lucas, de Oliveira, da Rocha, & Prentice (2019) emphasized on the beneficial fat composition of edible insects since they contain more unsaturated fatty acids than other animal sources. The moderate fat content, coupled with their high protein value, makes locusts and crickets nutritionally well-balanced and ideal for addressing both energy and protein deficiencies. Compared to beef and pork, insects have been reported to be rich in unsaturated fatty acid, which is about 75% of total fatty acid content. The fibre and carbohydrate contents ranged from (3.24 – 5.53 and 5.16-11.67) respectively in the selected insects which is consistent with the findings of Okweche *et al.* (2022) who reported that crickets contain a significantly higher level of crude fiber which is significant compared to conventional Nigerian meat sources, such as fish, chicken, beef, and goat (Lange & Nakamura, 2023). Similarly, Aigbedion-Atalor, *et al.* (2024) showed a similar trend in the fibre and carbohydrate content of crickets (15 g/100g and 15.1 g/100g respectively) while the fibre content of winged termites was 5.5 g/100g. Edible insects are also an important source of dietary fibre, since the exoskeleton of many insects consists of chitin (Lange & Nakamura, 2023). The proximate content of these selected insects indicated that they could contribute to the realization of the first three UN SDGs -zero poverty, zero hunger, and good health and well-being. Hence, Edible insects are good source of food bioactives, such as minerals, polyunsaturated fatty acids and fibre, and may be able to provide a wide range of food supplements and functional food (Lange & Nakamura, 2023).

The mineral analysis showed that the studied insects are rich in essential minerals such as iron, zinc, and calcium, which are often lacking in many rural diets in Nigeria and West Africa. Iron content was particularly high in shea butter caterpillar and winged termites, ranging from 20-40 mg per 100g, which is consistent with values reported by Omotoso (2006) (18.9-22.5 mg/100g) which is higher higher than the values obtained in beef, chicken and fish (Adepoju & Omotayo 2014; Lange & Nakamura, 2023). However, Adepoju & Omotayo (2014) in similar study on the nutritional composition of termites in southwestern Nigeria reported a lower range (0.84-1.42 mg/100g). The high levels of iron are critical for preventing anemia, especially in women and children, who are often at risk of iron deficiency in these regions. since it is above the recommended dietary allowance (RDA) for women and children (8-27mg/day) for both adults and children (National Academies of Science 2019). Similarly, the zinc content ranged between 6.8 – 11 mg with shea butter caterpillar having the highest and locust the lowest, these values are within the RDA (3-14 mg/day) (National Academies of Science 2001). The mineral content in the selected insects could help in reinforcing their role in supporting immune function and overall health. For example, zinc is essential for growth, cell replication, fertility and reproduction, and hormonal activities. zinc deficiency is a common issue in sub-Saharan Africa, and the inclusion of these insects in the diet could help mitigate this problem, as suggested by Womeni *et al.* (2009) and Adepoju *et al.,* (2014) in Cameroon and Nigeria respectively, who found comparable levels of zinc in local edible insects. Similary studies by Oibiokpa *et al.* (2017); Ibitoye *et al.* (2021); Okweche *et al.* (2022) and Aigbedion-Atalor *et al.* (2024) also corroborated the high mineral content present in edible insects and their potential in solving micronutrient deficiency in Africa.

Calcium levels in the study were also noteworthy, ranging from 30-48 mg per 100g, making these insects valuable for bone health. This finding is consistent with that of i Bukkens (2005)**;** Oibiokpa *et al.* (2017) and Aigbedion-Atalor *et al.* (2024) who reported high calcium levels in winged termites compared to chicken, pork, and beef.

**Amino acid profile of the Edible Insects**

The amino acid profile of the edible insects consumed in Bida is as illustrated in Table 2.

**Table 2: Amino acid profile of the edible Insects**

| **EAA (mg/100g dry weight)** | **SBS** | **WT** | **Lc** |
|---|---|---|---|
| Leucine | 7.2 | 6.6 | 6.9 |
| Isoleucine | 4.5 | 4.3 | 4.6 |
| Lysine | 5.8 | 5.3 | 6.1 |
| Methionine | 1.4 | 1.5 | 1.3 |
| Phenylalanine | 4.6 | 4.3 | 4.1 |
| Threonine | 4 | 3.4 | 3.3 |
| Tryptophan | 1 | 1.4 | 1.2 |
| Valine | 4.7 | 4.4 | 4.2 |
| Histidine | 2 | 1.3 | 1.6 |
| **TEAA** | **38.2** | **32.5** | **33.3** |
| | | | |
| **NEAA** | | | |
| Alanine | 4.8 | 4.5 | 4.7 |
| Arginine | 6.3 | 5.6 | 5.2 |
| Aspartic acid | 8.8 | 7.3 | 8.2 |
| Glutamic acid | 11.8 | 11.2 | 11.5 |
| Glutamine | 5.7 | 4.5 | 5.2 |
| Proline | 4.2 | 3.5 | 3.8 |
| Serine | 4.3 | 3.9 | 3.9 |
| Tyrosine | 2.9 | 2.7 | 2.8 |
| **TNEAA** | **48.8** | **43.2** | **45.3** |

EAA=Essential amino acids, NEAA=Non Essential amino acids, TEAA=Total Essential amino acids, TNEAA= Total Non-Essential amino acids, SBC=Sheabutter caterpillar powder
WT=Winged termite powder
Lc=Locust powder

The presence of essential amino acids further underscores the suitability of these insects as a protein source. This is in tandem with the study on the amino acid profiles of edible insects in West Africa (Ekpo & Onigbinde, 2007; Oibiokpa *et al.* 2017; Stull *et al.* 2019). Similarly, Okweche *et al.* (2022) and Adepoju *et al.* (2014) reported that African crickets and termites are rich in essential amino acids. Edible insects contain all essential amino acids necessary for human growth and maintenance and is considered to be of high quality compared to animal sources (Oibiokpa *et al.* 2017; Stull *et al.* 2019; Ibitoye *et al.* 2021; Okweche *et al.* 2022; Cunha *et al.* 2023; Lange & Nakamura, 2023).

## CONCLUSION

In conclusion, this study reaffirms the significant nutritional contributions of shea butter caterpillar, winged termites, and locusts consumed in Bida, Niger State, Nigeria. These insects' high protein, fat, and mineral content make them a valuable addition to local diets and a promising solution to addressing nutritional challenges in the region. The study-further highlights the role of edible insects in enhancing food security and improving dietary diversity. Given the increasing global demand for sustainable food sources, promoting the consumption of edible insects could play a crucial role in achieving food security in Nigeria and beyond.

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# IMPACT ASSESSMENT OF VALUE ADDITION IN FISH PRODUCTION IN IBEJU-LEKKI LOCAL GOVERNMENT AREA OF LAGOS STATE, NIGERIA

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## ABSTRACT

This research investigates the impact of value addition in fish production within the Ibeju-Lekki Local Government Area of Lagos State, Nigeria. Given the region's significant potential for aquaculture and fisheries, enhancing value addition practices is critical for improving the livelihoods of local fish producers and ensuring sustainable development. The study's primary objectives are threefold: first, to describe the socio-economic characteristics of respondents in the study area; second, to assess the factors influencing value addition in fish production; and third, to identify the constraints faced by producers in implementing value addition strategies. To achieve these objectives, a structured questionnaire was administered to a representative sample of fish producers in Ibeju-Lekki. Descriptive statistics were employed to analyze the socio-economic data, while quantitative methods were used to explore the challenges and opportunities related to value addition. The findings reveal that the majority of respondents are engaged in small-scale fish production, with varying educational backgrounds and income levels. The result shows that people involved in fish production in Ibeju Lekki Local Government Area of Lagos State are mostly mature people within the age of 40-45 years(25%), followed by youth within the age of 28-33 years (21.25%) followed by those above the age of 46 years (18.75%) .Young adults within the age of 34-39 years were (15%), followed by younger youths of age 22-27 years (15%) and ordinary school boys and girls that helped their parents within the age range of 16-21 years (5%). Key factors affecting value addition include access to technology, market demand, and training opportunities, which significantly impact production efficiency and profitability. Moreover, the study highlights several constraints to value addition, including inadequate infrastructure, limited access to financial resources, and a lack of awareness regarding modern processing techniques. These constraints hinder the ability of producers to fully leverage the potential benefits of value addition. The research concludes that targeted interventions, such as policy support, training programs, and infrastructure development, are essential for enhancing value addition in fish production, ultimately contributing to the economic empowerment of local communities in Ibeju-Lekki. This study provides valuable insights for stakeholders aiming to improve the fish production sector in Nigeria and suggests pathways for sustainable development in aquaculture.

**Key words:** Value addition, Fisheries, Assessment, Production and Constraint

## INTRODUCTION

Fish is a cold blooded aquatic organism that breaths with gills and swims with fins. It is often referred to as "Rice Food for Poor People" as it provides essential nourishment with both macro nutrients and micro nutrients. In addition, fish contain low fat high quality protein with omega - 3 fatty acids and vitamins. According to World Fish Center (2005), fish comprises of a nutritionally important part of many people's diet in the developing countries even when consumed in small quantity, it is therefore an indispensable source of iron, zinc, magnesium, phosphorus, calcium, vitamin A & C and iodine. These nutrients are contained in low value fish which are largely consumed by the poor rural people than large volume of meat. The fatty acid is essential for the development of brain and body, Torpy *et al,* 2006), and are particularly crucial for the diet of babies, children, pregnant and lactating women. Global demand for dietary fish protein is increasing which has resulted in widespread overfishing in the wild fisheries, resulting in significant decrease in fish stocks and even complete depletion in some regions. However, Naylor, *et al* (2000), states that fish need to grow on freshwater or saltwater as habitat and natural food for consumption.

FAO, (2016) describes fish production as a form of aquaculture which involves the process of cultivating and domestication of a variety of fish species. In early days' fish production consisted of only capturing from fresh water, nowadays pisciculture or fish farming is a more popular and widely used method of fish production. Furthermore, this practice allows feeding, breeding, growing and harvesting of fish in a well-planned manner. A wide range of fish farming does exist including growing of fish in earthen ponds, concrete tanks, cages, pens or run - ways (Swift,2017). According to Plumb (1999), states that there are several methods of successful production of fish practiced but the popular and simple technique is the earthen pond which is the basic unit of fish farming worldwide and it is dependent on natural production of fish feed.

Fish production has not been fully explored as a strategy to reduce poverty levels despite its potential to improve livelihood in rural communities (Kudi *et al*, 2008). Low productivity, prohibitive establishment costs, high farm level losses and inefficient marketing often pose a problem. The low level of productivity results from lack of appropriate production knowledge and skills, sub-optimal stocking or overstocking, poor fish population control methods and inadequate feeding due to costly feeds. However, there are complications that have arisen from high capital requirements for establishing a fish farm, especially for excavation, stocking of fingerlings and installation of protective chain link, inefficient marketing results from lack of producers' ability to integrate production and marketing activities. It is therefore imperative that youth and fish producers are supported to initiate fish production using the fish farm approach through provision of start-up and other technical inputs for developing business plans. (MacLennan, 1995). Furthermore, value addition in fish production is the process of enhancing the value of fish and fish products through various methods. It involves transforming raw or unprocessed fish into higher value products that cater to specific market demands and also allows for diversification and the creation of new market opportunities. Kim and Lalancette (2013), describe value addition as product enhancement resulting from growing in ability, skills, knowledge plus other qualities the staffs have added from practice in their respective field over time. In this value addition would refer to the processing and packaging of fishery resources in order to reduce waste and hence increase final value above its initial value or raw form (IBF, 2022). Also, value addition is the talked about word in food processing industry particularly in export oriented fish processing industry because of the increased realization of valuable foreign exchange.

Value can be added to fish and fishery products according to the requirements of different markets. These products range from live fish and shellfish to ready to serve convenience products. As far as value addition is concerned, it is one of the possible approach to raise profitability since processing industry is highly competitive and increasingly expensive. Kyle et *al*, 2014), also added that it is an essential strategy that enhances economic value of fish, broadens the market performance and decreases the problem of post-harvest losses. It has a particular importance in that it offers a strategy for transforming an unprofitable enterprise into a profitable one because of the potential that it offers. In all this there are certain challenges faced in this industry like lack of credit facilities, inadequate knowledge of value addition, no training facilities, lack of equipment, lack of market and contacting extension agents (Priyaa, & R. Bharathi, 2003). The objectives of the study include to: describe the socio - economic characteristics of the respondent in the study area, assess the factors of affecting value addition in fish production in the study area and to describe the constraints of value addition in fish production in the study area.

## METHODOLOGY

The study area is Ibeju-lekki was located at approximately latitude 4015'north and 4017' north and longitude 13015'east and 13020' east along the coastal plain of Nigeria, has many creeks and lagoons and its mainly populated by Ijebu speaking people of the Yoruba tribe in Nigeria. It is bounded in the north by Ogun state and in the west by Eti-Osa local government and also in the east by Epe local government and its southern ends join it to the Atlantic Ocean. Ibeju-lekki has a tropical savanna climate with distinct wet and dry seasons but with double rainfall pattern which makes the environment a wetland region. The town is significantly into fishing activities which makes it a perfect location for studying impact assessment of value addition in fish production. The LGA has a population of over 140,000 people and is one of the fastest-growing areas in Lagos State. The name, Ibeju-lekki is derived from the names of two autonomous communities, namely Ibeju-Agbe and Lekki. A Simple random sampling technique was used to administer structured questionnaire to the respondents. A total of 80 questionnaires was administered to the respondents in the study area. Quantitative data analysis method was used for the research variable. Descriptive statistical analysis was employed to analyze the collected data. This includes chi square, frequency distributions, percentages, average (mean), and measures of central tendency.

## RESULTS AND DISCUSSION

The result in Table 1 shows the age distribution of fish marketers in the study area. The result shows that people involved in fish production in Ibeju Lekki Local Government Area of Lagos State are mostly mature people within the age of 40-45 years (25%), followed by youth within the age of 28-33 years (21.25%) followed by those above the age of 46 years (18.75%). Young adults within the age of 34-39 years were (15%), followed by younger youths of age 22-27 years (15%) and ordinary school boys and girls that helped their parents within the age range of 16-21 years (5%). The result also shows that most of the fish producers are married people with 71.25% of the respondents married, 22.5% of the fish producers are single.

**Table 1 Distribution of the demographic profile**

| | Categories | Frequency | Percentage |
|---|---|---|---|
| A | Marital Status | | |
| | **Single** | **18** | **22.5** |
| | **Married** | **57** | **71.25** |
| | **Widow** | **05** | **6.25** |
| **B** | Age | | |
| | **< 5** | **0** | **0** |
| | **16 -21** | **04** | **05** |
| | **22-27** | **12** | **15** |
| | **28-33** | **17** | **21.25** |
| | **34-39** | **12** | **15** |
| | **40-45** | **20** | **25** |
| | **46 and above** | **15** | **18.25** |
| **D** | Gender | | |
| | Male | **48** | **60** |
| | Female | **32** | **40** |
| **E** | Occupation | | |
| | Civil servant | **3** | **3.75** |
| | Trader | **53** | **66.25** |
| | Private sector | **24** | **30.0** |
| **F** | **Educational Status** | | |
| | No formal education | **5** | **6.25** |
| | Primary school certificate | **16** | **20.0** |
| | Secondary school certificate | **51** | **63.75** |
| | Tertiary | **08** | **10.0** |

**Field survey, 2024**

While 6.25% of the fish producers in the study area widowed. The result in Table 1 shows that fish production business is mainly control by male gender where 60% of the 80 respondents used for the research are male, while 40% are female. This shows that fish producers in Ibeju - Lekki are mostly male with very few female counterparts. The results also show that a higher percentage of the fish producers (63%) obtained secondary education. 20% of the people involved in fish production in the study area obtained primary education. 10% of have possess tertiary education. While 6.25% of fish producers in the study area have no formal education. The results further show that 66.25% of the respondents are traders, 30% of respondents are work in the private sector. While 3.75% of fish the respondents are civil servants and engage in fish marketing as a secondary source of income.

**TABLE 2 Distribution of Respondents according to factors affecting Production**

| FACTORS AFFECTING FISH PROUCTION | FREQUENCY | PERCENTAGE (%) |
|---|---|---|
| Lack of electricity | 42 | 26.1 |
| Shortage of water supply | 0 | 0 |
| Lack of storage device | 26 | 16.1 |
| Lack of good packaging material | 23 | 14.3 |
| Lack of basic infrastructure | 57 | 35.4 |
| Low level of education | 13 | 8.1 |
| Total | 161 | 100 |

**Source:** Field survey 2024

The data collected shows that lack of basic infrastructure is the most serious factor affecting fish marketing in the study area as indicated by 35.4%. Lack of electricity is also another factor affecting fish marketers in the area as indicated by 26.1% of the respondents. Due to the perishable nature of the fish, electricity is highly needed for preserving fresh fish, which is in high demand in the area. 16.1% identified lack of good storage device as a factor affecting fish production in the study area. 14.3% fish marketing in the study area. 8.1% of the respondents identified low level of education as a factor affecting fish production in the study area. None of the respondent identified shortage of water as a factor affecting fish production in the study area.

## CONCLUSION

The impact assessment of value addition in fish production in the Ibeju-Lekki Local Government Area of Lagos State reveals critical insights into the socio-economic landscape of local fish producers and the operational dynamics of the fish production sector. The study's findings indicate that fish producers exhibit diverse socio-economic characteristics, including varying levels of education, income, and access to resources, which significantly influence their production practices and capacity for value addition. Additionally, several key factors affect the level of value addition in fish production, including access to technology, market demand, and training opportunities. Producers who leverage modern processing techniques and have a better understanding of market trends tend to achieve higher profitability and product quality. However, the study also identified significant constraints that hinder effective value addition, such as inadequate infrastructure, limited access to financial resources, and a lack of awareness regarding best practices in fish processing and marketing. Overall, while there is substantial potential for enhancing value addition in fish production in Ibeju-Lekki, the existing challenges must be addressed to fully realize these opportunities and improve the livelihoods of local fish producers.

## RECOMMENDATIONS

To enhance value addition in fish production in Ibeju-Lekki, the following recommendations are proposed:

1. Capacity Building and Training Programs: Implement targeted training initiatives for fish producers on modern processing techniques, quality control, and marketing strategies. These

programs should focus on equipping producers with the skills necessary to enhance product quality and increase market competitiveness.

2. Infrastructure Development: Advocate for the improvement of infrastructure critical to fish production, including access to reliable processing facilities and cold storage systems. Investments in infrastructure will help reduce post-harvest losses and improve the overall quality of fish products in the market.

3. Access to Financial Services: Facilitate partnerships with financial institutions to provide accessible credit and micro-financing options for fish producers. Financial support is essential for enabling producers to invest in better equipment and expand their operations.

4. Promotion of Technology Adoption: Encourage the adoption of modern technologies in fish production and processing. This can include providing access to information on innovative practices and facilitating partnerships with organizations that offer technological support.

5. Market Research and Development: Conduct market research to identify consumer preferences and trends. This information can guide producers in tailoring their products to meet market demands, thereby enhancing sales and profitability.

6. Policy Advocacy and Support: Engage with local government and policy-makers to create supportive policies that promote value addition in fish production. This includes advocating for incentives for producers who adopt sustainable practices and invest in value-added processing.

7. Awareness Campaigns: Launch campaigns to raise awareness among fish producers about the benefits of value addition and best practices in fish production. Increased knowledge can empower producers to make informed decisions that enhance their productivity and profitability.

By implementing these recommendations, stakeholders can significantly improve the socio-economic conditions of fish producers in Ibeju-Lekki, fostering a more sustainable and productive fish production sector. These efforts will not only enhance individual livelihoods but also contribute to the overall economic development of the region, promoting food security and sustainable practices in the aquaculture industry.

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# ASSESSMENT OF FEEDING PRACTICES AND NUTRITIONAL STATUS OF UNDER FIVE CHILDREN IN DOKO, NIGER STATE

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## ABSTRACT

The study assessed the nutritional status and the feeding practices of under five children, using a descriptive and cross sectional study design. Data was collected using a well-structured questionnaire administered to 103 respondents in primary health care centers in Doko- lavun local government Area in Niger state. Data was analyzed using frequency and percentage while Person's correlation was used to find association between socio economic status of mothers/caregivers and nutritional status of the children. Results of feeding practices showed that majority (78.6%) of the children had colostrums given at birth, 21.4% had no colostrums given. Exclusive breastfeeding practice showed that more than half (62.1%)of the children were exclusively breastfeed while 37.5% had no exclusive breastfeeding. Approximately half (50.5%) of the respondents stopped breastfeeding their children between the age of 23-26 months. The nutritional status of the respondents showed that 61.2% had normal weight-for-age Z scores. Person's correlation showed weak negative association between educational level and method of feeding (r=-0.126). This research recommends continuous and increased awareness on the importance of exclusive breast feeding as recommended by WHO to prevent futher incidence of malnutrition.

**Keywords:** Assessment, Under-five children, Nutritional Status and Feeding Practice

## INTRODUCTION

Adequate nutrition in early childhood is crucial to the development of the child to full human capacity. The period from birth to two years of age is a "critical stage" for promotion of optimal growth, health and other physical development (Weber *et al*., 2023). Studies (*Desalew et al.,*2020) have shown that this is peak age for stagnated growth, deficiency of certain nutrient, and manifestation of common child diseases, such as protein energy malnutrition, which can later lead to infections conditions, such as cough, diarrhea measles, etc. after a child reaches 2years of age, it is very difficult to reverse any abnormality in growth that has occurred (Town *et al*., 2014). Infant and child feeding practice is a major determinant of nutritional status. Optimal infant feeding is defined as exclusive breastfeeding for six months followed by continued breastfeeding with age-appropriate complementary feeding for up to two years (Hospital *et al*., 2019). The World Health Organization recommends exclusive breastfeeding (EBF) for the first six months of life (UNICEF, 2018). This was recommended based on the evidence that good nutrition in the early months of life had a role in achieving good health. Inappropriate infant feeding practices lead to malnutrition which is a significant cause of morbidity and mortality particularly in developing countries. Inappropriate infant feeding and malnutrition can pose a threat to achieving the Sustainable Development Goals (SDGs) of ensuring healthy living and promoting the well-being for all at all ages (WHO/UNICEF 2020).

Nutritional status in children is important because it greatly influences their growth, development, and overall health. Good nutrition is crucial for the physical and cognitive development of children, as well as their ability to learn and perform well in school (Tim *et al*., 2019). The persistence of child malnutrition in low-income countries appears to be due to multiple of factors that include uncertain access to enough food and inappropriate dietary practices. Undernutrition remains a significant health burden among children living in low- and middle-income countries. Infant-feeding practices constitute a major component of child caring practices (Steve-Edemba and Nnam 2018). There have been many studies on nutritional status of under-five children and factors responsible but very few looks at this special group of women, their breastfeeding practice and its influence on the nutritional status of their under-five children in Doko Niger state Nigeria. The 2017 National Population Commission and Family Planning Board revealed that 37% of children under the age of five are stunted, while 21% are severely stunted, eighteen percent of under-five children in Nigeria are considered wasted and 9% are severely wasted while 29% are underweight, with 12% being severely underweight.

Globally, an estimated 1.3million lives are lost annually from lack of EBF and another 600,000 from inappropriate complementary feeding. (UNICEF, 2018). Protein energy malnutrition is said to be the leading cause of child deaths in developing countries. The high prevalence of childhood nutritional disorders in developing countries has been attributed to factors which affect the availability of good and nutritious food to the child (UNICEF and WHO 2021). It is important therefore to explore the role of infant feeding practices in the etiology of malnutrition in Nigeria as growth retardation is very high among under five children in Africa. This could be reduced to the barest minimum if wrong dietary patterns are corrected through health talks and nutrition counseling to mothers and caregivers during surveys. However, data establishing differences in dietary practices among under-five children in Doko community in Nigeria are lacking. Hence this study is aims to assess nutritional status and feeding practices of Under five children in Doko Niger state, Nigeria.

## MATERIALS AND METHODS

### Study Area/Location

The study was carried out among under five children in Doko (Lavun local government Area Niger State) Doko is located on latitude 8 N and longitude 5 E. It is a district in Lavun Local Government Area of Niger State. Doko is about fifteen kilometers away from Bida, sharing boundary with Bida in the North and Kwara State in the East.

### Study Design

A descriptive and cross-sectional design was adopted for this study.

### Target Population

The target population comprises of the under five children and their mothers/caregivers attending immunization clinic at three (3) primary health care centers in Doko, Niger State.

### Informed Consent

Permission was sought from the respondents for their willingness to participate in the research as the purpose was explained to them and their answers kept confidential.

### Method of Data Collection

A well-structured questionnaire was designed to obtain information on socio-economic and demographic characteristics, feeding practices and nutritional status of the respondents.

**Statistical Analysis**

Data was subjected to descriptive statistics such as frequency and percentage while Pearson's correlation was used to find association between the feeding practice and socio-economic status of the respondents.

## RESULTS AND DISCUSSION

Table 1: **Socio economic and demographic characteristics of the respondents**

| Variables | Frequency n=103 | Percentage% |
|---|---|---|
| Age (Years) | | |
| 18-20 | 32 | 31.1 |
| 20-25 | 38 | 36.9 |
| 25-30 | 26 | 25.2 |
| 30-35 | 7 | 6.8 |
| Total | 103 | 100 |
| **Age of Children (Months)** | | |
| 0-28 days | 27 | 26.2 |
| 29days-11months | 22 | 21.4 |
| 12-59 months | 29 | 28.2 |
| 5years | 25 | 24.2 |
| Total | 103 | 100 |
| **Educational Level** | | |
| None | 16 | 15.5 |
| Primary | 13 | 12.5 |
| Secondary | 26 | 25.2 |
| Quranic | 9 | 8.9 |
| Tertiary | 39 | 37.9 |
| Total | 103 | 100 |
| **Occupation** | | |
| Farming | 24 | 23.3 |
| Trading/ business | 34 | 33.0 |
| Civil servants | 26 | 25.2 |
| Artisans | 1 | 1.0 |
| Not employed | 18 | 17.5 |
| Total | 103 | 100 |
| **Number Of children** | | |
| 1-3 | 43 | 41.7 |
| 4-5 | 30 | 20.1 |
| 7-9 | 30 | 29.1 |
| **Family Size** | | |
| <7 | 25 | 24.3 |
| 7-12 | 45 | 43.7 |
| 13-16 | 18 | 17.5 |
| >\|equal to 19 | 15 | 14.5 |
| Total | 103 | 100 |
| **Ethnicity** | | |
| Nupe | 66 | 64.1 |
| Yoruba | 14 | 13.6 |
| Igbo | 13 | 12.6 |
| Others | 10 | 9.7 |
| Total | 103 | 100 |
| **Marrital status** | | |
| Single | 19 | 18.4 |
| Married | 72 | 69.9 |
| Divorced | 8 | 7.8 |
| Widowed | 4 | 3.9 |
| Total | 103 | 100 |
| **Type of family** | | |
| Nuclear | 59 | 57.3 |
| Extended | 38 | 36.9 |
| Polygamous | 6 | 5 .8 |
| Total | 103 | 100 |

**Table 2. Feeding Practices of mothers of under-five children**

| Variables | Frequency n=103 | Percentage% |
|---|---|---|
| **Gave Colostrum** | | |
| Yes | 81 | 78.6 |
| No | 22 | 21.4 |
| Total | 103 | 100.0 |
| **Exclusive Breastfed** | | |
| Yes | 64 | 62.1 |
| No | 39 | 37.5 |
| **Month of introduction of complementary Feeding** | 103 | 100.0 |
| 2 | 37 | 35.9 |
| 4 | 64 | 62.1 |
| 6 | 2 | 1.9 |
| Total | 103 | 100.0 |
| **Type of Complementary Feed** | | |
| Family diet | 22 | 21.4 |
| Pap only | 17 | 16.5 |
| Pap, crayfish, groundnut and soyabeans, | 17 | 16.5 |
| Pap, milk and sugar | 47 | 45.5 |
| Total | 103 | 100.0 |
| **Time of weaning(months)** | | |
| 7-10 | 6 | 5.8 |
| 11-14 | 16 | 15.5 |
| 15-18 | 8 | 7.8 |
| 19-22 | 11 | 10.7 |
| 23-26 | 52 | 50.4 |
| 27-30 | 10 | 9.7 |
| Total | 103 | 100.0 |
| **Method of feeding** | | |
| Spoon and cup | 49 | 47.6 |
| Bottle | 36 | 35.0 |
| Forced feeding | 18 | 17.5 |
| Total | 103 | 100.0 |

**Table 3. Nutritional status of under-five children**

| Variables/classification | | Frequency n=103 | Percentage% |
|---|---|---|---|
| **Weight for Age( Underweight)** | | | |
| Normal | (-2 to +2 Zscore) | 63 | 61.2 |
| Mild | (-2 to -3 Zscore) | 21 | 20.4 |
| Moderate | (-3 to -4 Zscore) | 3 | 2.9 |
| Severe | (below -4 Zscore) | 5 | 4.9 |
| Total | | 103 | 100.0 |
| **Length /Height for Age( Stunting)** | | | |
| Normal | (-2 to +2 Zscore) | 58 | 54.4 |
| Mild | (-2 to -3 Zscore) | 21 | 20.4 |
| Moderate | (-3 to -4 Zscore) | 9 | 8.7 |
| Severe | (below -4 Zscore) | 15 | 14.6 |
| Total | | 103 | 100.0 |
| **Weight for Length /Height(wasting)** | | | |
| Normal | (-2 to +2 Zscore) | 79 | 76.7 |
| Mild | (-2 to -3 Zscore) | 10 | 9.7 |
| Moderate | (-3 to -4 Zscore) | 4 | 3.9 |
| Severe | (below -4 Zscore) | 9 | 8.7 |
| Total | | 103 | 100.0 |

**Table 4: Educational level and feeding practices**

| Variables | R values | P value |
|---|---|---|
| Gave colostrums | -0.384 | 0.00 |
| Exclusively breastfed | -0.459 | 0.00 |
| Type of complementary food | 0.352 | 0.00 |
| Age of weaning | -0.236 | 0.01 |
| Methods of feeding | -0.120 | 0.22 |

** Correlation significant at 0.05 level (2tailed)

## DISCUSSION

Findings on socio-economic and demographic status of the respondents showed that majority of the mothers/caregivers had one form of education or the other. Only 15.5% had no form of education and this may have accounted for the high level of exclusive breastfeeding practice among the respondents. 62.1% of the respondents reported to have practiced exclusive breastfeeding 37.5% did not adhere to it. Exclusive breastfeeding has been a focus of many educational campaigns on different media platforms and at Healthcare facilities where Antenatal Care(ANC) visits are done. Mothers with adequate nutrition education are likely to demonstrate better knowledge and attitude to key infant and young children feeding practices (Steve-Edemba and Nnam 2018) and that no doubt reflected in the percentage of respondents who had adhered to exclusive breastfeeding of their infants. A statistically significant relationship existed between educational level and feeding practices of the respondents. This is similar to the study conducted in North western Nigeria which found that that mother's level of education leads to a decrease in malnutrition by 1.15% (NPC & FPB, 2017).

Noteworthy is the poor nutritional status of some infants observed in this study and this may have resulted from the early introduction of complementary foods, most likely are of low nutritional quality, inadequqtely and unhygienically processed and a potential harbor of pathoogenic organisms which could lead to childhood diseases like diarrhea and dysentery which are known causes of malnutrition (Ibrahim et *al*., 2019). The findings in this study is in agreement with the report of Town *et al*., (2017). Breastfeeding beyond one year (*up* to *two years*) continues to *benefit* the *baby's* development but it can also *benefit the breastfeeding* parent as it significantly impacts the health of the mother as her risk for breast cancer, ovarian cancer, arthritis, high blood pressure, heart disease, and diabetes is significantly reduced after 1 year or more of lactating (UNICEF 2018). However, a greater percentage (50.4%) of respondents breastfed their children for 23-26 months thereby adhering to WHO recommendation of stopping breastfeeding at 24 months, this might have significantly impacted on the nutritional status of the infants in this study as a higher percentage of the respondents were found to have had normal nutritional status based on the findings where the weight for age 61.2%, height for age 54.4% and weight for height 76.7% in this study.

## CONCLUSION

These socio-economic and demographic characteristics showed that 36.9% of the mothers/caregivers were between the ages of 20 - 25 years while 37.9% of them had tertiary education. 28.2% of the children were between 29days - 11 months. Results for feeding practices showed that 37.5% of the respondents observed exclusive breastfeeding while only1.9% introduced complementary food at the appropriate age of 6 months. The study established a statistical significant relationship between educational level and feeding practices of the respondents.

## RECOMMENDATIONS

Following the investigated report of malnutrition status of infants in Doko local government, the following recommendations are made;

i. There should be increased awareness campaigns on the importance of recommended feeding practices such as 6 months exclusive breastfeeding and breastfeeding till 24 months even after weaning as recommended by WHO.
ii. Girl child education should be encouraged.

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# GROWTH PERFORMANCE OF RABBITS FED DRY GRADED LEVEL OF BITTER KOLA (*GARCINA KOLA)* AS ADDITIVE

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**ABSTRACT**
This study investigated the effects of Bitter cola (*Garcina kola)* on the growth performance of growing rabbits. Twenty-four (24) weaner rabbits of mixed breed and mixed sexed (12:12) were used for the experiment, which lasted for eight weeks (56 days). The rabbits were randomly assigned to three dietary treatments: T1 with no bitter kola additive (0g), T2 (2.5g) and T3 (5g) of *G. Kola* inclusion and into four (4) replicate group. The experiment was design using completely randomized designs. During the eight weeks' period of the experiment, feed and water were given ad-libitum and while similar managerial and sanitary measured were applied for all the animals. Daily feed intake and growth performance of animals in each unit were monitored. The results showed significant difference on total feed intake (TFI), and daily feed intake (DFI) only. The initial weight (IW), final weight gain (FWG) and daily weight gain(DWG) did not differ significant (P>0.05. rabbits fed 0g BKSM had the highest figures followed by those fed with 2.5g, BKSM and 5g of BKSM respectively in both the daily feed intake and total feed intake. The result obtained for linear body measurements indicates that there was no significant (P>0.05) difference in the chest length (CL), fore leg length (FLL), hind leg length (HLL) and neck circumference (NC) respectively. The ear length (EL), body length (BL), tail length (TL) and head length (HL) shows significant (P<0.05) difference. As bitter kola inclusion increases, so as feed utilization, thereby leading to higher body gain. It thereby recommended that more research is necessary to find the perfect balance of BKSM in rabbit feed to achieve the best possible growth and feed efficiency.
**Key words**: Growth, Additive and Graded.

## INTRODUCTION
Rabbits are a significant source of protein in many parts of the world, particularly in regions where alternative protein sources are scarce. However, optimizing rabbit production efficiency is essential for sustainable meat production due to its lower environmental impact and efficient feed conversion compared to other livestock (Mohammed and Abdul Malik, 2014 and Cullere and Dalle Zotte, 2018). Rabbit meat is high in protein (22 %) low in fat (4 %) and cholesterol (5%) and thus possesses health-promoting properties (Aduku and Olukosi, 2000). Rabbits exhibit rapid growth, extremely high fertility, and prolificacy rates, providing a swift return on investment. They have a short gestation period and produce high-quality, nutritious meat. Additionally, they can be managed with simple techniques. Unlike cattle, sheep, poultry, or pigs, rabbits do not need much space and can thrive on a concentrated diet. (Hassan *et al.,* 2012). The use of certain materials and herbal preparations known as ethno veterinary medicine is rapidly gaining traction in the livestock industry, particularly in Asian and African nations (Ebenebe *et al.,* 2010; Ojelade, 2015). Phytogenics have been advocated in animal feeds as growth promoting feed additives, because of their abundance in our natural environment and the fact that they do not have residual effect (Ndelekwute *et al*., 2015). The South western states and Edo State of

Nigeria are home to a large population *G. kola. G. kola* is utilized for social, medicinal, dietary purposes claims by Chilaka (2009). Many authors have recorded the pharmaceutical usage which is quite important in many part of Africa (Ofor *et al.,* (2010) opined that synthetic antibiotics can disrupt the balance of gut micro biota in rabbits and other monogastric animals, and prolonged or excessive use can lead to a decrease in beneficial bacteria, allowing opportunistic pathogens to thrive. Given these challenges, there is a pressing need to find alternatives to antibiotics that can maintain or improve animal health and productivity without contributing to Resistance issues.

The rising concern on the use of antibiotics and the after effect on animal, human and the environment is a major problem (FAO2019), however numerous materials have been used to improve the productivity and health of growing rabbits. Kuldeep *et al.,* (2014). Reported that feed additives have garnered increased interest as an alternate feeding approach to replace antibiotic, prevent illnesses and at the same time lower production expense. According to medical theories, *G. kola* seed has a broad range of chemical components, including flavonoids, which give it some antibacterial and antifungal properties against both gram-positive and gram-negative germs (Adesuyi *et al.,* 2012). However, there is inadequate information about the amount needed to increase rabbit performance. Therefore, this study aims to investigate the effects of dry graded bitter kola on rabbit growth performance.

## METHODOLOGY

### Study Location

The Research were conducted at the Teaching and Research Farm, Department of Animal Production, Federal University of Technology Minna (Gidan Kwano), Niger State. Minna is located between latitude 9038' and 9037' North, longitude 6023' and 6033' East, which has an annual rainfall of between 1000-1500mm and an average temperature of 320c (FUTMINNA Student Handbook, 2020).

### Experimental Animals and Management

Twenty-four (24) composite wearners' rabbits, were used for this study. The animals were acquired from Ministry of Livestock, Rabbit Unite, Minna, Niger State, Nigeria, and were acclimatized for two (2) weeks before the start of experiment. The rabbits were paired into two and housed in wooden hutches, receiving a diet formulated with 16% crude protein and 2600 ME/kg energy along with grass-legume forages. Vitalyte ® plus was given orally to manage stress. Ivermec was administered subcutaneously at 0.2 ml/rabbit as a preventive measure against internal and external parasites, while Neoceryl ® plus was administered orally to combat gram-negative and gram positive bacteria. Coccimix was given orally to prevent coccidiosis, and Sulphadimidine was administered orally to guard against possible gastrointestinal disorders.

### Source of Experimental Material

Bitter kola (*Garcina kola*) were sourced from Itobe Kogi state, other feed materials (blood meal, maize offal, salt, and vitamin premix) were source within Minna metropolis,

**Experimental diet fed to the animals**

| Ingredient | Composition (%) |
|---|---|
| Maize | 40.0 |
| Soya bean | 7.00 |
| Wheat offal | 48.0 |
| Blood Meal | 3.00 |
| Bone meal | 1.00 |
| Methionine | 0.25 |
| Lysine | 0.25 |
| Premix | 0.25 |
| Salt | 0.25 |
| Total | 100 |
| Calculated value of experimental diet (%) | |
| Crude protein | 16.00 |
| ME (Kcal/kg) | 2600.00 |
| Crude fibre | 10.00 |
| Calcium | 0.30 |
| Phosphorus | 0.37 |

Processing of "Bitter kola seed (*Garcina kola*)" The outer testa of each bitter kola seed will be removed washed and air dried for about twenty-four (24) hours. Each seed were cut into smaller pieces and the resulting pellets will be dried in hot air oven at 40 $^{0}$C in two hour (2) for about twelve (12) hours at 25ºC and the dry seed pellets will be ground to fine powder using a grinding machine. The grinding powder will be stored in an airtight container throughout the experimental period.

**Experimental Design**

Composition of experimental diet which were varying levels in accordance with the design of the experiment. Treatment 1 (T) had 0g/100g bitter kola and severed as control. Treatment (T2) had 2.5g/100g bitter kola and while Treatment (T3) which have 5g/100g and bitter kola inclusion level. The design of the experiment was completely randomized design with each treatment having eight (8) rabbits in four (4) replicates per treatment.

**Data collection**

Feed intake (g), body weight (kg) and body linear measurement (cm) (body length, head length, fore leg length, hind leg length, ear length, tail length was taken using measuring tape).

**Statistical Analysis**

Data collected were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 17.0. Differences among means was separated using Duncan's Multiple Range Test.

## RESULTS

**Table 1: Growth performance of growing Rabbit of bitter kola seed meal diet**

| Parameters | T1(0g) | T2(2.5g) | T3(5g) | SEM | PV |
|---|---|---|---|---|---|
| IW (g) | 812.50 | 806.25 | 799.50 | 19.07 | 0.97 |
| FWG (g) | 1546.50 | 1456.25 | 1568.25 | 52.50 | 0.38 |
| TWG (g) | 744 | 650 | 769.25 | 51.24 | 0.32 |
| DWG (g) | 13.29 | 11.61 | 13.74 | 0.91 | 0.32 |
| TFI (g) | $3602.8^{a}$ | $3317.6^{ab}$ | $3119.2^{b}$ | 94.98 | 0.03 |
| DFI (g) | $64.34^{a}$ | $59.24^{ab}$ | $55.70^{b}$ | 1.70 | 0.003 |
| FCR | 4.89 | 5.33 | 4.09 | 0.20 | 0.20 |

$^{1\ ab}$: Mean on the same row with different superscripts are significantly different (p<0.05)
IW: Initial weight, FWG: Final weight gain, TWG: Total weight gain, DWaG: Daily weight gain, TFI: Total feed intake, DFI: Daily feed intake, FCR: Feed conversion ratio.
**Key: T1**: control**,** T2: (2.5g) bitter kola**,** T3: (5g) bitter kola**,** SEM: Standard error of mean**,** NS: Not significant and ******: Significant

**Table 2: Body linear measurement of growing rabbits fed bitter kola seed meal diet**

| **Parameter** | **T1 (0g)** | **T2 (2.5g)** | **T3 (5g)** | **SEM** | **PV** |
|---|---|---|---|---|---|
| CL (cm) | 8.23 | 8.04 | 8.1 | 0.11 | 0.82 |
| FLL (cm) | 5.64 | 5.44 | 5.73 | 0.08 | 0.4 |
| HLL (cm) | 8.02 | 8.2 | 8.65 | 0.17 | 0.35 |
| NC (cm) | 5.19 | 5.23 | 5.36 | 0.13 | 0.87 |
| EL (cm) | 4.29ab | 4.02b | 4.60ab | 0.1 | 0.05 |
| BL (cm) | 10.88b | 10.63ab | 11.77bc | 0.19 | 0.12 |
| TL (cm) | 4.19a | 3.38b | 3.69ab | 0.13 | 0.01 |
| HL (cm) | 4.49b | 4.85ab | 5.00a | 0.06 | 0.04 |

$^{abc}$ Means in the same row having different superscripts are significantly different (P ≤ 0.05)
CL: Chest Length, FLL: Fore Leg Length, HLL: Hind Leg Length, NC: Neck Circumference, 4
EL: Ear Length, BL: Body Length HL, TL: Tail length, Head Length,
**Keys:** T1: control**,** T2: 2.5g bitter kola**,** T3: 5g bitter kola**,** SEM: Standard error of mean**,** NS: Not significant and ****:** Significant

## DISCUSSION

In the present study, growing rabbits fed bitter kola seed meal diet showed decrease in feed intake progressively in all rabbits subjected to the BKSM-based diet as the inclusion level increased from 0 % to 5 %. This result agrees with the finding of Ebenebe *et al*. (2016), who reported similar findings that rabbits fed dietary supplementation of BKSM had decreased feed intake as the inclusion levels increased. Similarly, Beyang *et al*. (2023) observed weight loss in rats fed different bitter kola cultivars and concluded that bitter kola powder can be used to prevent obesity in high-fat diets. Studies with *Garcinia kola* revealed decreased weight gain 8
and organ mass in rats (Adesanya *et al*., 2007). The decrease in feed intake of rabbits fed higher inclusion levels of BKSM may be associated with the tannin content of *G. kola*, as reported by Fructos (2004). The results obtained in this study for ear length (4.02–4.60 cm) show significant differences (P<0.05), disagrees with earlier reports of Ebenebe *et al.,* (2016) that BKSM diet has proven to show a depressed growth rate in rabbits. The result of the Body length (10.88–10.63

cm) disagrees with Beyang *et al., (*2023) who observed weight loss in rats fed different bitter kola cultivars and concluded that bitter kola powder can be used to prevent obesity in high-fat diets. The result also disagrees with the result of the Studies of Adesanya *et al.,* (2007) who observed decreased weight gain and organ mass in rats fed *Garcinia kola*.

**CONCLUSION**

The study investigated the effects of bitter kola seed meal (BKSM) on growth performance and linear body measurements in growing rabbits at an inclusion level of 2.5g. The results showed that BKSM increases in feed utilization as inclusion level of bitter kola increases give rise to higher body weight gain.

**RECOMMENDATION**

It is recommended that bitter kola can be included in rabbit diet for a better linear body measurement.

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# ANALYSIS OF FISH MARKETING IN IKORODU LOCAL GOVERNMENT AREA OF LAGOS STATE, NIGERIA

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## ABSTRACT

This study examined the socio-economic analysis of value addition in fish marketing within the Ikorodu Local Government Area of Lagos State, Nigeria. A stratified random sampling technique was employed to select 90 fish marketers used as respondents for the study. Data were collected through structured questionnaire administered to the respondents. Descriptive statistics was used to analyze the data collected. The analysis result revealed that the majority of fish marketers engage in both wholesale and retail, with a significant proportion specializing in smoked and dried fish, reflecting consumer preferences and market trends. The result above reveals that a higher percentage of the respondents (37.7%) prefer to consume their fish fresh, 13% prefer Frozen, 27.8% prefer smoked fish and 21.1% prefer to consume their fish in the dried form. Furthermore, the study identifies several challenges faced by fish marketers, including inadequate access to quality processing facilities, fluctuating market prices, and competition from unregulated sources. Respondents also reported issues related to transportation and storage, which negatively impact the freshness and quality of their products. The findings underscore the need for targeted interventions to enhance the socio-economic conditions of fish marketers, including better access to training on value addition techniques, improved marketing infrastructure, and the establishment of regulatory frameworks to support fair trade practices.

**Keywords:** Value addition, Fish marketing, Challenges, Socio-economics, Fish marketers

## INTRODUCTION

Fisheries development depends on improved production and processing technology and also on effective marketing system. About 40 million people are employed directly in the fishery sub-sectors of industrial, artisanal, fish farming, processing, preservation and marketing worldwide. According to the National Bureau of Statistics (2012), fisheries contribute about 3.24% of the Agriculture GDP. Its employment opportunities come from different fishing activities such as production, processing, preservation and transportation (Ali *et al.,* 2008). Fish supply in Nigeria is either through capture fisheries, fish farming or by importation (Adewumi *et al.,* 2012), unfortunately, larger quantity of fish consumed in Nigeria is imported. To reverse this situation and improve fish production in the area, there is need for the development of perfect marketing performance which satisfies consumer demands with the minimum margin between producers and consumer prices. Hibbard (2017) confirmed that marketing is a series of activities involved in directing the flow of goods and services from producers to consumers. The need for the efficient marketing system of fish cannot be over emphasized. As important as marketing is, most of the studies on fish have concentrated on production (Dagtekin, 2009; Zabbey, 2010), which was thought would solve the problem of high fish importation. Production and marketing constitute a continuum and the absence of development in one retards progress in the other. Also, there is limited information regarding fish marketing in Nigeria generally and particularly how specific aspects of the market (such as market concentration, market share, the nature of competition, and behaviour of market participants) affect the performance of the market. This information gap can be addressed by analysing the market structure; conduct and performance of fish marketing in Ikorodu local government area. Also, the factors influencing the income of fish marketers in the study area and the constraints of fish marketing system in the study area were examined. Fish is a very important agricultural product in Nigeria, and is largely consumed in the country especially due to its rich nutritional and medicinal values. More so, the large coastal area and continental shelf available in the country makes diverse varieties available in different areas at affordable prices.

Despite these rich coastal and continental resource base of the country, demand for fish far exceeds production, resulting in the importation of over 800,000 metric tonnes of fish annually (FBS, 2007). This trend may not change in the nearby future considering the rising population of the country and the increasing distance between fish producers and consumers. This therefore calls for efficiency in fish marketing. Furthermore, fish is the most important animal protein food available in the tropics, and this could account for its large consumption in the country. In Nigeria, fish constitutes 40% of protein intake (Eyo, 1992: Federal Department of Fishery, FDF, 2000), while, according to Adekoya and Miller (2004), fish and fish products contribute more than 60% of total protein intake in adults especially in rural areas. Amiengheme (2005) asserts that nutrient from fish is superior to all terrestrial meats such as beef, mutton, pork and chicken being a rich source of high quality animal protein and also contains highly digestible energy. More so, it is a good source of sulphur and essential amino acids such as lysine, leucine, valine and arginie. Fish is a good source of thiamine and polyunsaturated fatty acids, fat soluble vitamins such as vitamins A, D E and K, and water soluble vitamins for example, B complex, and minerals, such as, calcium, phosphorous, iron, iodine and selenium.

According to Ovie and Raji (2006), Fish contains omega 111 fatty acids that are known to reduce cardiovascular diseases, hypertension and arteriosclerosis, thus becoming a preferred source of protein for those nearing 50years and above. In fish marketing, problems of shortage of supply, price fluctuations due to drying up of sources of water, and spoilage in transit, have been identified in the country (Tomek and Robinson, 1981, as cited in Ali et al., 2008). Eze *et al.* (2010), identified inadequate processing skills, produce deterioration and lack of storage facilities as the major constraints perceived by women marketers. However, this may not be exhaustive bearing in mind the paucity of research in fish marketing, and also the rural nature of participants in fish marketing. Therefore, the economics of fish marketing evaluates the structure, conduct and performance of fish marketing system as indicators of the overall efficiency of the system. It is of essence in the determination of both consumers' living cost and producers' income and hence, the overall wellbeing and development of the country. Furthermore, the level of gender participation in fish marketing has not been empirically evaluated. It is a common knowledge that agricultural activities in developing countries like Nigeria are predominantly carried out by women. According to the Federal Bureau of Statistics, over 70 per cent of agricultural activities are carried out by women in Nigeria (FBS, 2010). However, results from different studies on fish marketing differ from the Federal Bureau of

Statistics report. Ali *et al.* (2008) reported that majority of fish marketers in Maiduguri were males while a similar study carried out in Adamawa State showed that majority of the marketers were females (Gaya et al., 2010). The objectives of this study were to profile the socio-economic characteristics of the respondents, the socio- economic characteristics of the respondents in the study area, determine the form of fish sold in the study area (Smoked, Fresh and Dried) and identify the challenges encountered by the respondents in the study area.

## METHODOLOGY

The study was conducted in Ikorodu Local Government Areas of Lagos State, Nigeria. The area was chosen due to its significant fish marketing activities and potential for value addition. It includes the geographical location, socio-economic background, demographic characteristics, and the significance of fish marketing in the region. Ikorodu is situated in the north-eastern part of Lagos State. It is bordered by Lagos Lagoon to the south, Ogun State to the north, Kosofe to the west, and Epe to the east. It constitutes approximately 6.6194° N latitude and 3.5072° E longitude (Editors of Encyclopedia Britannica). Ikorodu spans an area of around 345 square kilometers. Ikorodu's economy is diverse, encompassing fishing, agriculture, manufacturing, and commerce. Fish marketing is a key activity, supported by the area's rich aquatic ecosystem. The LGA boasts well-developed markets, fish processing plants, and transportation facilities that facilitate efficient fish marketing.

Ikorodu is home to numerous schools, colleges, and healthcare centres, contributing to the overall socio-economic growth of the region. Ikorodu has a population of about 535,619 people (NPC, 2006). In order to ensure a representative sample of fish marketers and value-added fish product processors in Ikorodu Local Government Area, a stratified random sampling technique was employed. A total of 90 respondents were selected for the study. The sample size was determined based on the estimated population of fish marketers and value-added fish product processors in the study area. Data was analysed using descriptive statistics and chi-square to summarize and describe the features of the data.

## RESULTS AND DISCUSSION

### Socio-economic profile of the respondents

The result in Table 1 revealed that the age of the respondent in the bracket of 17-23 constitutes 5.6% while the age of the respondent 24-32 constitutes 35.6%, the age of respondent 33-40 constitutes 38.9%, the age of respondent 41-46 constitutes 13.3%, the age of respondent 47-55% constitutes 4.4% and that of 56 and above constitutes 2.2%. The result in Table 1 shows that single respondent constitutes 37.8%, the married respondent constitutes 57.8%, and the widow respondent constitute 4.4%. This suggest that the married respondents were more than the single and the widow respondent in the study area. The research result also shows that the male respondent constituted 43.3% while the female respondents constitute 56.7%. This suggests that the female respondent wee more than the male respondent in the study area. The result above shows that the respondents with primary education constitutes 28.9%, secondary education constitutes 38.9%, tertiary education 32.2%. This suggest that the respondents with secondary education are more than the primary and tertiary respondent in the study area. The result in the Table above shows that the family size less than 2 constitutes 15.7%, the family size 4-6 constitute 46.3, the family size 5-7 constitutes 27.8% family size 8-10 constitutes 7.8% This suggests that majority of the respondents with the family size 2-4 respondents are more in the study area.

**Table 1: Distribution of the respondents based on their socio-economic profile (n = 90)**

| Variables | Frequency | Percentage |
|---|---|---|
| **Household size** | | |
| Less than 2 | 15 | 16.7 |
| 2 – 4 | 43 | 47.8 |
| 5 – 7 | 25 | 27.7 |
| 8 – 10 | 07 | 7.8 |
| **Marital status** | | |
| Single | 63 | 70.0 |
| Married | 27 | 30.0 |
| **Occupation** | | |
| Fishing | 12 | 13.3 |
| Fish marketer | 40 | 44.5 |
| Fish Producer | 18 | 20.0 |
| Fish Processors | 20 | 22.2 |
| **Gender** | | |
| Male | 39 | 43.3 |
| Female | 51 | 56.7 |
| **Educational level** | | |
| Primary | 26 | 28.9 |
| Secondary | 35 | 38.9 |
| Tertiary | 18 | 20.0 |
| No formal | 11 | 12.2 |

**Source:** Field Survey, 2024

**Forms of fish marketed by the respondents**

The result in Table 2 revealed that 37.7% of the respondents prefer to sales fish fresh, followed by 27.8% who marketed smoked fish. Also, 21.1% of the respondents marketed dried fish fresh, while 13.3% of the respondent marketed frozen fish. This implies the fish marketers are into sales of different forms of fish in the study area.

**Table 2 Distribution of Respondent According to forms of fish consumed**

| Forms of fish | Frequency | Percentage |
|---|---|---|
| Fresh | 34 | 37.8 |
| Frozen | 12 | 13.3 |
| Smoked | 25 | 27.8 |
| Dried | 19 | 21.1 |
| Total | 90 | 100.0 |

**Source:** Field **Survey, 2024**

**Constraints of fish consumed by the respondents**

The result in Table 3 revealed that 27.2% of the respondents are faced with challenge of high price of fish, 25.7% indicated that they are faced with the challenge of rapid spoilage of fish and 22.8% indicated to be faced with challenge of low level of income. Other constraints faced by the respondents include distance to market (16.5%), health reason (14.1%), low traded volume of fish (12.6%) and religious belief (8.3%). This implies the fish marketers are faced with various constraints associated with fish marketing in the study area.

**Table 3: Distribution of respondents according to the constraint faced in fish marketing**

| Constraint | Frequency | Percentage | Ranking |
|---|---|---|---|
| High price of fish | 56 | 27.2 | 1st |
| Rapid Fish Spoilage | 53 | 25.7 | 2nd |
| Low level of income | 47 | 22.8 | 3rd |
| Distance from market | 34 | 16.5 | 4th |
| Health reason | 29 | 14.1 | 5th |
| Low traded volume of fish | 26 | 12.6 | 6th |
| Religious belief | 17 | 8.3 | 7th |

**Source: Field Survey, 2024**

## CONCLUSION AND RECOMMENDATIONS

Based on the evidence emanating from this study, the respondents are young, married and largely single with varying levels of education which influence their marketing strategies and outcomes. The fish marketers sell various forms of fish such as fresh, smoked, dried and frozen fish reflecting local consumer preferences and the need for longer shelf-life in a competitive market. The top most challenges faced by the fish marketers are high price of fish, rapid fish spoiled and low level of income. It is against this backdrop the study makes the following recommendations:

i. Access to Financial Resources: Establish partnerships with microfinance institutions to provide tailored financial products for fish marketers. Access to credit will enable them to invest in better processing equipment and expand their operations, ultimately increasing profitability.

ii. Investment in Infrastructure: Advocate for the development of adequate processing and storage facilities. Investments in cold storage and modern processing plants can significantly reduce post-harvest losses and improve the quality of fish products available in the market.

iii. Market Support and Regulation: Implement policies that promote fair trade practices and protect local fish marketers from external competition. Encouraging the establishment of cooperatives can help strengthen market power and improve negotiation capabilities.

iv. Promotion of Value-Added Products: Encourage the diversification of fish products to include ready-to-eat and processed items. This can attract a broader consumer base and enhance profit margins for local marketers.

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# EFFECT OF TWINE SIZES ON CATCH PERFORMANCE OF GILLNETS IN JEBBA LAKE, NIGERIA

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## ABSTRACT

This study investigates the impact of twine size on catch efficiency and selectivity of surface monofilament and multifilament gillnets in Jebba Lake. Four set of gillnets with twine size 0.14mm, 0.16mm, 210d/2 and 210d/3, a stretched mesh size of 76.2mm, length of 15 m each and depth of 3m and hanging ratio of 50% were constructed. The experimental fishing trials for the gillnets were carried out in Fakun and New Awuru fishing grounds, Jebba Lake for six months. 29 fish species belonging to 13 families were recorded by all gillnets in this study. The fish Relative Species Diversity Index revealed that monofilament gillnet with twine size 0.14 mm recorded the highest index of 0.97 followed by 0.16 mm monofilament (0.90) and the least index of 0.59 was obtained in 210d/3 multifilament gillnet. A total of 399 fish weighing 138.9 kg was caught, 168 (42.1%) with weight of 51.3 kg (37%) was caught by 0.14 mm gillnet, followed by 0.16 mm with 120 (30.1%) fish weighing 42.25 kg (30.4%) and the lowest number of 40 (10%) fish weighing 17.3 kg (12.5%) was obtained by 210d/3 gillnet. Also in term of relative efficiency, 0.14 mm twine size net had the highest efficiency of 0.32, next by 0.16 mm net (0.23) and the least was obtained by 210d/3 twine size with 0.08. The statistical Analysis of Variance (ANOVA) for weight and Catch Per Unit Effort showed no significant difference (P>0.05) between gillnet with 0.14 mm, 0.16 mm and 210d/2, but there was significant difference between 0.14 mm gillnet and 210d/3. Based on the size of fish, 0.14 mm twine size caught large proportion of smaller fish. In contrast, 0.16 mm, 210d/2 and 210d/3 caught larger fish which aligns with the objective of minimizing growth overfishing.

**Keywords*:*** Twine size, Catch performance, Gillnet, Jebba Lake

## INTRODUCTION

Gillnet is described as vertical wall of mostly rectangular netting held erect in water column in the form of a curtain by floats attached to the head rope and sinkers attached to the foot rope, into which fish swim unnoticed (He and Pol, 2010; Eyo and Isangedighi, 2016). Gillnetting is used by both industrial and artisanal fishers worldwide to capture a variety of bottom dwelling and pelagic fish in inland, marine, and brackish water for artisanal or commercial fisheries (Gilman *et al.,* 2016). It is regarded one of the oldest and most frequently used gears by artisanal fisherman in inland waterways in Nigeria (Emmanuel and Chukwu 2010), accounting for approximately 85% utilization among artisanal fishers (Ago *et al.,* 2014). The catch performance of gillnet can be influenced by mesh size, twine size, filament type, hanging ratio, visibility, and soaking (He and Pol, 2010). Several studies focused on the effect of mesh size and hanging ratio on catch performance of gillnet (Ahmed and Tagogo, 2013; Ago *et al.,* 2014; Nuhu and Yaro, 2005; Biyontubo and Obhahie, 2006). However, information on the effect of twine sizes on the catch performance of gillnets within the context of Jebba Lake remains uninvestigated and therefore present a significant research gap. The findings of this study can offer insights into how fish yield can be optimized by harvesting sizable fish and avoiding under-sized fish which could lead to growth over-fishing.

**Objectives**

The objectives of the studies were to:

Determine the effect twine sizes on catch composition of gillnet.
Determine the catch efficiency of gillnets constructed with different twine sizes.
Assess the size of fish caught by gillnets of different twine sizes.

## MATERIALS AND METHODS

### Construction Site and Study Area

The experimental gillnets were constructed at the Fishing Gear Unit of National Institute for Freshwater Fisheries Research (NIFFR), New Bussa. The experimental gillnets were then tried at Fakun and New Awuru fishing ground, Jebba Lake. Jebba Lake is located in North-central Nigeria and is situated between latitudes 9°35' N and 9°50' N and longitudes 4°30' E and 5°00' E. The lake is man-made and was impounded in 1983 for the purpose of hydro-electric power generation but with opportunities for fishing, drawdown farming and navigation (Abiodun and Oshungade, 2009).

### Construction material and Fabrication

Based on the methods of FAO (2015), four sets of net of 0.14 mm, 0.16 mm (monofilament), 210d/2 and 210d/3 (multifilament) gillnets each with stretched mesh size of 76 mm were constructed; the length and depth of the nets were 15 m and 3 m respectively. They were all hung at 50% (E = 0.5) hanging ratio, and each net was replicated three times.

### Experimental Design

The experimental gillnets were ganged together randomly using a randomized numbering techniques to form a fleet of 12 gangs of net based on the method adopted by Adimula *et al.* (2003). The ganged nets were then set at the sampling sites. Three sampling stations (upper, mid and lower) were selected at each sampling sites and the nets were set in the evening (between 6:30 pm – 7 pm) and hauled in the following morning (between 6:30 am – 7 am), maintaining a soaked time of 12 hours.

### Fish identification and measurement

The fish caught were identified using fish identification guide by Olaosebikan and Raji (2021). The fish caught in each net were sorted and identified into different species and the following measurements were taken; total length (cm) and weight (kg) using measuring board and weighing balance respectively.

### Data Analysis

The data on catch composition of fish both in number and weight was computed using percentage. The weight of fish capture by different twine sizes was analyzed using one-way Analysis of Variance (ANOVA). Dunkan Multiple Range Test was used to determine which twine size differ from each other. Total length of fish caught by different twine size of gillnet was measured to the nearest cm and presented using bar chat.

**Species Diversity Index (SDI), Relative Abundance (RA) and Relative Efficiency (RE)**

The species diversity index (SDI) was computed based on the method of Ahmed *et al.* (2005)

$$SDI = \frac{\text{Number of species caught by each gillnet}}{\text{Total number of species caught by all gillnets}}$$

The relative abundance of fish species was estimated using the formula of Ahmed *et al.* (2005).

$$RA = \frac{SA}{TA} X\ 100$$

Where;

RA = Relative abundance of each species

SA = Species abundance

TA = Total abundance of all species

The Relative efficiency (RE) of gillnets was determined by comparing the efficiency of a net with that of other nets, since the nets were operated same time, same location and equal effort. This method had been used successfully by Adimula (2003).

$$RE = \frac{Ci_a}{Ci_a + Ci_b + Ci_c + Ci_d} K$$

Where,

$RE_a$ = Relative efficiency of gear A

$Ci_a$ = Catch of gear A (Number of fish caught)

$Ci_b$ = Catch of gear B (Number of fish caught)

$Ci_c$ = Catch of gear C (Number of fish caught)

$Ci_d$ = Catch of gear D (Number of fish caught)

K = Fishing Efforts of the gear

## RESULTS AND DISCUSSION

### Types of fish species caught by different twine size gillnets

The types of fish caught comprised 29 species belonging to 13 families (Table 1). The family and species of fish caught in this study were similar to those reported by Abiodun and Odunze (2011). However, the species of fish caught in this study were less than those of Abiodun and Odunze (2011) who recorded 51 species belonging to 12 families. The family Cichlidae (*Sarotherodon galilaeus* (62), *Oreochromis niloticus* (31) and *Coptodon zillii* (14)) had the highest number of 107 (26.82%) fish, followed by Mochokidae (*Synodontis schall* (36), *Synodontis, clarias* (9), *Synodontis sorex* (4) and *Synodontis membranaceus* (10)) 59 fish (14.9%) and the family Malapteridae (*Malapterurus electricus* (3)) and Distichodontae (*Distichodus rostratus* (3)) had the lowest number of 3 fish (0.75%) respectively. The result of finding is in line with that of Ibrahim *et al.* (2019) who reported high dominance in the family Cichlidae and Mochokidae. The dominance of fish caught in the study could be due to prolific nature of some fish species, the ability of tolerating wide range of environmental changes, better adaptation and availability of food (Ibrahim *et al.,* 2019).

**Table 1: Families and species of fish caught by Gillnets during the study**

| Family | Total fish caught | % of total catch | Fish species caught | Total fish caught | % of total catch |
|---|---|---|---|---|---|
| **Cichlidae** | 107 | 26.82 | *S. galilaeus* | 62 | 15.5 |
| | | | *O. niloticus* | 31 | 7.77 |
| | | | *Coptodon zillii* | 14 | 3.51 |
| **Mormyridae** | 43 | 10.78 | *M. anguilloides* | 13 | 3.26 |
| | | | *Mormyrus rume* | 10 | 2.51 |
| | | | *M. senegalensis* | 9 | 2.26 |
| | | | *Hyperopisus bebe* | 11 | 2.76 |
| **Latidae** | 10 | 2.51 | *Lates niloticus* | 10 | 2.51 |
| **Bagridae** | 25 | 6.27 | *Bagrus bayad* | 16 | 4.01 |
| | | | *Bagrus docmak* | 9 | 2.26 |
| **Schilbeidae** | 30 | 7.52 | *Schilbe* | 16 | 4.01 |
| | | | *micropogon* | 14 | 3.51 |
| **Alestidae** | 32 | 8.02 | *Schilbe mytus* | 9 | 2.26 |
| | | | *Alestes baremose* | 11 | 2.76 |
| | | | *Alestes nurses* | 12 | 3.01 |
| **Cyprinidae** | 21 | 5.26 | *H. forskahlii* | 9 | 2.26 |
| | | | *Labeo coubie* | 12 | 3.01 |
| **Clarotidae** | 55 | 13.78 | *Labeo* | 15 | 3.76 |
| | | | *senegalensis* | 18 | 4.51 |
| | | | *A. occidentalis* | 10 | 2.51 |
| | | | *Clarotes laticeps* | 12 | 3.01 |
| **Mochokidae** | 59 | 14.79 | *C. filamentus* | 36 | 9.02 |
| | | | *C. nigrodigitatus* | 9 | 2.26 |
| | | | *Synodontis schall* | 4 | 1.00 |
| | | | *Synodontis clarias* | 10 | 2.51 |
| **Malapteridae** | 3 | 0.75 | *Synodontis sorex* | 3 | 0.75 |
| **Distichodontae** | 3 | 0.75 | *S. membranaceus* | 3 | 0.75 |
| **Clariidae** | 4 | 1.00 | *M. electricus* | 4 | 1.00 |
| **Citharinidae** | 7 | 1.75 | *D. rostratus* | 7 | 1.75 |
| | | | *Clarias gariepinus* | | |
| | | | *Citharinus citharus* | | |
| **Total catch** | **399** | **100** | | **399** | **100** |

**Number, weight and Species Diversity Index (SDI) of fish caught during the study**

Table 2 contains number, weight and Species Diversity Index (SDI) of fish caught during the study. A total of 399 fish of 29 species belonging to 13 families were caught by the different twine sizes of gillnets during the study (February-July, 2024), monofilament gillnet with twine thickness of 0.14 mm having the highest number of fish 168 (42.1%) , weight 51.3 kg (37%) and SDI (0.94), followed by 0.16 mm twine monofilament net with 120 (30.1%) fish, weight 42.25 kg (30.4%) and SDI (0.90) and the least number of fish caught was obtained by multifilament gillnet with twine size of 210d/3 with 40 fish (10%), weight 17.3 kg (12.5%) and RSDI (0.59). The result from this finding agrees with the report of Adjarho *et al.* (2009) who reported that thinner twine has high catch composition of fish both in number and weight. The result also agrees with the findings of Holst *et al.* (2002) who discovered a similar effect in the Baltic cod fishery and reported that gillnets with thinner string size caught greater number fish than gillnets with thicker yarn. The high catch observed in the study could be due to the fact that thinner twines are more elastic, less visible and flexible than thicker twines, allowing them to stretch more readily (Kim *et al.,* 2016).

**Table 2: Number, weight and RSDI of fish species caught during the study**

| Species | 0.14mm | | 0.16mm | | 210d/2 | | 210d/3 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No | Wt (kg) | No | Wt (kg) | No | Wt (kg) | No | Wt (kg) | No | Wt (kg) |
| *S. galilaeus* | 28 | 9.8 | 19 | 7.7 | 10 | 4.9 | 5 | 2.6 | 62 | 25 |
| *O. niloticus* | 12 | 4.6 | 9 | 4.4 | 7 | 3.2 | 3 | 1.4 | 31 | 13.6 |
| *Coptodon zillii* | 10 | 2.8 | 2 | 0.6 | 2 | 0.8 | - | - | 14 | 4.2 |
| *M. anguilloides* | 6 | 1.7 | 5 | 1.4 | 2 | 0.7 | - | - | 13 | 3.8 |
| *Mormyrus rume* | 3 | 1.0 | 5 | 1.6 | - | - | 2 | 0.6 | 10 | 3.2 |
| *M. senegalensis* | 5 | 1.8 | 2 | 0.7 | 2 | 0.6 | - | - | 9 | 3.1 |
| *H. bebe* | 7 | 2.4 | 4 | 1.9 | - | - | - | - | 11 | 4.3 |
| *Lates niloticus* | 1 | 0.2 | 3 | 0.9 | 4 | 1.5 | 2 | 0.8 | 10 | 3.4 |
| *Bagrus bayad* | 5 | 1.9 | 6 | 2.5 | 3 | 1.5 | 2 | 1.2 | 16 | 7.1 |
| *Bagrus docmak* | 3 | 1.2 | 2 | 0.7 | 2 | 1.0 | 2 | 1.0 | 9 | 3.9 |
| *Schilbe micropogon* | 5 | 0.5 | 7 | 0.7 | 3 | 0.3 | 1 | 0.1 | 16 | 1.6 |
| *Schilbe mytus* | 7 | 0.6 | 5 | 0.6 | 2 | 0.25 | - | - | 14 | 1.45 |
| *Alestes baremose* | 3 | 0.7 | 3 | 1.1 | 3 | 0.9 | - | - | 9 | 2.7 |
| *Alestes nurses* | 4 | 1.2 | 2 | 0.65 | 3 | 1.1 | 2 | 0.8 | 11 | 3.75 |
| *Hydrocinus forskahlii* | 4 | 1.4 | 3 | 1.2 | 2 | 0.8 | 3 | 1.2 | 12 | 4.6 |
| *Labeo coubie* | 4 | 1.5 | - | - | 3 | 1.2 | 2 | 1.0 | 9 | 3.7 |
| *Labeo senegalensis* | 2 | 0.7 | 5 | 1.7 | 2 | 0.7 | 3 | 1.2 | 12 | 4.3 |
| *A. occidentalis* | 8 | 2.9 | 3 | 1.3 | 2 | 0.9 | 2 | 1.0 | 15 | 6.1 |
| *Clarotes laticeps* | 8 | 1.9 | 6 | 1.8 | 4 | 1.3 | - | - | 18 | 2.9 |
| *C. filamentus* | 3 | 0.9 | 5 | 1.8 | - | - | 2 | 0.6 | 10 | 3.3 |
| *C. nigrodigitatus* | 6 | 2.2 | 3 | 1.2 | 2 | 0.8 | 1 | 0.7 | 12 | 4.9 |
| *Synodontis schall* | 18 | 4.2 | 9 | 3.0 | 5 | 1.5 | 4 | 1.3 | 36 | 10 |
| *Synodontis clarias* | 4 | 1.5 | 3 | 1.3 | 2 | 0.9 | - | - | 9 | 3.7 |
| *Synodontis sorex* | 3 | 0.5 | 1 | 0.2 | - | - | - | - | 4 | 0.7 |
| *S. membranaceus* | 2 | 0.8 | 4 | 1.4 | 1 | 0.5 | 3 | 1.4 | 10 | 1.4 |
| *M. electricus* | 2 | 0.6 | - | - | 1 | 0.4 | - | - | 3 | 1.0 |
| *D. rostratus* | - | - | 2 | 0.9 | 1 | 0.5 | - | - | 3 | 1.4 |
| *Clarias gariepinus* | 2 | 0.6 | - | - | 1 | 0.3 | 1 | 0.4 | 4 | 1.3 |
| *Citharinus citharus* | 3 | 1.2 | 2 | 1.0 | 2 | 1.5 | - | - | 7 | 3.7 |
| **Total** | **168** | **51.3** | **120** | **42.25** | **71** | **28.05** | **40** | **17.3** | **399** | **138.9** |
| **Mean weight (kg)** | | **0.31** | | **0.35** | | **0.40** | | **0.43** | | **0.35** |
| **RSDI** | | **0.97** | | **0.90** | | **0.86** | | **0.59** | | |

**Size of fish caught by different twine size gillnets**

Figure 1 shows the size of fish caught by different twine sizes of gillnets. A total of 173 large fish (length range of 31 cm-50 cm) were caught while 100 small fish (length range of 10 cm-20 cm) were caught across all twine sizes of gillnet during the study period. 0.16 mm monofilament gillnet obtained the highest number of 66 (38.2%) large fish, followed by 210d/2 multifilament gillnet with 48 (27.7%) and the least was recorded by 0.14mm monofilament gillnet with 28 (16.2%) fish. Out of the 100 small fish caught, 0.14 mm monofilament gillnet had the highest with 72 (72%) fish, followed by 0.16 mm monofilament gillnet with 19 (19%) and the least was recorded by 210d/3 multifilament gillnet with 2 (2%) fish caught. This finding agrees with Adjarho *et al.* (2009) who reported that thinner twines catch fish more both in quantity and weight, with larger proportion of small size fish than thicker twines. It also agrees with Kim *et al.* (2016) who stated that thinner twines capture fish of varying lengths, both smaller and bigger individuals, but thicker twines have a restricted selection range.

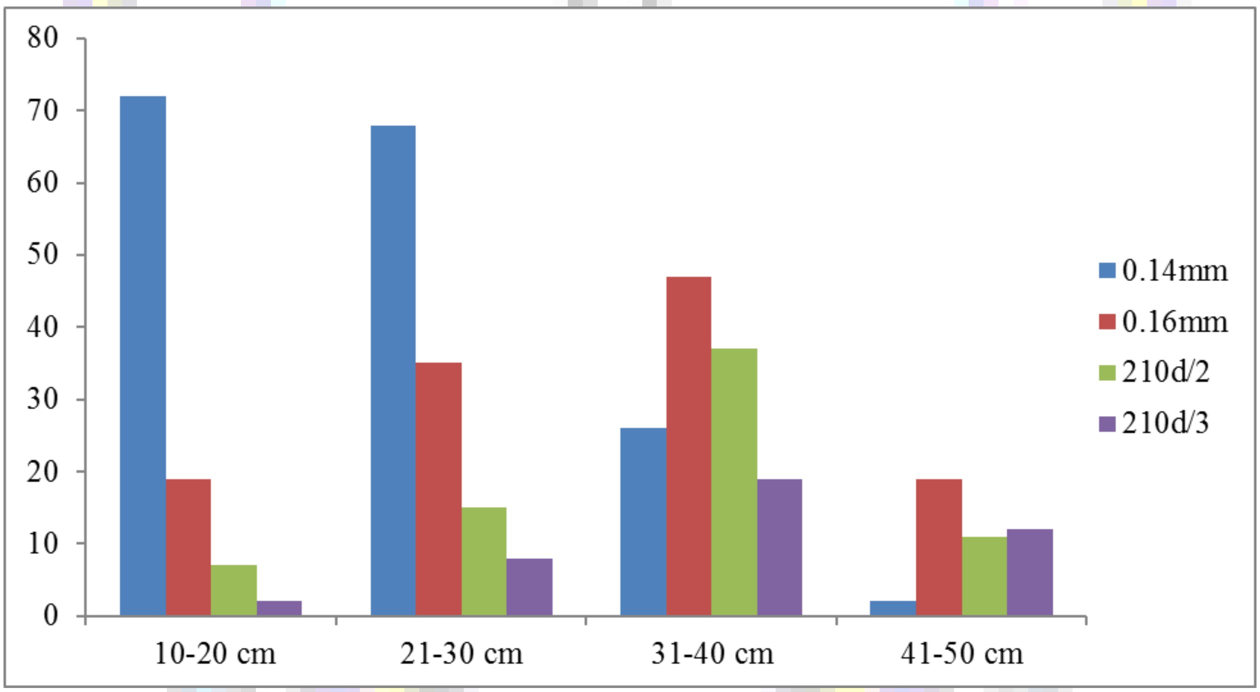


**Figure 1: Size of fish caught by different twine size gillnets**

**Relative Efficiency and One-way Analysis of Variance of fish weight caught by different twine sizes**

Table 3 shows relative efficiency (RE) and One-way Analysis of Variance of fish weight caught by different twine sizes**.** Gillnet with 0.14 mm twine size had the highest relative efficiency (0.32), followed by 0.16 mm gillnet (0.23) and 210d/3 twine size gillnet had the lowest relative efficiency (0.08). The result of this study agrees with Holst *et al.* (2002) discovered that thinner thread achieved greater fish capture efficiency than thicker string. Based on One way Analysis of

Variance of the weight of fish caught by different twine sizes, 0.14 mm and 0.16 mm twine size gillnet had no significant difference (P>0.05) between them, but there is significant difference (P>0.05) between 0.14 mm and 210d/3 and 210d/3.

**Table 3: Relative Efficiency and one-way Analysis of Variance of fish weight caught by different twine sizes**

| Twine size | Relative Efficiency | Average weight |
|---|---|---|
| **0.14 mm** | 0.32 | $1.77 \pm 1.89^{a}$ |
| **0.16 mm** | 0.23 | $1.46 \pm 1.52^{ab}$ |
| **210d/2** | 0.14 | $0.97 \pm 1.00^{bc}$ |
| **210d/3** | 0.08 | $0.60 \pm 0.66^{c}$ |

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The results from this finding indicate that twine size significantly influences catch composition, Relative Efficiency (RE) and size of fish. Monofilaments gillnet with 0.14 mm twine size demonstrated superior catch performance in terms of numbers, weight and relative efficiency. However, this twine size also resulted in a significantly higher catch of undersized fish, which is a major concern for sustainable fisheries management. In contrast, 0.16 mm, 210d/2 and 210d/3 gillnets caught larger fish, aligning with the objective of targeting sizable fish and minimizing capture of undersized fish which could lead to growth overfishing.

### Recommendations

1. To minimize catch of sizable fish and avoid undersized fish, 0,16 mm, 210d/2 and 210d/3 twine size gillnets are recommended for use in gillnet fisheries.
2. 0.14 mm twine size gillnet, although efficient in terms of catch quantity, should be avoided due to its tendency to catch smaller fish, potentially contributing to growth overfishing.
3. Further research on twine size and mesh size combinations be carried out in order to optimize eco-friendly gillnet design.

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# PHYTOCHEMICAL ANALYSIS AND EFFECT OF ETHANOLIC EXTRACT FROM LEMON PEELS (*Citrus limon*) ON THE SENSORY QUALITY OF SMOKED *Oreochromis niloticus*

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## ABSTRACT

The research titled "phytochemical examination and effect of ethanolic extract from lemon peels (*citrus limon*) on the sensory quality of smoked fish (*Oreochromis niloticus*)" was carried out in order to use *Citrus limon* as a preservative to prolong the shelf life of the smoked *Oreochromis niloticus*. The lemon epicarp was peeled off manually with the aid of a sharp knife, 40g of the lemon peel and 100g of 95% alcohol was used for extraction. The peels were pounded in to a coarse mash using pestle and mortar and were poured into three (3) different glass beakers for first, second and third runs of the experiment and ethanol was added to it and stirred and was allowed to stand for 48 h. The extract was filtered with the aid of Muslin cloth into a glass beaker and was heated in the water bath chamber for about 24h at a temperature of (78°C) and allowed to cool for qualitative and quantitative phytochemicals analysis. The smoking was done using the improved GTZ smoking kiln at a temperature of 100°C for eight (8) h. The lemon extract was rubbed on the smoke dried fish ready for sensory evaluation. The sensory evaluation was conducted by selected students comprising 20 judges from different departments. The panellists were oriented prior to the sensory tests. The fish specimens were coded and presented to the panellists individually. They all evaluated the samples for appearance, taste, aroma, texture and overall acceptability using a nine hedonic point (Jaclyn *et al*., 2014), where 1 was the lowest score and 9 the highest. Qualitative analysis revealed that four compounds were present: alkaloid, flavonoid, tannin, and steroid. The flavonoid, tannin and steroid had a strong level of concentration. Ethanolic extract revealed five compounds which are alkaloids, flavonoids, tannin, steroid, and triterpenoid. In this extract, only flavonoid and tannin were present in strong level of concentration. The study showed that the extracts of lemon peel possess phytochemicals which have anti-bacterial and anti-fungal effects. There was significant difference in appearance and texture, but there was no significant difference in aroma, taste and overall acceptability. Commercialization of this product can contribute to diversification in the fish industry through better utilization of undersized tilapia. This study concluded that various phytochemicals are present in the lemon peel have anti-bacterial and anti-fungal properties that could enhance smoked fish preservation. Also, the study revealed a significant difference in appearance and texture and an insignificant difference in aroma, taste and overall acceptability of smoked *Oreochromis niloticus*. It is recommended that lemon peel be used as an alternative preservative for smoked fish.

**Keywords**: Ethanolic extract, lemon peel, phytochemicals, smoked fish, *Oreochromis niloticus*, sensory evaluation.

## INTRODUCTION

Fish is a food of excellent nutritional value, providing high quality protein and a wide variety of vitamins and minerals, including vitamin A and D phosphorus, magnesium, selenium and iodine. Its protein, like that of meat is easily digestible and favourably complements dietary protein provided by cereals and legumes that are typically consumed in many developing countries (Ahmed *et al*, 2006). Experts agree that, even in small quantities, fish can have a significant positive impact in improving the quality of dietary protein by complementing the essential amino acids that are often present in low qualities in vegetable based diet. Recent research shows that fish is much more than just an alternative source of animal protein. Fish oil in fatty fish is the richest source of a type of fat that is vital to normal brain development in unborn babies and infants. Without adequate amount of these fatty acids, normal brain development does not take place (Dupart *et al.,* 2002). Post-harvest losses of fish reached thirty-five percent (35%) which is nearly twenty-five million tons of the word's fishing catch (Kanaze *et al.,* 2008). In some developing countries such as Nigeria, post-harvest losses of fish exceed those of other commodities often surpassing fifty (50) per cent of the landed catch (Droby *et al.,* 2000). The losses are highest in the countries whose population have could increase protein availability improve nutritional status and eliminate some of the need to import food post-harvest of fish occur during the numerous steps from catch to market. Lack of appropriate methods to preserve the catch on board result in heavy losses. Additional losses occur in the period after docking and before marketing.

Processing fish involves primarily the application of preservation techniques in order to retain quality and increase shelf life. It may also deal with value addition to produce a wide variety of products (Sofowara, 2004). The first and most obvious handling technique for preserving the quality of fish is to keep them alive for as long as possible before cooking and consumption. A number of methods are used to preserve fish, some preservation techniques are based on temperature control by the use of ice, refrigeration or freezing while others involve the control of water activity of fish such as drying, salting, smoking and freeze – drying (Uchechi *et al.,* 2010). Citrus is one of the most important commercial fruit crops grown in all continents of the world (Tao *et al,* 2008). Importance is attributed to its diversified use and growing world demand with about 102.64 million tonnes total world production and probably stands first largest among the produced fruit (Harbone *et al*., 1998). Citrus fruits are mainly used by juice processing industries while the peels are generally wasted since the juice yield of citrus is less half of the fruit weight. Therefore, a very large amounts of by – product wastes such as peels are formed every year (Manthey and Grohnann, 2001). Peel wastes which are mainly perishable and seasonal are a problem to the processing industries and pollution monitoring agencies. There is always an increased attention in bringing useful productions from waste materials end and fruit wastes are no exceptions. Suitable methods have to be adopted in utilizing them for the conversion into value added products (Manthey and Grohnann, 2001).

The citrus peels are rich in nutrients and contain many phytochemicals they can be efficiently used as drugs (Ahmed *et al*., 2006). The peel of citrus fruit is a rich source of many polymethoxylated compounds which are very rare in other plants (Ahmed *et al.,* 2006). The antimicrobial abilities of essential oils, among which citrus oils are, have also shown to be a particularly interesting field for application within the food and cosmetic industries (Ahmed *et al.*, 2006). Lemon is a small densely and irregularly branched evergreen tree, about 5m tall and, twin armed with short stiff sharp spines. Limes are divided horticulturally into acid and sweet lime (Ahmed *et al*., 2006). Lemon fruit and juice are excellent sources of vitamin C (containing more than the minimum daily requirements of 60 mg of vitamin; (240mL of folic acid, vitamin B complex, thiamine and potassium (Nagy, 2003). Therefore, the objective of this study was to obtain an ethanolic extract, carry out the phytochemical screening (qualitative and quantitative) of the ethanol extract of lemon peels and evaluate the sensory properties of smoked tilapia treated with lemon peel extract.

## MATERIALS AND METHODS

The materials used in this experiment were: lemon (*Citrus limon*), two rubber bowls, ethanol (absolute), Muslin clothe, pestle and mortar glass beaker, water bath, knife, sample bottle, slab and dish plates. The lemon epicarp was peeled off manually with the aid of a sharp knife, 40g of the lemon peel and 100g of 95% alcohol was used for extraction. The peels were pounded in to a coarse mash using pestle and mortar and were poured into three (3) different glass beakers for first, second and third runs of the experiment and ethanol was added to it and stirred and was allowed to stand for 48 h. The extract was filtered with the aid of Muslin cloth into a glass beaker and was heated in the water bath chamber for about 24h at a temperature of (78°C) and allowed to cool for qualitative and quantitative phytochemicals analysis. The smoking was done using the improved GTZ smoking kiln at a temperature of 100ºC for eight (8) h. The lemon extract was rubbed on the smoke dried fish ready for sensory evaluation. The sensory evaluation was conducted according to Jaclyn *et al*., 2014 by selected 20 man panellists from different Departments of Federal College of Freshwater Fisheries Technology New Bussa, Niger State. The panellists were oriented prior to the sensory tests. The fish specimens were coded and presented to the panellists individually. They all evaluated the samples for appearance, taste, aroma, texture and overall acceptability using a nine hedonic point (Jaclyn *et al*., 2014), where 1 was the lowest score and 9 the highest.

### Source of Materials

The lemon was bought from a nearby garden situated in Federal College of Freshwater Fisheries Technology Staff Quarters New Bussa, Borgu Local Government, Niger state.

**Qualitative Analysis**

The extracts were analyzed for the presence of alkaloid, flavonoid, tannin, steroids, and triterpenoids.

**Alkaloid Test**

This was carried out according to the method described by Harbone, (1998**).** Five (5) $cm^3$ of the extract was added to $2cm^3$ of hydrochloric acid (HCL). To this acidic medium, $1cm^3$of dragendroff's reagent was added, an orange/red precipitate/turbidity was produced immediately indicating the presence of alkaloid.

**Flavonoid Test**

This was carried out using the method of Harbone (1998), Three (3) $cm^3$ of the extract was added to $1cm^3$ of sodium hydroxide (NaOH) a yellow colouration indicated a positive test for flavanoid.

**Tanin Test**

This was carried out according to the method of Harbone (1998). Two drops of 5% $Fecl_3$ (Iron iii chloride) was added to $3cm^3$ of the extract and the presence of a precipitate indicates the positive for the presence of tannin

**Salkowki's Test for Steroids**

This was carried out according to the method of Harbone (1998). To $1cm^3$ extract, 5 drops concentrated hydrogen tetraoxosulphate (vi) acid was added. A red coloration indicates a positive test for steroid.

**Triterpenoids Test**

This was carried out according to the method described by Odebiyi (1978). Ten (10) mg of the extract was dissolved in 1cm' of chloroform; 1cm' of acetic anhydride was added following the addition of $2cm^3$ of $H_2SO_4$. Formation of reddish violent colour indicated the presence of triterpenoid.

**Quantitative Analysis of Phytochemical**

**Determination of alkaloids**

This was done by alkaline precipitation gravimetric method described by (Harbone 1998). A measured weight of the sample was dispersed in 95% acetic acid solution. The mixture was allowed to stand for 24h. The filtrate was concentrated to one-quarter of its original volume by evaporation and treated with drop wise addition of concentrated aqueous ammonium hydroxide ($NH_4OH$) until the alkaloid was precipitated. The alkaloid precipitate was collected by filtration, washed with 1% ammonia solution dried in the oven at 80°C

**Determination of flavonoids**

This was determined according to the method of Harbone (1998). Three hundred (300) g of the same sample was boiled in 150mL of 2M HCL solution for 30min under reflux. It was allowed to cool and then filtered through Whatman No 42 filter paper. A measured volume of the extract was treated with equal volume of ethyl acetate starting with soap. The flavonoid precipitate was recovered by filtration using weighed filter paper. The resulting weight difference gave the weight of flavonoid in the sample.

**Determination of tannins**

This was determined by Van Borden and Robinson (1981) method- 500mg of the sample was weighed in a 50mL glass beaker. Fifty (50) mL of distilled water was added and shaken for 1h in a mechanical shaker. This was filtered in to a 50mL volumetric flask and up to the mark. Then 50mL of the filtered was pipetted out into test tube and mixed with 2ml of 0.1N HCl and 0.008M potassium ferrocyanide. The absorbance was measured at 120nm within 10min.

**Determination of saponin**

The method used was that of Obadoni and Ochuko (2001). The sample was grinded and 20g of it was put in a conical flask and 100cm³ of 20% aqueous ethanol was added. The sample was heated over a hot water bath for four hours with continuous steering at about 55°C. The mixture filtered and the residue re-extracted with another 200ml 20% ethanol. The combined extract was reduced to 4ml over water bath at about 90°C. The concentrate was transferred into a 250ml separating funnel and 20ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. 60ml n-butanol was added. The combined ethanol extract was washed twice with 10ml of 5% aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the sample was dried in the oven to constant weight. The saponin content was calculated as percentage.

**Statistical Analysis**

Data obtained from the study was statistically analysed using Analysis of Variance (ANOVA) and the means separated using the Duncan Multiple Range Test according to Sanders (1990) using the statistical package SPSS 17.

## RESULTS

### Table 1: Qualitative analysis of phytochemical screening on lemon extract

| S/No. | Physiochemical | Result |
|---|---|---|
| 1. | Alkaloid | ++ |
| 2. | Flavonoid | +++ |
| 3. | Saponin | +++ |
| 4. | Tannin | ++ |
| 5. | Cardiac glycoside | - |
| 6. | Reducing sugar | +++ |
| 7. | Quinone | ++ |
| 8. | Phenol | ++ |
| 9. | Terpenoid | ++ |
| 10. | Triperpenoid | - |
| 11. | Steroid | + |

**KEY**

+ = Present; - = Absent; ++ = Strong presence; +++ = Highly strong presence

### Table 2: Phytochemical analysis in % of ethanolic extract of lemon

| S/No. | Physiochemical | Percentage |
|---|---|---|
| 1. | Alkaloid | 0.0185 |
| | | 0.0208 |
| 2. | Flavonoid | 0.5060 |
| | | 0.5840 |
| 3. | Tannin | 0.0360 |
| | | 0.0410 |
| 4. | Saponin | 0.0340 |
| | | 0.0280 |

Table 3: Sensory Evaluation

| Sample | Appearance | Aroma | Taste | Texture | General Acceptability |
|---|---|---|---|---|---|
| A (0.5g/ml) | $7.35\pm1.73^{a}$ | $6.45\pm1.67^{a}$ | $7.20\pm1.67^{a}$ | $7.35\pm1.14^{a}$ | $7.40\pm1.70^{a}$ |
| B (0.25g/ml) | $5.85\pm1.14^{b}$ | $6.45\pm1.50^{a}$ | $7.70\pm1.26^{a}$ | $6.20\pm2.12^{b}$ | $6.65\pm1.76^{a}$ |
| C (Control) | $6.40\pm1.68^{ab}$ | $6.05\pm1.57^{a}$ | $7.45\pm1.52^{a}$ | $6.15\pm1.74^{b}$ | $7.15\pm1.70^{a}$ |

Mean standard deviation values with different superscripts letters in a column differ significantly at P<0.5

$$\% \text{ yield} = \frac{50.86 \times 100}{1000} = 5.086\ \%$$

KEY: Lemon Extract: Sample A = (0.5g/ml); Sample B = (0.25g/ml); Sample C = (Control)

## DISCUSSION

The Tables 1, 2 and 3 showed the level of concentration of the compound obtained from the lemon (*Citrus limon*). In the quantitative analysis, two compounds were related only, namely, alkaloid and flavonoid which shows high concentration of the compound. Therefore, the resistance of these *et al* compounds to the effect of heat in the ethanol extract is in line with the report of Anderson *et al*., (2002) that phytochemicals are not affected by processing. Generally, heating does not affect the alkaloid and flavonoid content of the peels. This indicates that alkaloid and flavonoid remained stable during heating, though there was slight reduction in the alkaloid and flavonoid content in the ethanolic extract.

A study by Prakash *et al.,* (2017) also explored the phytochemical composition of lemon (Citrus limon), identifying several bioactive compounds, including flavonoids, alkaloids, phenols, and terpenes. This study highlighted the presence of these compounds in the peel, with particular emphasis on flavonoids like rutin and hesperidin, which are known for their antioxidant and anti-inflammatory properties. The stability of these phytochemicals under different conditions was also examined, noting that heat processing may reduce certain compounds, but many remain resilient to changes during cooking or extraction.

There was no significant difference ($p>.0.05$) in the colour, aroma, taste, and overall acceptability of smoked tilapia fish. There was a significant difference ($p<0.05$) in the appearance and texture of the smoked tilapia fish. A relevant research by **Akinmoladun et al., (2020)** focused on the sensory evaluation of *Oreochromis niloticus* (Nile tilapia) treated with lemon peel. This research explored the effects of lemon peel extract on the sensory properties of preserved tilapia fish. The study found that while there were no significant differences in aroma and taste among the samples treated with lemon peel, significant changes were observed in the texture and appearance of the fish, similar to the effects seen in smoked tilapia. These results highlight the potentials of lemon peel as a natural preservative while maintaining the overall acceptability of the fish.

## CONCLUSION AND RECOMMENDATION

The study demonstrates that lemon (*Citrus limon*) peels possess phytochemical compounds which have anti-bacterial anti-fungal properties. The study also revealed that the treatments of the smoked tilapia (*Oreochromis niloticus*) using ethanol extract of lemon peels did not have any negative effects on the sensory properties of the fish; it rather improved the appearance and texture of the smoked fish.

The following recommendations are made;

Lemon peel should be used as a preservative since it contains phytochemicals that possess anti - fungal and anti-bacterial properties.

Oils from other citrus species should be experimented to determine the outcome of its usage and be compared with the result obtained from this study.

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# GROWTH PERFORMANCE AND GUT MICROFLORA COUNTS OF ROSS 308 BROILER CHICKENS FED PROBIOTIC BASED DIET AT THE STARTER PHASE

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## ABSTRACT

This study was conducted to evaluate the effect of probiotics on growth performance, nutrient digestibility, and gut microflora of broiler chicken at the starter phase. A total of thirty (30) broiler chickens were randomly allotted to five treatments groups, with each group consisting of three replicates with each replicate containing two chickens. The treatments were as follows: T1 (control no probiotics), T2 (5.50g of oxytetracycline), T3 (6.25g of probiotics), T4 (12.50g of probiotics) and T5 (18.50g of probiotics). Data were collected on growth performance, nutrient digestibility, and gut microflora counts. The results indicated a significant ($P<0.05$) difference on total and daily feed intakes while the final weight, total weight gain, daily weight gain and feed conversion ratio were not significantly ($P>0.05$) different among dietary treatments. For the nutrient digestibility, dietary treatment had significant effect ($P < 0.05$) on crude fibre, ash, and ether extract while there were no significant ($P>0.05$) differences on crude protein, nitrogen free Extract, dry matter, and total digestible nutrient. Findings on the gut microflora showed that there was no significance ($P>0.05$) difference in *Lactobacillus* sp. (LS), *Pediococcus acidilactici* (PA), *Streptococcus acidophilus* (SA), *Escherichia coli* (EC), *Streptococcus pneumoniae* (SP), *Bacillus cereus* (BC) across all treatments. It was concluded that the addition of probiotics to broiler diets could improve feed intake and nutrient digestibility. Hence poultry farmer should include it in their broiler chicken diets at the starter phase at 6.25g to enhance fast growth rate in broiler chicken.

**KEYWORDS:** Growth Performance, Nutrient Digestibility, Gut Microflora, Probiotics, Broiler Chickens

## INTRODUCTION

The global livestock industry is continuously seeking ways to enhance product quality, improve animal performance, and boost profitability. The gut microbiota, a complex community of microorganisms in the gastrointestinal tract, plays a vital role in immunological regulation, nutrient absorption, and digestion (Singh *et al*., 2019; Shang *et al*., 2018). Poultry production particularly that of broiler chickens, serves as a major source of high-quality protein for an ever-growing population, making it essential for global food security (Food and Agricultural Organization, 2023). Broilers are valued for their rapid growth and efficient feed conversion, contributing significantly to the economy (Aviagen, 2024). The steady increase in the cost of chicken feed ingredients and multiplied feed is limiting revenues for poultry growers. The gut microbiome, a diverse ecology of bacteria in the intestines, is essential for immune function, digestion, and defense against pathogens (Coles *et al*., 2019). The growing concerns about antibiotic-resistant bacteria and antibiotic residue in meat and eggs, the chicken industry is reducing its use for growth promotion (Mashayekhi *et al*., 2018) and because of this problem, there is a rising concern about finding safer replacements for the use of antibiotics for growth promotion in broiler production. Probiotics are being assessed as effective alternatives to antibiotics and possibly can promote growth effects, antibacterial properties, and other health-related advantage. They also function by promoting food absorption, balancing the population of good bacteria in the intestines, and preventing the formation of dangerous infections (Hill *et al*., 2014). The intestinal health of broiler chickens directly affects their performance, overall well-being, and nutrient utilization (Gilmour *et al*., 2019).To ensure a sustainable and productive chicken industry, it is crucial to optimize the health and performance of these animals. As a result, the aim of this study is to investigate the effects of adding locally manufactured probiotics on the growth performance, apparent nutrient digestibility, and gut microflora response of Ross 308 broiler chickens at the starter phase.

## MATERIALS AND METHODS

### Experimental Design

The research was carried out at the Department of Animal Production Teaching and Research Farm of the Federal University of Technology, Minna, Niger State, Nigeria. Minna is located within latitude 931'18.2 N and longitude 6°27'4940°E, the annual rainfall is between 1100 and 1600mm. A total of thirty broiler chickens (Ross308) were used for this study. The chicks were allocated to five (5) dietary experimental treatments with three (3) replicates in each treatment in a completely randomized design and were fed with the experimental diet for the period of seven (7) weeks. Treatment 1 served as the positive control while treatment 2 contain 5.50g of antibiotics (oxytetracycline), treatment 3,4 and 5 contains 6.25g, 12.50g and 18.50g of probiotics respectively.

### Management of Birds

The poultry house was cleaned and disinfected before the arrival of birds. The source of ventilation was properly covered for brooding purpose and heat source was provided accordingly. On the day of the birds' arrival, anti-stress (glucose) was administered and on the 7th day of their arrival, Gumboro vaccine IBDV (infectious bursal disease virus) was utilized for immunity against coccidiosis. On the 14th day, Lasota vaccine was administered for immunity against Newcastle disease and these vaccines were repeated on 21st and 28th day respectively. Water was provided *ad libitum.* All management practices and health recommendations were strictly abided by.

### Preparation of Probiotics

The dried probiotic was produced using fermented rice water, following a methodical procedure of Thilagavathi *et al*., (2019). Rice was soaked in clean water for 7 days to encourage natural fermentation. This process allowed the growth of *Lactobacillus* bacteria, known for their probiotic properties. After the fermentation period, the liquid was strained to remove solid rice particles, leaving behind the nutrient-rich fermented rice water containing the beneficial bacteria. To convert this liquid into a dry form, maize bran was used as a carrier to absorb the moisture from the probiotic liquid. The mixture was stirred thoroughly to ensure that the probiotic liquid was evenly distributed across the maize bran. Following this, the mixture was spread in thin layers and left to air dry under sunlight. Once dried, the mixture was grounded into a fine mash using an electric grinder. The dry probiotic produced was then stored in an airtight container in a cool, dry place for long-term preservation before been used at different inclusion levels.

**Data collection**

Data were collected on the growth performance, nutrient digestibility and gut microflora of Ross 308 broiler birds raised under the intensive system of management. The apparent nutrient digestibility was conducted on the third week of the experiment. Total collection method was adopted, and digestibility trial was performed in single bird battery cages for seven days. Three broiler chickens were randomly selected for each replicate and acclimatized for three days. The birds were off feed overnight between 7:00pm to 7:00am for 12 hours prior to fecal collection but allow free access to water, aside to the respective diets supplemented with Nano zinc® and Selenium® for four days. Each cage was fastened with a plastic sheet for the collection of total excreta. The droppings of the birds in each replicate where collected, preserve with boric acid in aluminum foil paper, oven-dried at 90°C and recorded daily on (dried matter basis). The proximate composition of the feeds and feaces were determined and nutrient digestibility of the birds were evaluated using the formula:

$$\frac{\textbf{Nutrient in feed intake} - \textbf{nutrient voided in feaces}}{\textbf{nutrient in feed intake}} \times \mathbf{100}$$

The general procedures for gathering the intestinal microbiota of broiler chicken are as follows:
i. Get a sterile container to hold the sample collection.
ii. After choosing the birds for sample, move them to a hygienic location.
iii. To reduce tension and discomfort, anesthetize the chick using a technique that has been approved.
iv. Gather the sample with a sterile swab or another suitable technique for sampling.
v. To gather the microflora, gently swab the chicken crop, throat and inside of its mouth.
vi. Seal the sterile container after inserting the swab for sample.

**Data Analysis**

Data collected on growth performance, nutrient digestibility and gut microflora were subjected to one-way analysis of variance (ANOVA) of completely randomized design using statistical system (SAS, 2012). Where the means were significant, they were separated using Duncan multiple range test.

**Table 1: Effects of probiotics on the growth performance of Ross 308 broiler chicken at the starter phase**

| Parameters | T1 | T2 | T3 | T4 | T5 | SEM | P-Value | LS |
|---|---|---|---|---|---|---|---|---|
| Initial body weight (g) | 46.00$^{a}$ | 42.66$^{b}$ | 43.33$^{ab}$ | 44.30$^{ab}$ | 44.67$^{ab}$ | 0.39 | 0.035 | * |
| Final body weight (g) | 677.66 | 649.00 | 673.33 | 703.66 | 685.66 | 7.76 | 0.275 | N.S |
| Total Weight Gain (g) | 631.66 | 606.33 | 630.00 | 659.36 | 640.99 | 7.60 | 0.292 | N.S |
| Daily Weight Gain (g) | 22.56 | 21.65 | 22.50 | 23.55 | 22.89 | 0.27 | 0.293 | N.S |
| Total Feeding (g) | 1392.11$^{c}$ | 1454.66$^{b}$ | 1538.77$^{a}$ | 1454.66$^{b}$ | 1520.78$^{a}$ | 14.31 | 0.000 | * |
| Daily Feeding (g) | 49.71$^{c}$ | 52.36$^{b}$ | 54.95$^{a}$ | 51.95$^{b}$ | 54.31$^{a}$ | 0.51 | 0.000 | * |
| FCR | 2.21 | 2.42 | 2.44 | 2.21 | 2.37 | 0.03 | 0.022 | * |

a,b,c: means in the same column are significantly ($p<0.05$) different, *** = Significant difference ($p<0.05$), T1: Control, T2: (5.50g of oxy-tetracycline), T3: (6.25g of probiotics), T4: (12.50g of probiotics), T5: (18.50g of probiotics), SEM: Standard Error of Mean, LS: Level of Significant, NS: Non-Significant

**Table 2: Effects of probiotics on the digestibility of Ross 308 broiler chicken at the starter phase**

| Parameter | T1 | T2 | T3 | T4 | T5 | SEM | P-value | LS |
|---|---|---|---|---|---|---|---|---|
| CP | 68.78 | 71.30 | 70.01 | 71.16 | 71.98 | 0.97 | 0.89 | NS |
| CF | 45.80$^{ab}$ | 55.66$^{a}$ | 32.14$^{c}$ | 24.05$^{c}$ | 34.80$^{bc}$ | 3.09 | 0.00 | * |
| ASH | 31.73$^{c}$ | 44.27$^{ab}$ | 52.20$^{a}$ | 26.64$^{c}$ | 35.46$^{bc}$ | 2.60 | 0.00 | * |
| EE | 50.23$^{ab}$ | 55.06$^{a}$ | 40.48$^{bc}$ | 34.59$^{c}$ | 30.07$^{c}$ | 2.66 | 0.00 | * |
| NFE | 57.22 | 54.38 | 52.95 | 54.75 | 53.77 | 1.00 | 0.78 | NS |
| DM | 89.11 | 89.09 | 94.39 | 94.72 | 94.21 | 1.16 | 0.29 | NS |
| TDN | 59.48 | 60.35 | 58.04 | 55.97 | 56.77 | 1.02 | 0.70 | NS |

a,b,c: means in the same column are significantly ($p<0.05$) different; *** = Significant difference ($p<0.05$); T1: Control; T2: (5.50g of oxy-tetracycline); T3: (6.25g of probiotics); T4: (12.50g of probiotics); T5: (18.50g of probiotics); SEM: Standard Error of Mean; LS: Level of Significant; NS: Non-Significant

**Table 3: Effects of probiotics on the gut microflora of Ross 308 broiler chicken at the starter phase**

| Parameter,(µm) | T1 | T2 | T3 | T4 | T5 | SEM | P-Value | LS |
|---|---|---|---|---|---|---|---|---|
| KP | 216333.33 | 246000.00 | 302000.00 | 2293333.33 | 566666.66 | 348492.00 | 0.282 | NS |
| PA | 600000.00 | 683333.33 | 723333.33 | 2310000.00 | 2386666.66 | 452819.17 | 0.566 | NS |
| SA | 480666.66 | 656666.66 | 570000.00 | 2160000.00 | 556666.66 | 325265.00 | 0.472 | NS |
| EC | 252333.33 | 428000.00 | 530000.00 | 640000.00 | 533333.33 | 58282.76 | 0.302 | NS |
| SP | 215000.00 | 563333.33 | 510000.00 | 2193333.33 | 2346666.66 | 459899.21 | 0.464 | NS |
| BC | 553333.33 | 653333.33 | 370000.00 | 410000.00 | 1686666.66 | 243363.07 | 0.452 | NS |

KP: *Klebsiella pneumonia*., PA: *Pediococcus acidilactici*, SA: *Streptococcus acidophilus*, EC: *Escherichia coli*, SP: *Streptococcus pneumonia*, BC: *Bacillus cereus*, T1: Control, T2: (5.50g of oxytetracycline), T3: (6.25g of probiotics), T4: (12.50g of probiotics), T5: (18.50g of probiotics), SEM: Standard Error of Mean, LS: Level of Significant, NS: Non-Significant

## RESULTS AND DISCUSSION

Table 1 showed the results of the effects of probiotics supplemented diets on growth performance of Ross 308 broiler chickens at starter phase. The dietary treatments had effects ($P<0.05$) on total and daily feed intakes. However, the final weight, total weight gain, daily weight gain and feed conversion ratio were not ($P>0.05$) affected by probiotic supplementations. Chickens on T3 and T5 had higher ($P<0.05$) total (1538.77g), (1520.78 g) and daily (54.95 g), 54.31 feed intakes, respectively, when compared to the other treatments. The birds on T2 and T4 also had higher ($P<0.05$) total and daily feed intakes when compared to those on the control diet which had the least values. The results were similar with the study by Hafez *et al.,* (2022) who found that probiotic supplementation enhanced feed consumption but did not significantly impact weight gain or FCR during the starter phase. The higher feed intake in T3 and T5 is similar with the study by Wang *et al.,* (2023), who observed increased feeding in probiotic-supplemented broilers. However, in a study by Liu *et al.,* (2021), it was stated that the starter phase may be insufficient for translating increased feed intake into enhanced growth performance, because the gut microbiota is still stabilizing. The higher feed intake in the antibiotic group (T2) compared to control agrees with the Gilmour *et al.,* (2019), where it was suggested that both probiotics and antibiotics can stimulate appetite through different mechanisms, although it does not improve feed efficiency during the starter phase. The significant ($P<0.05$) different in total and daily feed intake observed in probiotic-supplemented groups (T3 and T5) agrees with the work of Mountzouris *et al.,* (2010), who reported enhanced feed consumption in broilers fed probiotic-enriched diets.

Table 2 shows the results of the effect of probiotics supplemented diets on Digestibility of Ross 308 broiler chickens at starter phase. The dietary treatment had significant effects ($P < 0.05$) on crude fibre, ash and ether extract, However, crude protein, nitrogen free extract, dry matter and total digestible nutrient were not ($P>0.05$) affected by probiotics supplementations. Chickens on T3, T4, T5 showed higher ($P<0.05$) dry matter digestibility (94.39%, 94.72%, 94.21%) respectively, compared to the control and antibiotic T1 and T2 treatments. While T2 (antibiotic) showed the highest TDN value (60.35%), the birds on the control group T1 and T5, also had the highest NFE digestibility (57.22%) and crude protein digestibility (71.98%) respectively. In agreement to this finding, Liu *et al.,* (2021) reported that crude fibre, ether extract, and ash were significantly ($p<0.05$) different among treatment groups. In their study, probiotics enhanced fibre utilization through increased fibrolytic enzyme production. However, improved ether extract digestibility aligns with Kumar *et al.,* (2023), who attributed this to enhanced bile salt activity in probiotic-supplemented broilers. The non-significant ($p>0.05$) difference on crude protein digestibility, despite improvements in T5, does not agree with Zhang *et al.,* (2022), who found variable protein utilization responses to probiotics. Higher dry matter digestibility in probiotic treatments (T3-T5) agrees with findings by Rodriguez-Sanchez *et al.,* (2020), although they observed significance differences. The improved ash digestibility supports Wang *et al.,* (2023) findings of enhanced mineral utilization, possibly due to lower intestinal pH from probiotic activity. The highest TDN in the antibiotic treatment (T2) agrees with Singh *et al.,* (2019), suggesting different mechanisms of action between probiotics and antibiotics.

The results of the effects of probiotics supplemented diets on gut microflora of Ross 308 broiler chickens at starter phase are shown in Table 3. It was found that there was no significance ($P>0.05$) difference in *Lactobacillus sp*. (LS), *Pediococcus acidilactici* (PA), *Streptococcus acidophilus* (SA), *Escherichia coli* (EC), *Streptococcus pneumoniae* (SP), *Bacillus cereus* (BC) across all treatments. The non-significant ($P>0.05$) difference in the population of *Lactobacillus sp*. (LS), *Pediococcus acidilactici* (PA), Streptococcus acidophilus (SA), Escherichia coli (EC), Streptococcus pneumoniae (SP), *Bacillus cereus* (BC) across all treatment suggests that the treatments do not affect the microbial population. This may indicate that varied amount of antibiotics (Oxytetracycline) and probiotics may have influenced these outcomes. This finding was similar to the study by Cengiz *et al*. (2015) who reported that there was no effect ($P > 0.05$) on total aerobes, *Salmonella sp*., and *Lactobacilli* populations in the intestines of broilers.

**CONCLUSION**

This study showed that the supplementation of probiotics at the starter phase improved feed intake significantly, although it had no effect in improved growth outcomes like weight gain or feed conversion ratio. However, probiotics showed some improvements in digestibility measures, with probiotic-containing treatments displaying higher dry matter digestibility than both the control and antibiotic groups. The lack of significant changes in gut microbiota between treatments indicates that probiotics did not significantly affect the intestinal bacterial population during the starter phase. From this study’s findings, probiotics should be used with caution during the starter phase, particularly to promote nutrient digestibility, since it improves the dry matter digestibility. However, farmers should examine the economic impacts, as greater feed intake did not result in improved growth performance. In addition, further study may be required to improve probiotic supplementation to determine the growth outcomes during the starter phase of broiler production.

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# ASSESSING THE EFFECTS OF GRADED LEVEL OF GINGER (*ZINGIBER OFFICINALE*) ON THE GROWTH PERFORMANCE OF QUAILS (*Coturnix coturnix japonica*)

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## ABSTRACT

This study evaluates the efficacy of ginger as a natural feed additive in the diet of Japanese quails, focusing on its impact on growth performance. Recognizing the antibacterial, anti-inflammatory, antiseptic, anti-parasitic, and immunomodulatory properties of ginger, the research aims to address the insufficient documentation regarding its influence on quail growth. Conducted at the Teaching and Research Farm of the Federal University of Technology, Minna, Nigeria, the experiment involved ninety quails of two-weeks-old divided into three treatment groups, with varying levels of ginger powder incorporated into their diets. The results indicated significant improvements in body weight gain and final weight among quails fed a diet containing 2.5% ginger, suggesting that ginger can enhance growth performance. The study also observed that while higher levels of ginger reduced feed intake, they improved feed conversion ratios, indicating enhanced feed efficiency. Overall, the findings support the inclusion of ginger powder in quail diets, up to 2.5% for optimal growth benefits. This research contributes to the potential use of affordable natural additives to enhance poultry nutrition and improve animal protein availability.

**Keywords:** Quails, ginger, protein, feed, weight, growth performance

## INTRODUCTION

In Nigeria, chickens appear to be the most popular of all the avian species. However, an alternative source of poultry meat and egg within a relative shorter time and at cheaper cost has been found in Japanese quails (Ojo *et al*., 2011). Quails (*Coturnix coturnix japonica*) were brought to Nigeria with the sole aim of bridging the protein gap due to its fast multiplication rate and low investment cost. It has proven to be the quickest and cheapest substitute to the expensive sources of protein (Ayanwale and Arziki, 2005). Quails, chickens, *pheasants* and patridges belong to the family *phasanoidea*; order *Galliformes* and class of *Aves* (Shim, 2005). Ginger (*Zingiber officinale*) is an underground rhizome plant that belongs to the family *Zingibeaceae* and a common constituent of diet worldwide as it is also widely used as a spice. The pungent taste of ginger is caused by gingerol which contains an enzyme called “zingibain” that aids digestion (Adulyatham and Owusu- Apenten, 2005). Antibiotic-based growth promoters have been commonly used as supplements in animal feeds for many years because they are well known to help growing animals to digest their feed more efficiently and to grow strong and healthy individuals (Sojoudi *et al*., 2012). Some of the common antibiotics used in animal feeds are virginiamycin, salinomycin, neomysin, doxycyclin and avilamycin (Kumar *et al*., 2010). The use of antibiotic-based growth promoters has faced serious criticism and global concern due to their purported hazardous effects including microbial resistance, and their potentially harmful effects on human health (Rahmatnejad *et al*., 2009). These shortcomings have led to the search for alternative substances that eliminate these threats. Recently, many countries tended to prohibit the use of antibiotics as growth promoters because of their side effect on both birds and human health. Consequently, a remarkable increase in the use of medicinal plant products has been observed in the past decade. It has been known from ancient times that essential oils from aromatic and medicinal plants possess biological activity, antibacterial, anti-helminthes, anti-fungal and antioxidant properties. Ginger (*Zingiber officinale*) has been reported to posses' useful pharmacological potent chemical substances for use in poultry (*Akhtar et al., 1984*). Consequently, such plants have attracted increasing interest as an alternative feeding strategy to replace antibiotic growth promoters. Nowadays there is increasing interest in the use of natural growth promoters such as probticsio, probiotics or their combination and medicinal plants as additives in quail's diets to enhance the performance of the birds (Khan *et al.,* 2010).

Ginger as natural feed additive in poultry nutrition has a great benefit and value especially for quails. This is due to their antibacterial, anti- inflammatory, antiseptic, anti-parasitic and immunomodulatory properties of ginger. However, the influence of ginger on growth performance has not been sufficiently documented. Thus, the aim of this study is to evaluate the efficacy of ginger as feed addictive and its subsequent influence on the growth performance of quails. Animal protein is of great importance to both human health and growth. However, availability and intake are low because of high cost. Therefore, there is a need to provide cheap sources of animal protein that can be within the reach of the populace. One way of doing this is to produce animals and birds at very low prices. There is need to check the efficacy of ginger as a feed addictive in respect to growth performance of quails.

## MATERIALS AND METHODS

**Experimental site:** The research work was carried out at the Teaching and Research Farm of the Department of Animal Production, Bosso Campus, Federal University of Technology, Minna, Niger State, Nigeria. Minna is located in the southern Guinea Savanna vegetation zone at Latitude 9˚ 28¹ N to 9˚ 37¹ N and longitude 6˚ 23¹ E to 6˚ 33¹ E, with a mean annual rainfall of 1000-1500mm and Temperature of 39-42 Celsius. (FUTMIN, 2012).

**Duration of the experiment**: The research was carried out during the first four week's age of two weeks old quails.

**Source of experimental birds and materials**: A total of Ninety (90) two weeks old quails were procured from National Veterinary Research Institute (NVRI) of Nigeria, Vom, Plateau State, Nigeria. Ginger and maize were sourced from Kure ultra modern market, Minna, Niger State. Bone meal, fish meal, ground nut cake, lime stone, premix, salt, methionine and lysine were sourced from Dominium feed adjacent U.K Bello Theater in Minna metropolis. These ingredients were used in compounding the experimental diets.

**Sample preparation**: Ginger was manually peeled and cut into chips. The chips were washed, and sun dried, ground into fine powder and then blended with other ingredients for feed formulation.

**Experimental design:** A total of ninety (90) quails were randomly and equally allotted into three treatment groups, with three replicates per treatment. Thus, there were 10 quails per replicate and 30 quails per treatment in a completely randomized design (CRD) experiment.

**Experimental diet:** Three diets were formulated using ginger powder as feed addictive. Treatment 1($T_1$) was the control diet with 0 % ginger powder, treatment 2 ($T_2$) contained 1.5 % of ginger powder, and treatment 3 ($T_3$) contained 2.5% ginger powder.

**Table 1: Percentage composition of experimental diets at starter phase**

| Ingredients | T1 | T2 | T3 |
|---|---|---|---|
| Maize | 44.40 | 44.40 | 44.40 |
| GNC | 38. 90 | 38. 90 | 38. 90 |
| Maize bran | 10.00 | 10.00 | 10.00 |
| Fishmeal | 2.00 | 2.00 | 2.00 |
| Bone meal | 2.50 | 2.00 | 2.00 |
| Methoinine | 0.10 | 0.10 | 0.10 |
| Lysine | 0.10 | 0.10 | 0.10 |
| Limestone | 1.50 | 1.50 | 1.50 |
| Premix | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 |
| Total | 100 | 100 | 100 |
| Ginger | 0% | 1.5% | 2.5% |

Calculated analysis:
Crude protein: 24%
Metabolizable energy: 33066.04

**Management of the experimental quails:** The quails were raised in battery cages. The cages were cleaned, washed and disinfected with a germicide a week before the arrival of the quails. Drinkers and feeders were cleaned, washed and disinfected before the arrival of the birds. 100 watts' electric bulbs were used for the first one week to supply the required heat while it was later replaced with 60 watts' bulbs to provide illumination at night. Additional heating source was supplied using charcoal stove and lamps. On arrival, the birds were gently unboxed into the cage. Litter was regularly turned when wet and changed weekly to ensure a healthy environment. Routine management operations carried out on daily basis include cleaning of drinkers and feeders. Weighed quantities of feed were given to each replicate daily and the left over weighed at the end of each day.

**Proximate analysis of experimental diets:** The ginger powder and the formulated experimental diets were analyzed for crude protein, crude fibre, ether extract, moisture content and ash according to the procedure outlined by A.O.A.C (2000). The chemical analysis was carried out at the Animal Production Technology laboratory of the Federal University of Technology, Minna, Niger state.

**Parameters measured**

**Body weight (g):** The initial body weight of each bird was taken before the start of the experiment using a top loading balance and quails were subsequently weighed weekly thereafter, throughout the 4 weeks of the experiment.

**Daily feed intake (g):** Weighed quantities of feed that was supplied in each replicate and the leftovers weighed at the end of each day using weighing scale weekly. Feed intake for each replicate was determined by subtracting the leftover from the total amount of feed given for the week.

**Weekly body weight gains (g)**: Weekly body weight gains for each replicate were obtained by the difference between the body weights of the new week from that of the preceding week.

**Feed conversion ratio:** From the weight gain and feed consumption of each replicate, the feed conversion ratio was computed by dividing the quantity of feed consumed by the body weight gain of the birds in each replicate using the formula

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Average daily feed intake (g)}}{\text{Average daily weight gain (g)}}$$

**Water intake**: The volume of water supply on daily basis was measured for birds in each replicate and volume consumed per day were obtained by subtracting the amount left over from the quantity given. Weekly record of average water consumption per bird was obtained for each replicate by dividing the total amount of water consumed by the number of birds in each replicate

**Statistical analysis**: All the data obtained were subjected to statistical analysis using one way analysis of variance (ANOVA) and separation of the mean values was carried out using Duncan Multiple Range Test at $P<0.05$ using SPSS (Statistical Package for the Social science) version 16.0 software.

## RESULTS

**Proximate composition of ginger powder:** Table 2 shows Proximate composition of ginger powder that ginger has moisture content of 8.60 %, dry matter of 91.40 %, ash of 8.00 %, ether extract of 12.50 %, crude fibre of 0.10 %, crude protein of 11.90 % and Nitrogen free extract 58.90 %.

**Proximate composition of experimental diets fed to Japanese quails:** Table 3 showed the proximate composition of experimental diets fed to Japanese quails. The moisture content ranged from 7.80 - 10. 96 % in diet 1, the dry matter ranged from 89.04 - 92.20 %, ash of the diets varied from 7.61 - 17.00 % with diet 2 recording the lowest ash (7.61) while diet 2 recorded the highest value. Ether extract of the diets also varied from 9.50 - 13.50 %, crude fibre content of the experimental diets ranged from 0.09 -0.10 %. The results of crude protein showed that diet 2 has 23.45 % which is the lowest and diet 3 had 28.00 % which is the highest. Nitrogen free extracts varied from 36.77 - 47.33 %.

**Performance characteristics of Japanese quails fed ginger powder**: The growth performance characteristic of Japanese quails fed graded levels of ginger powder is shown in Table 4. The results showed significant differences ($P \le 0.05$) in the body weight gain, daily feed intake, and feed conversion ratio of the Japanese quails. However, a significant difference was also seen in initial body weight which shows that diet 3 is significantly ($P<0.05$) higher compared to diet 1 and 2. In final body weight and body weight gain, diet 3 is significantly ($P<0.05$) higher than diet 2; similarly diet 2 is higher than diet 1. In daily feed intake and total feed intake, birds fed diet 1had is significantly ($P<0.05$) higher than those fed diet 2 and 3. The total water intake and daily water intake result shows that birds fed diet 2 had significantly ($P<0.05$) higher than diet 1 and 3. In feed conversion ratio, birds fed diet 1 had significantly ($P<0.05$) higher feed conversion ratio than those fed diet 2 and 3 however, birds fed diet 3 had the lowest value which is the best.

**Table 2: Proximate composition of ginger powder**

| Parameters | Composition (%) |
|---|---|
| Dry matter | 91.40 |
| Ash | 8.00 |
| Ether extract | 12.50 |
| Crude fibre | 0.10 |
| Crude protein | 11.90 |
| Nitrogen free extract | 58.90 |

Source: Authors laboratory work, 2015

**Table 3: Proximate composition of experimental diets fed to Japanese quails (%)**

| Parameters | Diet 1 | Diet 2 | Diet 3 |
|---|---|---|---|
| Moisture content | 10. 96 | 9.20 | 7.80 |
| Dry matter | 89.04 | 90.80 | 92.20 |
| Ash | 7.61 | 17.00 | 12.00 |
| Ether extract | 9.50 | 13.50 | 12.50 |
| Crude fibre | 1.19 | 1.09 | 1.15 |
| Crude protein | 24.50 | 23.45 | 28.00 |

| | | | |
|---|---|---|---|
| Nitrogen free extract | 47.33 | 36.77 | 39.55 |

**KEYS:**
Diet 1 - 0 % Ginger powder
Diet 2 - 1.5 % Ginger powder
Diet 3 - 2.5 % Ginger powder

**Table 4: Performance characteristics of Japanese quails fed ginger powder**

| Parameter | Diet 1 | Diet 2 | Diet 3 | LS |
|---|---|---|---|---|
| Initial body weight (g) | 42.07±0.03$^{b}$ | 42.74±0.08$^{b}$ | 43.62±0.71$^{a}$ | * |
| Final body weight (g) | 106.67±0.08$^{c}$ | 111.67±0.23$^{b}$ | 116.67±0.02$^{a}$ | * |
| Body Weight Gain (g) | 64.60±0.06$^{c}$ | 68. 93±0.03$^{b}$ | 73.05±0.02$^{a}$ | * |
| Daily Feed Intake (g) | 33.75±0.02$^{a}$ | 33.04±0.12$^{b}$ | 31.37±0.05$^{c}$ | * |
| Total Feed Intake (g) | 945.00±7.55$^{a}$ | 925.00±0.12$^{b}$ | 878.34±0.01$^{c}$ | * |
| Total Water Intake (ml) | 1496.00±1.73$^{b}$ | 1593.83±0.46$^{a}$ | 1394.49±0.54$^{c}$ | * |
| Daily Water Intake (ml) | 53.43±0.01$^{b}$ | 56.92±0.05$^{a}$ | 49.80±0. 91$^{c}$ | * |
| Feed Conversion Ratio | 14.63±0.07$^{a}$ | 13.42±0.03$^{b}$ | 12.02±0.03$^{c}$ | * |

a,b and c means with difference superscript in the same row significantly different (P<0.05).
**KEYS:**
Diet 1 - 0 % Ginger powder
Diet 2 - 1.5 % Ginger powder
Diet 3 - 2.5 % Ginger powder
* - Significant
LS - Level of significant

**DISCUSSION**

The result obtained in this experiment revealed that body weight gain (g) and final weight gain (g) were significantly affected by the different ginger powder levels in the diets fed with quails. Quails on 2.5 % ginger diets performed generally better in final body weight gain than other diets. Increase in the ginger levels in the ration up to 2.5 % increased the growth performance of quails. This is in agreement with earlier work reported by Ademola *et al*. (2009) and Onimisi *et al*. (2005) who observed that ginger increased body weight when included in the diet up to 2%. The higher feed intake recorded by the quails fed diet 1 might be as a result of low energy values of the feed due to high fat content and low fibre which leads to high cholesterol an energy dilution effect on the diet and a consequential increase in feed intake. This is also in collaboration with the findings of Ademola *et al*. (2009); Doley *et al*. (2009) who observed that there was no difference in feed intake in broilers fed with ginger and pepper extract for a period of six weeks. In spite of the low consumption compared with other by the fact that is help herbal plant may provide some compounds that enhance digestion and absorption of some nutrients in these diets. Other researchers proved that there is an increase in body weight and feed conversion ratio with decreasing of some important growth parameters using of ginger or black pepper in broiler diets (Iqbal et al., 2011).

Namur *et al* (1988) reported that supplementation with 2.5% of ginger decreased feed intake by 0.71% and 2.38 % more than that of the control treatment and experimental diet 1 respectively. Natural feed additives had beneficial effect for stimulation and activity of digestive system by improving the palatability and enhancing appetite of poultry, thus increasing the amount of feed consumed. The significant difference observed between the control, 1.5% and 2.5% in water intake in favour of birds fed diet 2, could be the effect of level test ingredient. The decreased in water intake (ml) as the level of ginger inclusion increases could be due to level of ginger inclusion in the diet. As the water content in an animal increases, the fat content decreases and vice-versa. The results of feed conversion ratio showed a decrease and improvement in feed efficiency utilization in 1.5% and 2.5% ginger level in the experimental diet as compared to the control treatment during the experimental period. Quails fed with 2.5% ginger level during the experimental period recorded the best feed conversion. This is in agreement with the work reported by (Abd El-Galil and Henda 2015).

**CONCLUSION**

The result of this work showed that ginger inclusion up to 2.5% in the diet of Japanese quail improved body weight gain significantly over those fed on control diet. Japanese quail fed 0% ginger powder had significantly higher feed intake over those fed 1.5% and 2.5. Base on the result of this study, it is recommended that ginger powder can be included in the diet of Japanese quail up to 2.5% without any deleterious effect.

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# DEVELOPMENT OF A DEEP LEARNING BASED WEED DETECTION SYSTEM FOR MAIZE FARMS

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## ABSTRACT

One of the major problems associated with crop production is the prevalence of weeds which compete with crops for their growth factors. Traditional weed control techniques have various limitations which can be addressed with the application of technologies like robotics and artificial intelligence. This study presents a deep learning based weed detection system for intelligent weed control in maize farms. The model architecture used for the implementation of the system is the YOLOv8 nano model due to its light weight and fast inference time. The validation results for the model shows a high mAP for the maize class (94.7% mAP and 94.8% mAP@0.5) and a lower mAP for the weed class. The model's F1-confidence curve indicated optimal performance at a 0.35 confidence threshold with a peak F1 score of 79%. The system demonstrated an inference time of 280 ms and an overall detection accuracy of 86.3% when evaluated on a Raspberry Pi microcontroller, making it suitable for autonomous weed control operations.

**Keywords:** Artificial Intelligence, Computer Vision, Deep Learning, Weed Detection, YOLO

## INTRODUCTION

The global population is projected to reach nine billion by 2050, necessitating a 70% increase in agricultural production to meet food demands (Hasan et al., 2021). Achieving this requires innovative solutions, as conventional methods alone are insufficient. Among the significant challenges in crop production is weed infestations which poses a major threat to crop yield. Weeds, often described as unwanted plants growing in undesired locations, compete with crops for vital resources such as sunlight, nutrients, and space, adversely affecting crop growth and productivity (Shanmugam *et al.,* 2020; Pandey *et al*., 2021). Traditional weed management methods such as manual, mechanical, and chemical, are effective, but have various drawbacks. Manual weeding, though precise, is labor-intensive and time-consuming. Mechanical methods can damage the soil structure, increasing erosion risk (Chacko *et al*., 2021; Woyessa, 2022). Chemical herbicides, though widely used, are costly, environmentally hazardous, and can degrade soil health when overused (Shamkuwar *et al*., 2019). Advancements in technology, particularly in Artificial Intelligence (AI) and robotics, offer promising solutions to these challenges. These technologies have transformed precision agriculture by enabling precise interventions in planting, fertilizing, and harvesting, thereby reducing resource waste and enhancing productivity (Adewuyi *et al*., 2024; Raj *et al*., 2024). In weed detection, AI-driven systems leverage computer vision and machine learning to identify and classify weeds with high accuracy (ElSayed *et al*., 2024). Key requirements for such systems include high detection speed, robustness to varying environmental conditions, and compatibility with hardware constraints (Fatima *et al*., 2023).

Recent advancements in robotics and AI-driven technologies have shown significant potential for targeted weed control, reducing reliance on broad-spectrum herbicides. Studies highlight the effectiveness of integrating computer vision, deep learning, and mechanical systems for precise weeding, with models like YOLOv3 achieving over 90% detection accuracy (Chang et al., 2021) and CNN-based systems reaching over 99% in controlled environments (Patel et al., 2023). Mechatronic systems, such as vision-based prototypes for intra-row weeding (Berkmortel et al., 2021) and robotic inter-row hoeing for sugar beet farming (Bručienė et al., 2022), have demonstrated promise but face challenges in scalability and soil impact. Autonomous robots incorporating RNNs for crop rotation prediction (Dupuis et al., 2023) and machine-learning models like YOLOv5 for weed detection (Gajbhiye & Thalor, 2023) offer innovative solutions, although dataset dependency and adaptability to diverse environments persist as limitations (Chinnasamy et al., 2022; Kumar, 2023). Furthermore, AI-powered autonomous pesticide sprayers, while effective in navigation, highlight the need for greater precision to minimize waste and environmental harm (Kassim *et al*., 2020; Agilesh *et al*., 2022). This study focuses on developing an autonomous robot equipped with a weed detection system for monoculture maize fields. Using the YOLOv8 nano model, the system achieves precise weed identification with fast inference times, making it ideal for deployment on resource-constrained platforms. By integrating robotics and AI, this solution aims to address the inefficiencies of traditional methods, contributing to sustainable weed control and enhanced maize crop production.

## METHODOLOGY

The weed detection system for the autonomous weed control robot is composed of several components: a Raspberry Pi 4B+ microcomputer, a camera, a servo motor, and a power supply. The system uses the camera as an input source to capture images of the maize farm. These images are processed by the Raspberry Pi microcomputer, which hosts a trained YOLOv8 nano model. The servo motor positions the camera to acquire images from different ridges in the farm. The overall block diagram is shown in Figure 1, where the camera feeds images to the Raspberry Pi, the central processing unit. The YOLOv8 model processes the images, identifying and localizing weeds and maize via bounding boxes. The processed data is sent to the autonomous robot for precise weed control. Once a control action is executed, the servo motor adjusts the camera to the next ridge, repeating the process. This operation is depicted in Figure 2, illustrating data acquisition, processing, and transmission across system components.

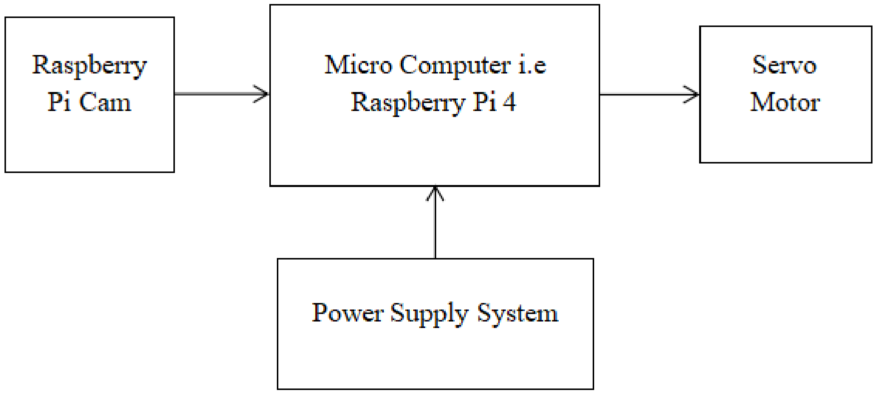


Figure 1: System Block Diagram

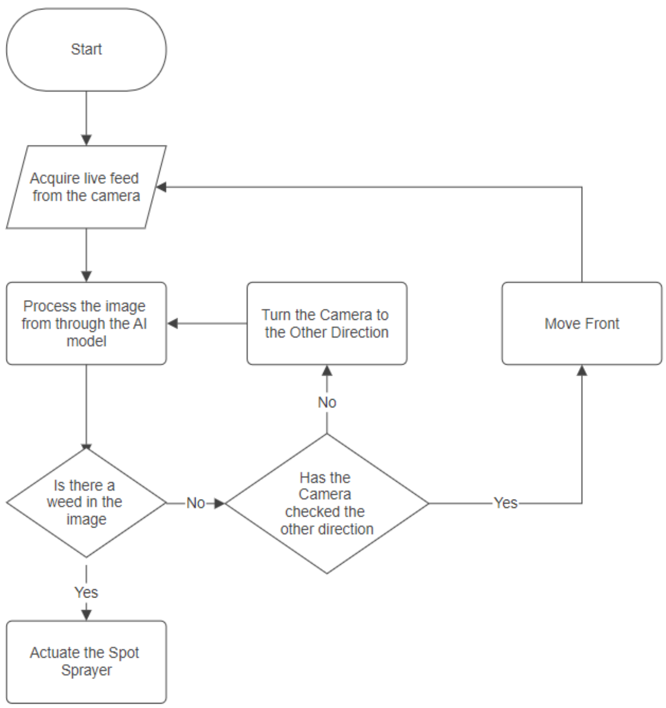


Figure 2: System Operation Flowchart

***Weed Detection Model***

The deep learning technique implemented for this system is YOLOv8 which stands for You Look Only Once. It performs object detection and bounding box generation in one forward propagation hence the name. The YOLO algorithm unlike other deep learning techniques, provides a variety of computationally effective options from the YOLOv8 nano (YOLO version 8 nano) to YOLOv8L (YOLO version X Large for different versions of the YOLO algorithm, with little losses in precision, recall and detection accuracy. This makes YOLO a fast, reliable and computationally effective solution to deep learning tasks. The pipeline in Figure 3, outlines the various steps and processes carried out for the implementation of the weed detection system design. The details of the model building process and the materials required are discussed further in this section.

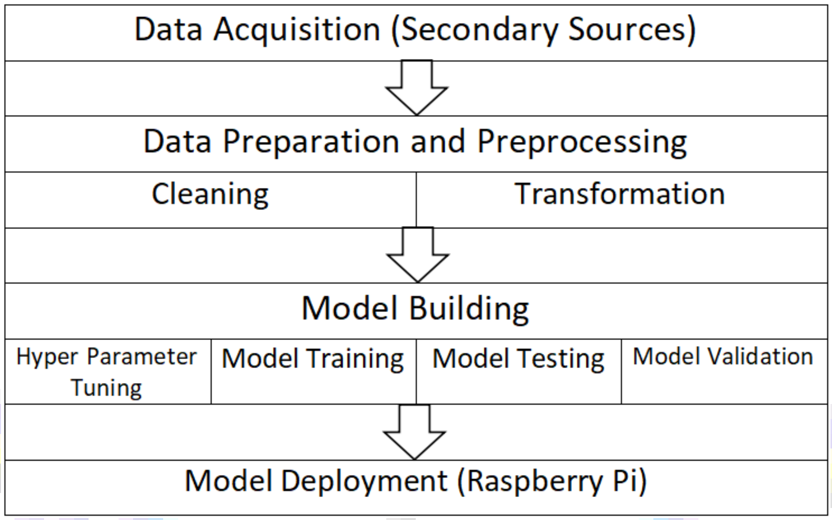


Figure 3: Model implementation pipeline

*Data Acquisition:* The dataset used for the training of the model was adopted from Olaniyi *et al.,* (2022). It consists of 2500 images annotated images with two classes i.e. Maize and Weed in Darknet format. The original data gotten from the farm where 500 images in total then augmented with a blur, noise, dark and light filter to make the total of 2500 images.

*Data Cleaning and Preparation:* The data cleaning procedure was carried out through visual inspection and python scripting. After data cleaning, Roboflow which is a computer vision platform for data preparation and model testing, was used to carryout data transformations which involved resizing each image to 640x640 pixels. Lastly, the dataset was split into a 70:20:10 ratio for train, validation and test images.

*Model Training:* The Google Colab platform was utilized for model training due to its large library environment and free computational. The model was trained using transfer learning on the pre-trained YOLOv8 nano model which leverages the information gotten from training on vast amount of data leading to reduction in computational resources and training time. The model was trained using the hyper parameters outlined in the Table 1.

Table 1: Summary of selected hyper parameters for training

| **Parameter** | **Value** |
|---|---|
| Total Images | 2500 |
| Number of Classes | 2 |
| Number of Epochs | 150 |
| Batch Size | 32 |
| Learning Rate | 0.001 |
| Optimization Function | Auto |
| Training-Validation-Testing Split | 70:20:10 |

*Model Deployment*: The built model was deployed on a Raspberry pi microcomputer. It uses a camera to capture live image data from its surroundings and returns the bounding box information for each plant identified.

*Hardware Design Considerations*

Table 2 shows the components used in this project and their respective specifications. The Raspberry Pi Microcomputer is powered by a 5V 3A power supply unit and the camera and servo motors are controlled and powered by the raspberry pi. The camera serves as the input, while the outputs are the bounding box coordinates and the servo motor to the system.

Table 2: Hardware Components and Rating

| **Component** | **Specifications** |
|---|---|
| Raspberry Pi 4B+ | Processor: Broadcom BCM2711 quad-core Cortex-A72; Clock Speed: 1.5 GHz; RAM: 4 GB; Operating Voltage: 5V; Operating Power: 3 Amp |
| Raspberry Pi Cam | Resolution: 5 mp (1080p @ 30fps); Mass: 3g; Voltage: 5V; Current: 250 Ma |
| SG90 Servo Motor | Voltage: 5V; Current: 300 mA; Weight: 9g; Range: 180 degrees; Torque: 1.8 kg/cm at 4.8V |

**Software Design Considerations**

Python was the primary programming language used for the development of the weed detection system because it was the official programming language of the raspberry pi microcontroller. Data preparation and cleaning as carried out using the Roboflow online platform and training was down on the Google Colab due to access to larger computing resources which result in lower training time for the deep learning model.

**Performance Evaluation**

The weed detection system is evaluated based on various metrics such as the precision, recall and f1 score of the model. It is also evaluated based average inference time and detection accuracy when deployed on the Raspberry Pi microcomputer. The metrics are expressed mathematically as:

$$\text{Precision (P)} = \frac{TP}{TP + FP} \tag{1}$$

$$\text{Recall (R)} = \frac{TP}{TP + FN} \tag{2}$$

$$\text{F1score} = 2\left(\frac{PR}{P + R}\right) \tag{3}$$

$$\text{Detection Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \tag{4}$$

**Where**:

TP = Number of True Positives

TN = Number of True Negatives

FP = Number of False Positives

FN = Number of False Negatives

## RESULTS

The methodology for the training of the weed detection system was implemented with the use of Google Colab. Figure 4 and Figure 5 show the different loss functions and evaluation metrics from the training of the YOLOv8 nano model over 150 epochs. The loss is a measure of how much the predictions of the model differs from the truth. The box loss, class loss and distributional focal loss refer to error in predicting the bounding box coordinates, correct classes and the error in localizing objects within the image. As seen in Figure 4, the loss functions steadily decrease over epochs and evens out as it approaches 150 epochs. This shows the models steady increase in accuracy while making predictions. This can be also observed in Figure 5 which shows the steady increase in precision and recall during the training process. Also the similarities between the validation loss and training loss indicates the model is not over-fitting.

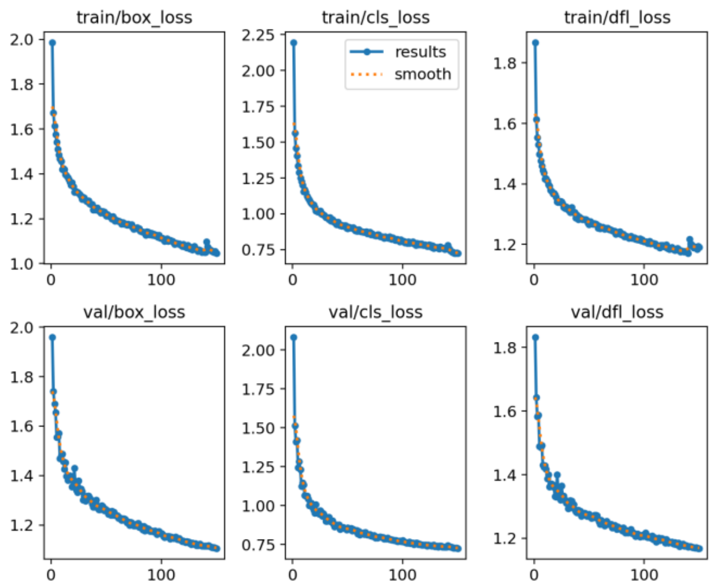


Figure 4: Varying box, class and loss over training epochs for training and validation data

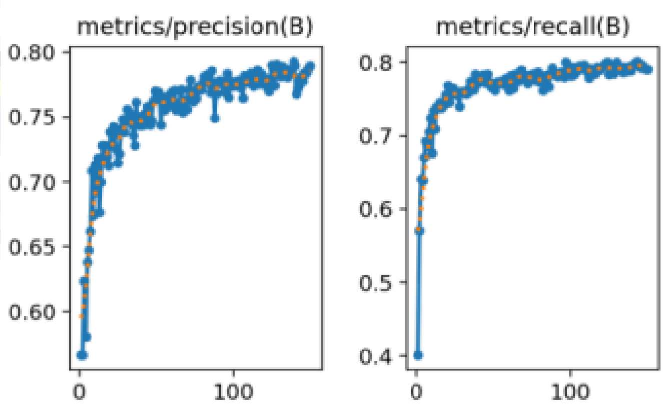


Figure 5: Precision and recall over training epochs

The model was validated on 500 images containing 6,977 instances of the maize and weed classes. Figure 6 shows the confusion matrix of the model obtained after the training process. It gives a visual representation of the predictions obtained from the validation of the model using the validation dataset. The right diagonal shows the number of true positive instances while other sections of the matrix show the number of falsely predicted instances. Observations from the confusion matrix shows out of the 6,977 instances, 85.3% were correctly predicted and 24.7% predicted falsely with 21.7% false predictions mistaking the surroundings for weeds. This high false prediction rate is due to the similarities between the surroundings and weeds class as annotated in the dataset.

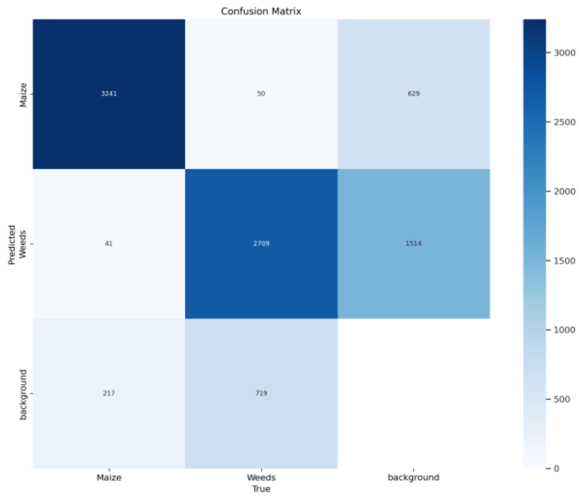


Figure 6: Confusion Matrix

Table 3 shows the summary of the results obtained from the validation of the model. It contains the Precision, Recall, mAP and mAP@IOU of 0.5 from the validation process. From the table, the model demonstrates good performance for the maize class with each evaluation metric above 85%. The model performs poorly on the weed class with an mAP of 76%. The noticeable difference between the predictions for these classes is due to the major variances in weed appearance because it covers a wide range of plants.

Table 3: Summary of training results

| **Class** | **Instances** | **Precision** | **Recall** | **mAP** | **mAP@50** |
|---|---|---|---|---|---|
| All | 6977 | 0.793 | 0.790 | 0.853 | 0.857 |
| Maize | 3499 | 0.869 | 0.903 | 0.947 | 0.948 |
| Weed | 3478 | 0.716 | 0.678 | 0.760 | 0.766 |

The detection accuracy as expressed in Eq 4 is a measure of the number of correct predictions to the total number of predictions. Figure 7 shows the output of the model after inference with the plotted bounding boxes, predicted classes and confidence scores for the image. From the image, the detection accuracy is 73.3%. This same process was carried out for the test dataset containing 250 images in total. This resulted in a detection accuracy of 86.3% for all classes.

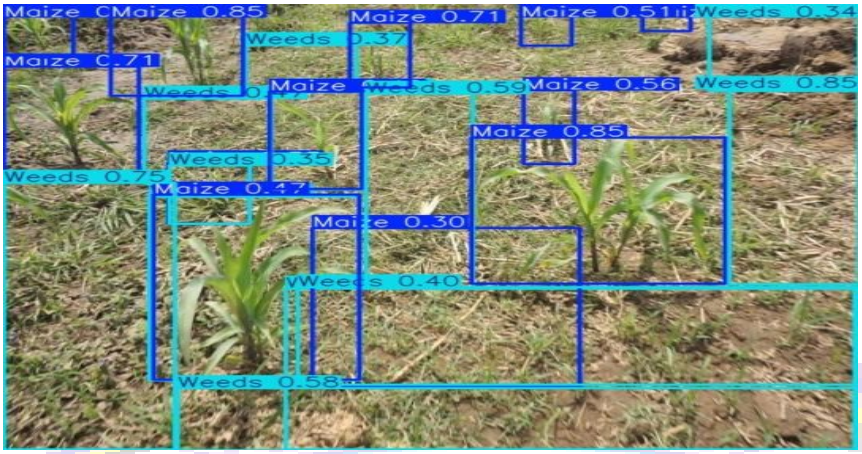


Figure 7: Result from model with plotted bounding boxes

## CONCLUSION

This paper examined the application of computer vision for autonomous weed control, focusing on the development of a lightweight weed detection model deployable on a Raspberry Pi 4B+. The YOLOv8 nano model was trained on a dataset of 2,500 images over 150 epochs. The validation results demonstrated high mAP and mAP@0.5 for the maize class at 94.7% and 94.8%, respectively. The weed class, however, showed lower mAP (76%) and mAP@0.5 (76.6%), influenced by similarities between weeds and their surroundings and limited dataset diversity. System evaluation yielded a detection accuracy of 86.3%, making it suitable for autonomous operations. Future research should prioritize the inclusion of varied weed species in the dataset to enhance model generalization and improve detection performance across diverse conditions.

## ACKNOWLEDGEMENT

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# A COMPUTER VISION-BASED ROBOTIC WEED SPRAYER FOR MAIZE FARMLAND PRECISION FARMING

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## ABSTRACT
Maize, a staple crop of great worldwide significance, often experiences large production losses due to weed competing with its nutrients. It is important to treat these weeds without any harm on the maize crop. Existing approaches to weed management relied on traditional application of the herbicide which is marred by wastages, and could damage the crops also causing health issues to the consumers. In this research, an advanced robotic weed sprayer that uses deep learning and computer vision to solve the ubiquitous problem of weed control in maize farmland is proposed. The research employed an advanced deep learning algorithm that was trained on a large image dataset of common weed species and maize, allowing for accurate weed identification and focused herbicide application. The system's real-time image analysis guarantees efficient weed control. The system performs exceptionally well, with 75% precision, 80% recall, 77% F1-score and 85.12% mean Average Precision (mAP) in weed recognition. This highlights its potential to completely transform conventional weed control techniques and represents a significant advancement in precision farming technologies as well as a promising option to improve productivity and sustainability in maize cultivation by minimizing crop damage through precise herbicides usage.
**Keywords:** Agriculture, Computer vision, Convolutional Neural Network, Deep learning, Maize, Precision Farming.

## INTRODUCTION
The most prevalent cereal produced worldwide is maize Zea *mays* L. Except in Antarctica, it is grown everywhere. Maize has over 50 different species, each with unique colors, textures, shapes, and sizes [1]. According to a survey done in 2019, nearly 50 percent of farmers in Nigeria were cultivating maize crops, making maize the most frequent crop in the country [2]. Unwanted plants known as weeds grow on fields and compete with crops for space, sunshine, and nutrients. They impede crop growth if they are left on the farm, which lowers agricultural productivity and, consequently, the farmers' profit margin [3]. Weed has accounted for 62-100% agricultural yield loss in maize, 50-90% loss in cassava, and 29-55% loss in soya beans [4]. The three main techniques for controlling weeds are chemical application, automated methods, and cultural approaches. The cultural method to weed control includes hand weeding, changing cultivation, clearing fires, clearing land, early flooding, bush fallowing, and maintaining clean harvesters. High work intensity and cost are the problems associated with this approach.

Herbicide application has been considered a significant improvement over manual weeding. However, overuse of the herbicides can result to major harvest losses, environmental harm, contaminated crops, increased production costs, and the development of herbicide resistance [5]. Precision agriculture offers a solution to the difficulties above by merging targeted weeding techniques with the use of computer vision. By attacking weeds at the individual plant or small cluster level, it is possible to drastically minimize, or eradicate, the dependency on agrochemicals [6].

Moreover, in [7] developed a unique object recognition model for monitoring and managing pasture weeds. California thistle served as the model's testing subject. The model achieved 95% accuracy and 93% mAP during testing. However, the work did not provide any weed control measure, it stopped at weed detection. In a similar vein in [8] CNN model was employed for weed detection through a designed user interface and an accuracy of 98% was achieved. Similarly, no weed control strategy was implemented. In addition, [9] offered a deep learning-based, precise mechanical control system for weeding. To locate and identify weeds, a deep convolutional neural network was employed. A novel modular weeder was created, with a weeding tool shaped like an upside-down pyramid that allows it to pull weeds out without contaminating the surrounding soil. The weed puller and the weed detection and control methods were integrated into an embedded system that was built on a Graphics Processing Unit (GPU) with high speed. The weight of the feeder posed significant obstacle to the system and the weeding tool's rotation speed needed some time to adjust to the varying vehicle speeds. In the same vein, [10] proposed an artificial intelligence-based digital image processing and weed identification method for maize seedlings. The weeds that were in the maize seedling stage may be distinguished and identified based on the shape of their leaves.

From the literature reviewed, it can be seen that most of the existing literature did not incorporate weed control strategies. The few that did rely on mechanical efforts to achieve weed control. Recent advances have integrated weed recognition models as a step in weed control; however, the accuracy of the models requires further improvement. As a result, this paper presents a compute vision and deep learning-based robotic weed sprayer to reduce environmental pollution by spraying precisely on the weed-affected area, resulting in an efficient usage of herbicide.

## MATERIALS AND METHODS

This section concentrates on the components and techniques utilized in the development of the robotic intelligent weed sprayer robot for maize farmland precision farming. The system overview, components of the system, final integration, and evaluation are presented in this section.

### System Overview

The intelligent robotic weed sprayer has different parts integrated together to achieve the desired result. This include the robot navigation algorithm, the weed recognition model, and the herbicide spraying module. The part that embodies electronic components comprises components such as Raspberry pi3B+, Raspberry pi camera module, Robotic arm, Direct Current (DC) pump, Arduino Mega, Mecanum omnidirectional wheel, Direct Current (DC) motor and power supply. The system acts in such a way that the camera module serves as input to the microcontroller (Raspberry pi4B+) while the DC pump serves as the output that sprays the herbicide. The system moves at 5cm each time to stop and check for weed using the recognition model. This component is being controlled by Arduino Uno microcontroller and it serves as input to Raspberry pi4B+ through the weed captured by the camera.

### The Robot Navigation Algorithm

In this section, the adaptability of the system's navigation algorithm tailored for a maize farm environment is highlighted. The algorithm, as presented in Table 1, was designed to give the system clear instructions, allowing it to navigate efficiently, regardless of the sensor data (from ultrasonic sensors) obtained in real-world conditions. It provides a detailed understanding of how the system moves through the farm, from the starting point to the endpoint.

**Table 1: The Robot Navigation Algorithm**

**ALGORITHM**: NAVIGATION ALGORITHM FOR THE ROBOT

**SensorRead:** *Reads the Sensor value*

**Rightdistance:** *distance of the right ultrasonic sensor*

**Leftdistance:** *distance of the left ultrasonic sensor*

**Moveforward***: forward movement of the robot*

**Turnright:** Robot turn right

**Turnleft:** Robot turn left

```
Count=0
constdistance=20
sensorRead;
If leftdistance<constDistance && rightdistance<constDistance;
    Moveforward
    Do safedistance=(leftdistance+rightdistance)/2;
        Let leftdistance=rightdistance= safedistance;
    While Moveforward=high;
ElseIf leftdistance>constDistance && rightdistance>constDistance;
    Turnright;
    Moveforward(5cm)
     SensorRead;
     If rightdistance<constDistance;
        Moveforward;
     Else turn right;
     Moveforward;
     SensorRead;
     Do count++1;
     For count=even;
         Turnleft;
         Moveforwar(5cm)
         SensorRead;
         If leftdistance<constDistance;
             Moveforward;
         Else turn left;
         Moveforward;
      End;
      SensorRead;
 ElseIf (leftdistance>constDistance &&
rightdistance<constDistance)||(leftdistance<constDistance && rightdistance>constDistance);
      While (leftdistance<constdistance)||(rightdistance<constdistance);
           Moveforward;
      Else;
           Stop;
```

### The Weed Recognition Model

The detection of weed and maize was carried out using a CNN based technique. The pipeline for the model is presented in Figure 1. In the data acquisition phase, considering the unavailability of online benchmark maize/weed datasets, 500 images of maize and weed were collected locally to create the dataset. These images were preprocessed and used to develop the preliminary model for weed detection. The data preparation and preprocessing phase, involved blurring, contrast enhancement, noise addition and data augmentation steps. After the augmentation, the dataset was increased to 2500 images, which was divided into 70:20:10 for training, validation, and testing ratio. The model building phase involved parameter tuning and then training the YoloV4 model, testing and validation. The model was evaluated based on accuracy, precision, recall and F1 score measures and finally deployed into a Raspberry Pi4 microcontroller board.


**Figure 1: Weed Detection Model Pipeline**

**The Herbicide Spraying**

The robotic arm is the module responsible for moving the nozzle to an angle to spray the detected weed. This component incorporates servo motors that allows the robotic arm to move independently. The robotic arm used in this project exhibit 4 Degrees of Freedom (DOF), which allows it to execute movements in 4 independent planes. The robotic arm is interfaced with the Raspberry pi (Rpi) and the Rpi sends appropriate signals to the servo motors. A DC pump was used to move herbicide from the herbicide container to the spraying nozzle. Precise movement of the robotic arm in response to weed detection was achieved. Fine adjustments were made to ensure accurate targeting of detected weeds. Activation of the DC pump for herbicide spraying was executed flawlessly.

**RESULTS AND DISCUSSIONS**

**Robot Navigation Evaluation Results**

**Navigation Accuracy and Precision Test Result**

The navigation algorithm exhibited impressive accuracy in directing the maize-farm robot along seedbed rows, showing a consistent deviation of ±2 cm during simulated tests (Figure 2). This level of precision is encouraging for the algorithm's real-world application in agriculture, where accurate navigation is essential. The line plot displays the deviation values of the navigation algorithm throughout the simulated tests, with each point representing an individual test run. The steady trend of the line, marked by minor fluctuations, indicates stable and dependable performance. Deviation values between 1.5 cm and 2.2 cm demonstrate a high degree of accuracy in guiding the row-crop robot through seedbed rows, highlighting the algorithm's effectiveness. Overall, the algorithm showcases both precision and reliability, underscoring its potential for practical use in agricultural environments where precise navigation is critical.

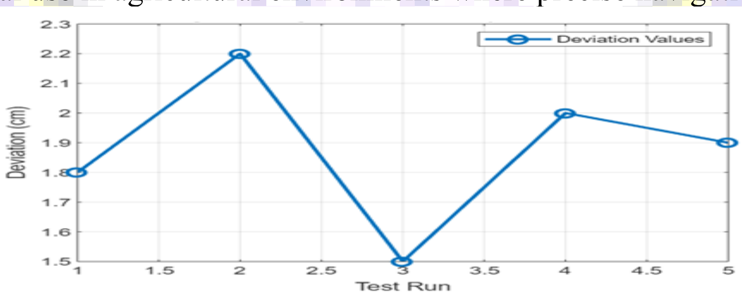


**Figure 2**: **Graphical representation of the navigation algorithm accuracy and precision**

**Navigation Efficiency and Adaptability Test Results**

The navigation algorithm demonstrated a quick response in steering adjustments, with an average time of 0.5 seconds. This efficiency highlights the algorithm's real-time capabilities, making it well-suited for dynamic field conditions. The bar graph in Figure 3 illustrates the efficiency of the navigation algorithm by displaying the steering adjustment times during simulated tests. Each bar represents a specific test run, showcasing the algorithm's responsiveness. The consistently low adjustment times, ranging from 0.3 to 0.7 seconds, reflect prompt steering responses, underscoring the algorithm's real-time capabilities. This favorable efficiency indicates that the algorithm is appropriate for dynamic field conditions in precision agriculture, where timely adjustments are essential for navigating varying terrains and ensuring accurate seed placement. On the adaptability of the navigation algorithm, it achieved an average 90% success rate as observed in Figure 4. This implies the algorithm's potential to navigate and perform reliably in real-world farming conditions, thereby enhancing its practical utility in ensuring precision agriculture.

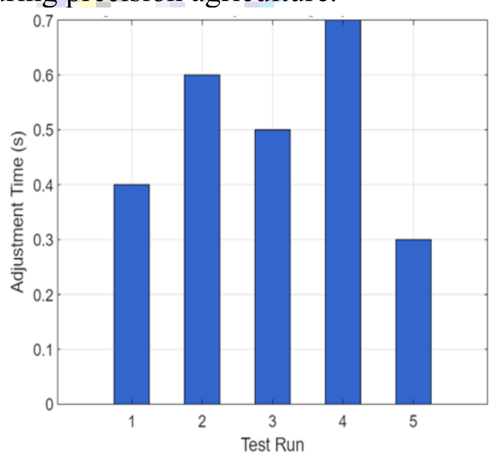


**Figure 3**: **Efficiency Test Graph**

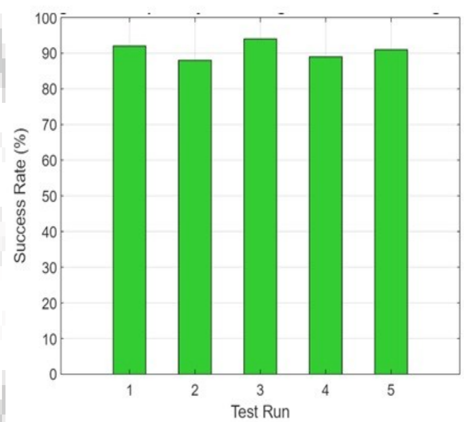


**Figure 4**: **Navigation Adaptability Test Graph**

**Weed Recognition Model Evaluation Results**

Table 2, shows the parametric findings for the training evaluation. The findings for each class are presented based on the True Positives (TP), False Positives (FP), Precision, and Average Precision (AP) acquired.

*Table 2: Training Evaluation Results*

| Class ID | Class | TP | FP | AP (%) |
|---|---|---|---|---|
| 0 | Weed | 2635 | 971 | 81.82 |
| 1 | Maize | 2935 | 883 | 87.32 |

The parametric findings of the performance evaluation are shown in Table 1. These findings were collected after the training procedure was completed by the model. The table displays the successfully predicted (TP) and mistakenly predicted (FP) classes. The table also displays the AP values, which are the area under the precision-recall (PR) curve. These parameters indicate how successfully the model was trained. The function presented in Equation 3 is used to calculate the AP values. The table shows that the Weed and Maize classes had average precisions of 81.82 %

and 87.32 %, respectively. These numbers suggest that the model performed well, with the Weed class doing the worst and the Maize class performing the best of the two classes. The parametric results for the testing evaluation are presented in Table 3. The results are presented based on the True Positives (TP), False Positives (FP), Precision and Average Precision (AP) obtained for each class.

*Table 3: Testing Evaluation Results*

| Class ID | Class | TP | FP | AP (%) |
|---|---|---|---|---|
| 0 | Weed | 1318 | 516 | 81.80 |
| 1 | Maize | 1483 | 440 | 88.44 |

The parametric findings of the performance evaluation are shown in Table 6. The table shows that the Weed and Maize classes had average precisions of 81.80% and 88.44 %, respectively. These numbers suggest that the model performed well, with the Weed class doing the worst and the Maize class performing the best of the two classes. Tables 2 and 3 show that the model's training performance outperformed its testing performance in all class cases. The overall performance of the model during training and testing was evaluated and compared. The results of this performance is presented in Figure 5 The Figure shows a comparison in terms of the precision, recall, F1-score, and mean Average Precision (mAP).

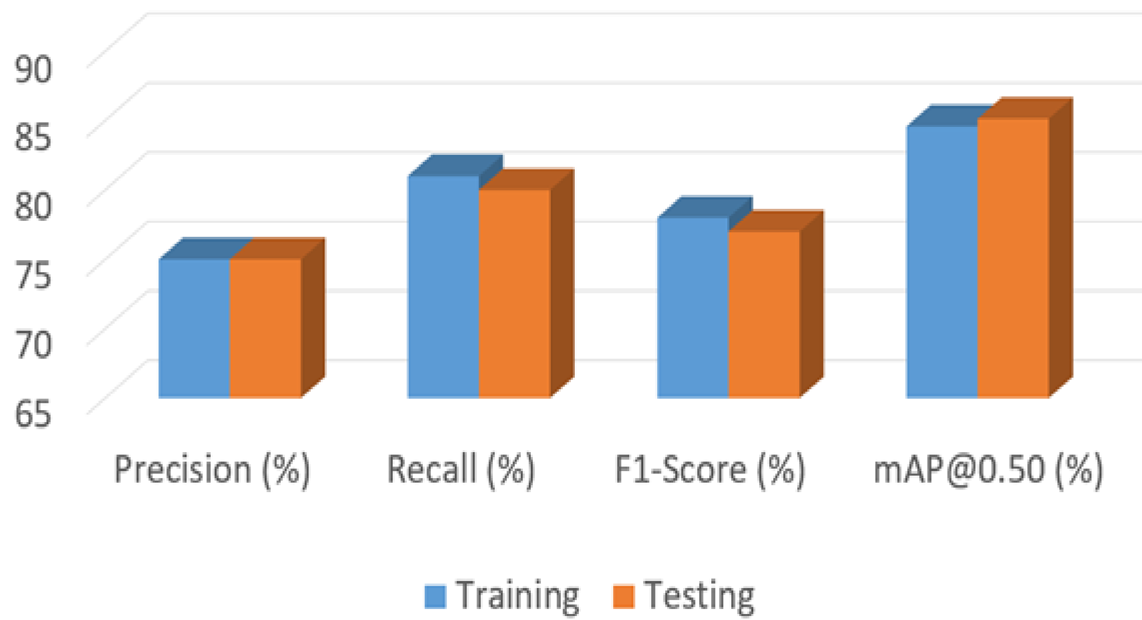


*Figure 5: Comparison between Training and Validation Performance*

From the Figure 5, the parametric values were acquired after training the model using 70 % of the data and testing it with 10%. The graph compares the model's performance during training, when it is learning, to its performance during testing, when it has learned. On the one hand, the training performance had 75 % precision, 81 % recall, 78 % F1-score, and 84.57 % mAP. The testing performance, on the other hand, showed a precision of 75 %, recall of 80 %, F1-score of 77 %, and mAP of 85.12 %. It is evident from the figure that the training performance of the model was slightly better than testing performance in all the metrics considered. This implies that the model did not overfit. The final fabricated prototype robot is shown in Figure 6.

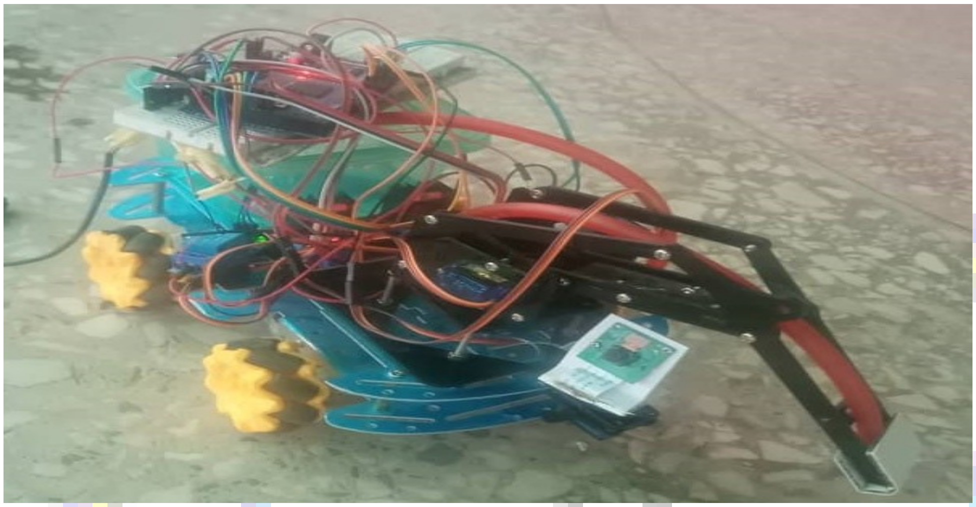

**Figure 6: Designed Robotic weed sprayer**

**CONCLUSION AND FUTURE WORK**

This research aimed at developing a computer vision-based robotic weed sprayer for maize farmland. The development is necessary to address the salient issues of traditional weed control methods and even most conventional methods that hinders good maize harvest in the country. In achieving that, a CNN model was trained through YOLOV4 for weed recognition. The model achieved 75% precision, 80% recall, 77% F1-score and 85.12% mean Average Precision (mAP). Also, a robot farmland navigation algorithm was formulated and evaluated. It achieved 90% success rate in adaptability, and it is highly responsive (0.5 seconds). Overall, the robotic weed sprayer robot has achieved a good precision and reliability levels, underscoring its potential for practical use in agricultural environments where precise navigation and herbicide application is critical. In a future research, provision will be provided for nighttime or low-light condition image capture, in order to make the system robust. This could be achieved by integrating infrared or LED lighting for effective capture of images. Also, a way to enhance the robotic arm system with collision detection and avoidance mechanisms will be researched.

**ACKNOWLEDGEMENT**

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# RESPONSE OF COMMERCIAL COWPEA VARIETIES TO INOCULATION WITH INDIGENOUS RHIZOBIA ISOLATES

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## ABSTRACT
Inoculation of legumes with appropriate rhizobia strain is a promising approach to enhancing cowpea productivity and sustainability. Therefore, this study was conducted to examine the response of two cowpea varieties two selected indigenous rhizobia. The treatments were two cowpea varieties (SAMPEA 18 and SAMPEA 19) and two rhizoia isolates (SAMFIX 618 and SAMFIX 679), along with positive and negative nitrogen control, factorially combined making eight treatment combinations (SAMFIX 618+18, SAMFIX 618+19, SAMFIX 679+18, SAMFIX 679+19, SAMPEA 18+N, SAMPEA 19+N, SAMPEA 18-N and SAMPEA 19-N). The plants were grown under axenic conditions and harvested at eight (8) weeks after sowing. Plant height, number of branches and leaves, shoot dry matter and nitrogen concentration were determined, while N uptake was calculated. They were subjected to analysis of variance and the means were separated using Duncan Multiple Range Test. The results showed significant ($P< 0.05$ to $P< 0.01$) differences among the parameters. The study indicates the role of symbiotic $N_2$ fixation as substitute for mineral N and indicates SAMFIX 618 more promising rhizobia inoculant strain in the Nigerian Savana than SAMFIX 679.
**Keywords**: Cowpea; rhizobium; root and shoot dry matter; nitrogen uptake

## INTRODUCTION
Cowpea (*Vigna unguiculata*) is an important legume, cultivated worldwide for its high nutritional value, ability to fix atmospheric nitrogen and adaptability to diverse agroecological conditions (Sharma *et al*., 2012). Cowpea is particularly an important dietary staple, especially in regions where animal protein is scarce and plays a significant role in food security and poverty alleviation in sub-Saharan Africa (Ureta *et al.*, 2015). The productivity of cowpea is however, limited by many factors such as soil nutrient deficiency, drought stress, and susceptibility to pests and diseases (Bationo *et al*., 2019), making the average yield of cowpea in Nigeria to be 417 kg $ha^{-1}$, while the potential yield is 1500 to 3000 kg $ha^{-1}$ (Joshua *et al.*, 2019). This calls for promising approaches toward enhancing its productivity and sustainability, since the use of inorganic fertilizers such as nitrogen is not sustainable due to high cost and adverse environmental effects (Masson-Boivin *et al*., 2009). Dakora *et al.* (2014) and Masson-Boivin *et al*. (2009) reported root nodule bacteria (rhizobia) to be capable of converting atmospheric nitrogen into forms that can be utilized by the plant directly (ammonium; $NH_3^{4+}$ and nitrate; $NO_3^-$), through symbiotic relationship with legumes such as cowpea, thereby reducing its reliance on the synthetic nitrogen fertilizers. This unique interaction between rhizobia and legumes is of great agricultural importance, since it enhanaces soil fertility and promotes the growth and productivity of legumes (Masson-Boivin *et al*., 2009; Dakora *et al*., 2014). This usually achieved through inoculating the legumes with appropriate rhizobia strains, Effectiveness

of rhizobia inoculation on cowpea is usually affected by indigenous rhizobia strains existing naturally in soils, adapted to local soil and environmental conditions. Hence, potentially more effective in promoting nitrogen fixation and crop growth compared to non-native strains (Sanginga and Woomer, 2009). Therefore, inoculation with selected indigenous rhizobia, especially those isolated from the same environment ensures effectiveness in nitrogen fixation (Udvardi and Poole, 2013). Therefore, aim of the study was to determine the response of two cowpea varieties released for the Nigerian Savanna to inoculation with indigenous rhizobia isolated from the same region. The specific objectives of the study were to determine the effectiveness of SAMFIX 618 and SAMFIX 679 rhizobia inoculants on SAMPEA 18 and SAMFIX 679 cowpea varieties.

## MATERIALS AND METHODS

### Experimental Site

The study was carried out in the Screenhouse of the Department of Soil Science, Faculty of Agriculture/Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria, located in the Northern Guinea Savanna (NGS) zone of Nigeria, within longitude 007º45.547 E and latitude 1111.542 N at altitude 611 m above sea level.

### Soil Sample Collection and Preparation

The experimental soil was collected at a depth of 0-20 cm from the Research Farm of the IAR, within longitude 007º36.653 E and latitude 11º10.510 N at 658 m above sea level, along with river sand from the same area. The soil sample was air dried, crushed and sieved through a 5 mm mesh sieve (for planting) and 2 mm mesh for physical and chemical analyses. A mixture of 1:2 ratios of both soil and the river sand was autoclaved. Four (4) kilogram of the mixture was filled into each of sterile plastic pots of 16.5 cm height. The pots had drainage holes at the bottom, which were plugged with autoclaved weaved wool.

### Sources of the Seeds, Isolates and Inoculant Preparation

The cowpea varieties selected for the experiment were SAMPEA 18 and SAMPEA 19 released by IAR for commercial production grown in Northern and Southern Guinea, Sahel and Sudan Savannas, while the rhizobia isolates (SAMFIX 618 and SAMFIX 679) were obtained from the Soil Microbiology Unit of the Department of Soil Science, Ahmadu Bello University Zaria, earlier isolated from Nigerian Savanna soils. The isolates were grown on Yeast Extract Mannitol Agar (YEMA) plate (Vincent, 1970) for three days and uniformity of the colonies were confirmed. Then the inoculants were prepared by carefully wiping the pure primary cultures with sterile wooden applicator sticks from the plate into 30 ml 1% w/v sucrose solution.

### Treatments and Experimental Design

The experiment involved two factors, four nitrogen sources; uninoculated (-N) control, Mineral N (+N) control (20 kg N $ha^{-1}$), two isolates of Nigerian indigenous rhizobia (SAMFIX 618 and SAMFIX 678) and two cowpea varieties; SAMPEA 18 and SAMPEA 19. These make up to eight (8) treatment combinations (SAMFIX 618+18, SAMFIX 618+19, SAMFIX 679+18, SAMFIX 679+19, SAMPEA 18+N, SAMPEA 19+N, SAMPEA 18-N and SAMPEA 19-N), replicated three times, making 24 pots, arranged in Randomized Comple Block Design (RCBD) (Gomez and Gomez, 1984) due to slight variation in the Screenhouse.

**Seed Surface Sterilization, Planting and Inoculation**

The seeds were surface sterilized prior to the germination test to rid them of contamination. They were immersed for 10 seconds in 70% v/v ethanol, followed by 3 minutes in 3% v/v sodium hypochlorite and subsequently rinsed in six fresh changes of sterile deionized (DI) water. The two cowpea varieties were separately set for pre-germination in plastic lunch boxes lined with moist papers towels, under sterile conditions and then wrapped with aluminum foil for incubation at 28ºc for three days. Four pre-germinated seeds were planted per pot, according to the experimental design. One ml of the inoculant was used to drench each seed. The surfaces of the pots were covered with gravels to reduce the rate of evaporation and prevent contamination from rhizobia aerosols (Woomer *et al*., 2010). The plants were thinned to two plants per pot at two weeks after sowing and uniformly watered with sterilized DI water and N free Centre for Rhizobium Studies (CRS), Murdoch University, Australia nutrients solution on weekly basis. These were done based in the plant's requirements using sterile polyvinyl chloride tubes (25 cm in diameter).

**Soil Characterization.**

Soil pH was determined at soil: water ratio of 1:2.5 (IITA 1982), particle size distribution, using hydrometer method (Gee and Bauder, 1986), total N using the macro kjeldahl digestion method (Bremner and Mulvaney,1982), soil organic carbon using dichromate oxidation method (Nelson and Sommers, 1982), soil available phosphorus by Bray No. 1 acid fluoride method (Nelson and Sommers, 1982) and Effective cation exchange capacity (ECEC) using summation method. Exchangeable bases (Ca, Mg, K, and Na) were extracted in 1N $NH_4OAC$ solution (Chapman, 1965). Calcium and magnesium determined by Atomic Absorption Spectrophotometer, while K and N using flame photometer (Juo, 1979).

**Data Collection**

At eight weeks after sowing, the plants were harvested and plant height, number of leaves and branches, shoot dry matter, root dry matter were recorded. The roots and shoots were oven dried at 65ºc for 48 hours to a constant weight and grounded using stainless-steel mill and nitrogen content determined using the above named methos used for total nitrogen in the soil. Nitrogen uptake was calculated as shoot dry matter (g) x nitrogen concentration (%) (Latif *et al*., 2014).

**Statistical Analysis**

Data collected analysis of variance (ANOVA) for the N sources at 5% level of significance. Where F values were significant at $P<0.05$, Duncan Multiple range test (DMRT) was used to separate the means. Correlation between N uptake and shoot dry matter was carried out using Microsoft excel (Office 2019). All statistical analyses were calculated using IBM SPSS Statistics Version 23.

**RESULTS AND DISCUSSION**

**Characterization of the Experimental Soil**

The results of some physical and chemical properties of the experimental soil is shown in Table 1. The soil was Silty loam, favourable for agriculture with pH value of 5.7; slightly acid suitable for many crops (Brady and Weil, 2016). The organic carbon was moderate (0.71 g $kg^{-1}$) indicating good potential for nutrient and water retention (Lar, 2004). The low soil total nitrogen (0.28 g $kg^{-1}$) indicatesthe need for supplementary nitrogen for crop growth and expected response of crop grown on it to atmospheric nitrogen fixation through cowpea-rhizobia symbiosis. While low soil available phosphorus (9.78 mg $kg^{-1}$) indicates potential deficiencies that was complemented in the N-free nutrient solution. The effective cation exchange capacity (ECEC) was also low; 8.33 cmol kg$^{-1}$, suggesting limited cation exchange capacity for plant nutrition (Sparks, 2003). The situation of the soil necessitates regular monitoring and management provided using the CRS N-free nutrient solution according to the plants' requirements. Moreover, the experimental soil was sterilized by autoclaving to prevent contamination form impending rhizobia in the environment, just as the whole experiment was conducted under axenic conditions.

Table 1. Physical and chemical analysis of soil

| Soil parameters | Values |
|---|---|
| Sand (g kg$^{-1}$) | 240 |
| Silt (g kg$^{-1}$) | 520 |
| Clay (g kg$^{-1}$) | 240 |
| Texture | Silt Loam |
| pH | 5.7 |
| Org. carbon (g kg$^{-1}$) | 7.14 |
| Total nitrogen (g kg$^{-1}$) | 0.28 |
| Avail. phosphorus (mg kg$^{-1}$) | 9.78 |
| Exch. K (C mol kg$^{-1}$) | 0.26 |
| Exch. Mg (cmol kg$^{-1}$) | 0.92 |
| Exch. Ca (cmol kg$^{-1}$) | 6.00 |
| Exch. Na (cmol kg$^{-1}$) | 0.36 |
| Exch. Acidity (cmol kg$^{-1}$) | 0.80 |
| ECEC (cmol kg$^{-1}$) | 8.33 |

**Response of Cowpea Growth Parameter of the Commercial Cowpea Varieties to Inoculation with Rhizobia Isolates**

**Plant height and Number of Branches and Leaves**

There were significant ($P<0.05$) differences among the treatments in influencing the plants height (Figure 1), number of branches (Figure 2) and leaves (Figure 3) of the plants at harvest. There was similar trend for all the parameters. The positive N control gave the highest plant height, number of branches and leaves, the plant height and number of branches were statistically similar to that of the plants inoculated with SAMFIX 618 and were taller and had more branches than those inoculated with SAMFIX 679, which in turn were taller with more branches than uninoculated plants. The positive N control and SAMFIX 618 and SAMFIX 679 gave 32, 26 and 9 % increase in plant height over the uninoculated control, respectively. There was 39, 31, and 19 % higher number of branches as influenced by the positive N control, SAMFIX 618 and SAMFIX 679, respectively over the uninoculated control. In the case number of leaves, SAMFIX 618 even gave the highest, while the positive N and SAMFIX 679 were similar and higher than the uninoculated control. SAMFIX 618 gave 23%, while the Positive N and SAMFIX 679 gave 33 and 27%higher number of leaves than the uninoculated control. SAMFIX 618 showed impressive growth and outperformed the rest of the treatments, with similar in performance to that of mineral N, indicating its superiority over SAMFIX 679. This could be attributed to more effective interaction between SAMFIX 618 and the cowpea to fix atmospheric nitrogen that directly influencing the growth and development of the cowpea plants as observed by Hirsch and McFall-( Kundu *et al*., 2007). The results align with the well-established role of effective rhizobia in legume development (Sprent, 2009; Vincent, 1970).

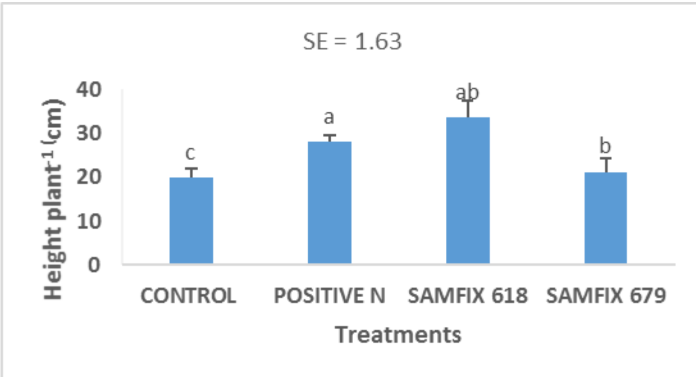
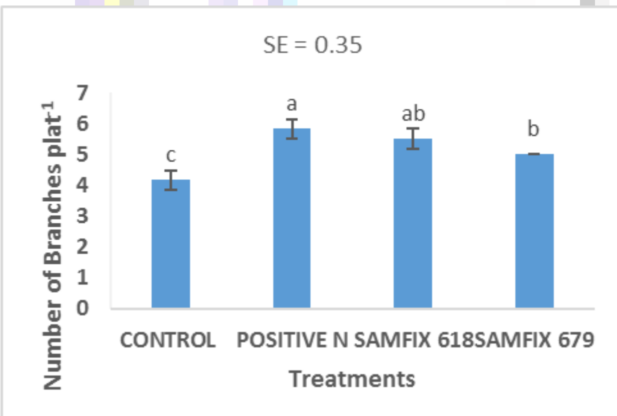
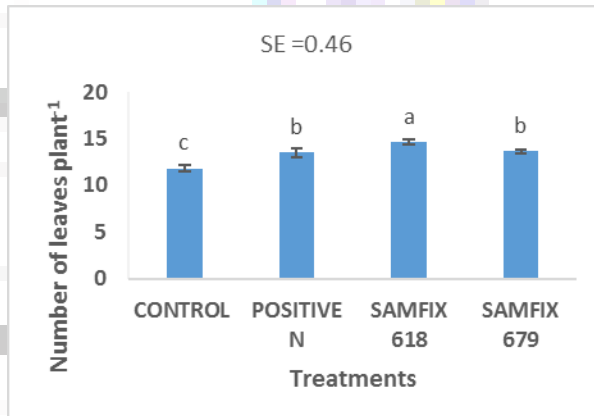



Figure 1. Plant height of two cowpea varieties as influenced by inoculation with indigenous rhizobia isolates




2 3

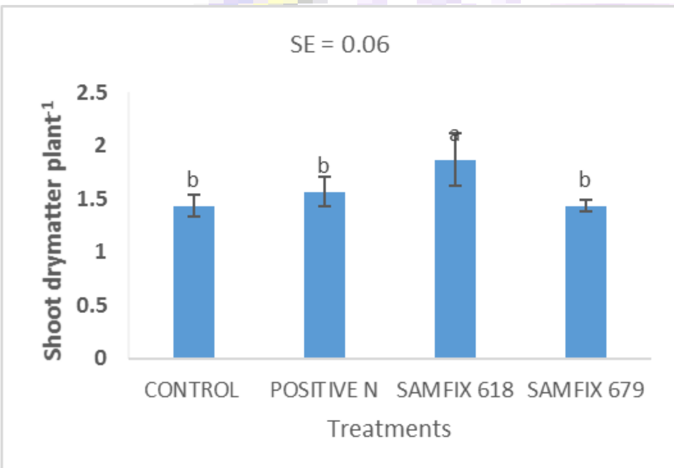
Figures 2. Number of branches and 3. Number of leaves of two cowpea varieties as influenced by inoculation with indigenous rhizobia isolates

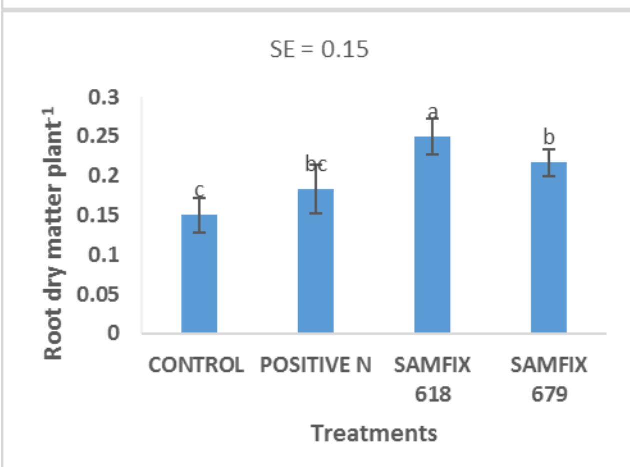
**Root dry matter**

Figure 4 shows the effect of the treatments on root dry matter of the plants. There was significant ($P<0.05$) difference among the treatments influencing the root dry matter. SAMFIX 618 gave the highest root dry matter, which was statistically higher than all other treatments. The positive N control and sample 679 were statistically similar, even though the positive N control and the uninoculated control were also statistically similar and gave the lowest root dry matter. The results indicate that rhizobia inoculation and nitrogen application can have positive impact on root development in cowpea varieties (Marschner, 2011). The specific effects may vary depending on the rhizobia strain used (Sprent, 2009), as evidenced by the differences between SAMFIX 618 and SAMFIX 679. The result also shows reduced root growth by the plants with positive control, showing how availability nitrogen discourage root development, nodulation and nitrogen fixation (Giller *et al*., 2009).

**Shoot dry matter**

The effect of the treatments on shoot dry matter of cowpea varieties is shown in Figure 5. There was significant difference among the treatments influencing the shoot dry matter of the plants. SAMFIX 618 gave the highest shoot dry matter, significantly higher than all other treatments. The Positive N control was in turn higher than SAMFIX 679, while the uninoculated control gave the lowest. The results highlight the impact of nitrogen in promoting both shoot fresh and dry matter (Taiz and Zeiger, 2010). Additionally, inoculation with SAMFIX 618 gave higher shoot dry matter than even the positive N control, which underscores it's role increasing growth and development of the plants (Sprent, 2009). The result also shows the superiority of SAMFIX 618 over SAMFIX 679 in compatibility and effectiveness with the cowpea varieties.

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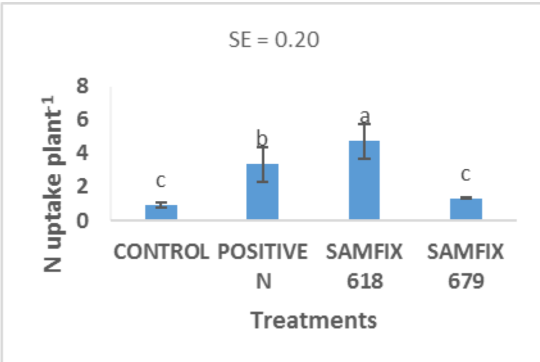
Figures 4. Root dry matter and 5. Shoot dry matter of two cowpea varieties as influenced by inoculation with indigenous rhizobia isolates

**Nitrogen Uptake**

Response of the N uptake of the plants by the cowpea (Figure 6) indicates variation among the treatments. They differ significantly ($P<0.05$) in influencing the nitrogen uptake of the plants, with SAMFIX 618 exhibiting highest nitrogen uptake, significantly higher than all other treatments. The Positive N control that gave significantly higher nitrogen uptake than SAMFIX 679, which was statistically similar to the uninoculated control. The results highlight the higher potential SAMFIX 618, indicating the importance of selecting the appropriate strain for optimizing nitrogen uptake through symbiotic nitrogen fixation, clearly shown by the high positive correlation between N uptake and shoot dry matter of the plants (Figure 7).

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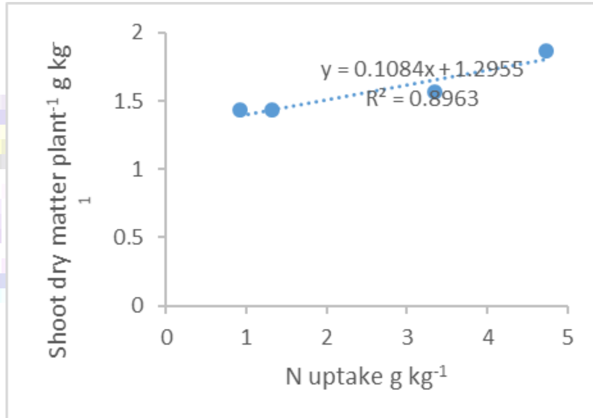


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Figures 6. Shoot dry matter and 7. Correlation between N uptake and shoot dry matter of two cowpea varieties as influenced by inoculation with indigenous rhizobia isolates.

## CONCLUSION

The study indicates the superiority of SAMFIX 618 an effective and promising indigenous rhizobia inoculant in the Nigerian Savanna, because it consistently gave significantly higher plant growth parameters; plant height, number of branches, leaves, root and shoot dry matter, as well as N uptake than SAMFIX 679. This was attributed to its higher symbiotic efficiency directly benefiting the the plants with available nitrogen, which synchronizes with the plant requirement, SAMFIX 618 to favourably compete with the positive N control. Performance of the uninoculated control confirmed the adverse effect of N deficiency, since the plants were left with neither inoculation nor inorganic N. The study indicates the role of symbiotic $N_2$ fixation as substitute for mineral N and indicates SAMFIX 618 as a promising rhizobia inoculant strain in the Nigerian Savana.

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# IMPACT OF SOIL PARENT MATERIALS ON LAND SUITABILITY FOR PRODUCTION OF SELECTED CROPS IN NIGER STATE

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## ABSTRACT
This study evaluated the suitability of some soils developed under two geological formations (that is, basement complex rocks and the sedimentary rocks) in Niger State, for maize (*Zea mays*) production. Four sites two each under the formations were selected for the study. Gidan Mangoro (GDM) and Mutun Daya (MTD) represented the basement complex while Enagi (ENG) and Ndayako (NDY) represented the sedimentary rocks. In each site, a mini profile pit (100 cm x 100 cm x 100 cm) was dug, described and sampled according to FAO guidelines. The samples were analysed in the laboratory following the standard analytical procedures. Square root method was used in the suitability evaluation of the soils. The results showed that, the texture of GDM, was loamy sand at topmost horizon (Ap), underlain by sandy clay loam at Bt horizon over sandy loam texture at Btv horizon. The texture of MTD was sandy loam at topmost horizon (Ap), underlain by sandy clay loam at Btv1 and Btv2 horizons. ENG, and NYK were sandy loam all through. The current (actual) status of the sites revealed temporally not suitable (N1) with indices of 21, 20, 22 and 17 for GDM, MTD, ENG and NYK respectively due to soil fertility and nutrient retention limitations. After correcting the limitations, the sites showed potentials for the production of maize with indices of 31 (S3), 28 (S3), 47 (S2) and 43 (S2) for GDM, MTD, ENG and NYK respectively. The soils under the sedimentary rock formation showed more potential for maize production.

**Key Words**: Parent materials; basement complex and sedimentary rocks, Land suitability evaluation, maize production.

## INTRODUCTION
Parent material is the material from which soil is thought to have been derived from (Shakeel, 2020). Predominantly, soils developed on basement complex rocks, have impervious subsurface horizons due to plinthization processes (Lawal *et al*., 2023). Productivity of a soil is a function of its physical and chemical properties. These properties are as a result of the interaction among the soil forming factors and processes, hence, making soil to be heterogeneous (Lawal *et al*., 2014). Evaluation of soils is increasingly becoming necessary as the need for precision agriculture increases (Adeyolanu *et al*., 2020). Land is an essential natural resource, comprises of physical component of the Earth, which is permanently not covered with water, and vital both for the

survival and prosperity of humanity (FAO/UNEP, 1999). It is important that agricultural land be used according to its capacity for optimal and sustainable production (Adeboye, 1994, Afolabi *et al*., 2014). Land suitability evaluation is the process of assessment and classification of land units according to their suitability for a particular use (Nguyen *et al*. 2020). Therefore, the objectives of this study were to characterize the soils derived from different parent materials in Niger State, Nigeria and to evaluate their suitability for maize production.

## MATERIALS AND METHODS

Niger State is underlain by two geological terrains namely the Basement complex rocks and the sedimentary rock formations. The study covered the four sites, two from the basement complex and two from sedimentary rock geological formation. The sites were Gidan Mangoro (Longitude: $6^0$ 29′ 30.570″ E and Latitude: $9^0$ 34′ 29.652″ N). Mutun Daya (Longitude: $7^0$ 03′ 03.090″ E and Latitude: $9^0$ 33′ 34.188″ N), Enagi (Longitude: $5^o$ 32' 8.220" E and Latitude: $9^o$ 7' 24.630" N) and Ndayako (Longitude: $5^0$ 00′ 49.440″ E and Latitude: $9^0$ 22′ 19.002″ N), all within the southern Guinea savanna agroecological zone of Nigeria. Niger State is sub-humid tropical and experiences two distinct wet season and dry seasons. Rainfall is bi-modal with mean total annual rainfall of 1,600 mm in the southern part and decreased to 1,200 mm in the northern part of the state, distributed from the months of May to October. The dry season is about 5 months' duration from November to March. The mean annual maximum rainfall is about 1600 mm. The average minimum and maximum temperatures are 20 ℃ and 37 ℃ respectively while the mean annual relative humidity is between 39% to 70%. Geomorphologically, Niger State was characterized by undulating landscape, upland, lowland, plains, flood plains, and rolling dissected plains (Alabi 2011).

### Field work and soil sampling

One profile pit measuring 1 m × 1 m × 1 m (or to permissible depth), was dug in each of the locations and were described according to FAO guidelines (FAO, 2006). Soil samples were collected from the identified genetic horizons, from bottom to the top of the profile. The following materials were used for the field study; handheld GPS device, Munsell Colour Chart (2009 version), a plastic bucket, zip-lock bags, digger, shovel, hand-trowel, hand note book, writing pen, permanent marker, stapler, and masking tape. The well-labelled soil samples were taken to the laboratory for processing and routine analysis.

### Laboratory Analysis

The air-dried soil samples were passed through a 2 mm mesh and analysed according to standard laboratory procedures (IITA, 2015). Briefly, particle size distribution was determined by Bouyoucos hydrometer method, using sodium hexametaphosphate as the soil dispersing agent. The textural classes of the soils were determined using IUSS soil textural triangle. Soil pH was determined in a 1:2.5 soil / water suspension using a standard pH meter and electrodes. Exchangeable acidity ($H^+$ and $Al^{3+}$) was determined by titrimetric method, while organic carbon (C) was determined by Walkley-Black method of wet combustion involving oxidation of organic matter with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid ($H_2SO_4$). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1N NH4OAc. Calcium and Mg in the soil extract were determined using atomic absorption spectrophotometer while K and Na were determined by flame photometry. Cation exchange capacity (CEC) was determined by the neutral 1N $NH_4OAc$ saturation method. Base saturation was determined by calculation, dividing the sum of exchangeable bases by their CEC and then multiplied by 100.

**Land Suitability Evaluation for Maize**

Suitability evaluation was performed for production of maize using the square root method (Khiddir, 1986) as expressed in equation (1) below:

$$S_i = R_{min} \text{ x } \sqrt{\frac{A}{100} X \frac{B}{100} X \frac{C}{100} \ldots\ldots}, \ldots\ldots\ldots\ldots \text{ equation (1)}$$

where, *Si*= suitability index, $R_{min}$= connotes the factor that has minimum rating; and A, B, C… are ratings of other factors besides the minimum. The land suitability evaluation took into consideration the soil characteristics related to land qualities affecting the land use types. Four (4) land quality groups: climate (c), soil physical properties (s), wetness (w) and fertility (f) were used in the evaluation. Final suitability for each crop was defined by applying the computed index values converted to its corresponding land suitability classes. According to suitability ranking of Sys *et al*. (1991), land suitability index of 0-12.5% connotes permanently not suitable (N2), 12.5-25% is currently not suitable (N1), 25-50% is marginally suitable (S3), 50-75 % is moderately suitable (S2) and 75-100% is highly suitable (S1). The soil and environmental requirements for maize production used in the evaluation are shown in Table 1.

**Table 1: Factor Rating of Land Use Requirements for Maize Production (Sys, 1991)**

| Land Qualities | Unit | Class, degree of limitation and rating scale | | | |
|---|---|---|---|---|---|
| | | S1 (100) | S2 (85) | S3 (60) | N (40) |
| Climate (c) | | | | | |
| Annual rainfall | (mm) | >800 | 700-800 | 600-700 | <600 |
| Mean temp | (C°) | 24-30 | 30-32; 20-24 | 32-35; 15-20 | >35; <15, |
| Soil drainage (w) | Drainage class | Well | Moderately well | Imperfect | Poor, very poor |
| Soil characteristics (s) | | | | | |
| Effective soil depth | (cm) | >100 | 75-100 | 30-75 | <30 |
| Soil Texture | | CL, L | SL, LS | LCS | CS |
| Nutrient availability (f) | | | | | |
| Soil reaction | pH | 6.0-6.5 | 5.5-6.0; 6.5-7.0 | 5.0-5.5;7.0-8.2 | <5.0; >8.2 |
| Topsoil organic carbon | (g $kg^{-1}$) | >2.0 | 1.0-2.0 | 0.5-1.0 | <0.5 |
| Total N content | (g $kg^{-1}$) | >0.2 | 0.1-0.2 | 0.02-0.1 | <0.02 |
| Available P content | (mg $kg^{-1}$) | >40 | 10-40 | 3-10 | <3 |
| Topsoil K content | (cmol $kg^{-1}$) | >0.3 | 0.2-0.3 | 0.1-0.2 | <0.1 |
| Nutrient retention capacity (n) | | | | | |
| Base saturation | (%) | >80 | 40-80 | 20-40 | <20 |
| Topsoil CEC | cmol $kg^{-1}$ | >25 | 13-25 | 6-12 | <6 |
| Sodicity ESP | (%) | <10 | 10-15 | >15 | - |
| Soil angle (Erosion hazard) | (%) | <4 | 4-8 | 8-16 | >16 |
| Soil angle (Erosion hazard) | (%) | <4 | 4-8 | 8-16 | >16 |

L=Loamy, SL=sandy loam, CL=clayey loam, SC=sandy clay, LS=loamy sand

**RESULTS AND DISCUSSION**

**Morphological Properties of the Soils**

The study showed that the soils from GDM and MTD were moderately-deep to deep, having 70-100 cm effective soil depth, with coarse fragments. The dominant colour spectral of the indicated a range of 7.5YR and 10YR hues which impacted the soils with colour variations such as dark yellowish brown, strong brown, brown, pale brown. According to Brady and Weil (1999) and Aki *et al*. (2014), these group of colours may be indicative of the presence of migmatite, gibbsite, goethite and haematite minerals in the soils. The presence of mottle colouration in the subsoils may be an indication of internal drainage problem due to presence of plinthic layers which restricted free movement of water within the soil body, during the rainy season. This causes the soils to be imperfectly to poorly drained during the rainy season. The soils from ENG and NDY were deep to very deep effective soil depth of 75-105 cm and were relatively free from course fragments and were well-drained. Similar to soils described under the basement complex, the colour features of soils of ENG and NDY indicated a range of 2.5YR to 10YR which impacted them with red, dark yellowish brown, dark red, dark yellow brown and dark reddish brown.

**Physical Properties**

The physical properties of the soils ot the four sites are presented in Table 2. The soils from GDM and MTD developed from basement complex, which have their textures to be loamy sand in surface horizons while sandy clay loam in sub-surface horizons respectively. The sand content followed the same pattern in all the soils of these sites, it decreased with soil depth. The silt content of these sites increased and decreased with soils depth except for MTD that decreased with depth. The clay content of MTD increased with soil depth while GDM increased and decreased with depth. The high sand fraction in surface horizon was also influenced by the parent material from which the soils are formed (Akpan-Idiok (2012); Peter and Umweni, 2021). The texture of ENG and NDY were sandy loam both in surface and sub-surface horizons. The sand content followed a particular pattern in all the soils, it decreased and increased with depth. Silt fraction from ENG and NDY were less in the topsoils than in the sub soils, while clay content increased with depth except for ENG that increased and decreased with depth. The relative high sand content in the area was the reflection of the effect of parent material such as Nupe sandstones. According to (Akamigbo and Asadu, 1983), the parent materials have been noted to influence the texture of the soils derived from them. The lower silt content in the soils may also be attributed to the effect of parent materials on the soils, as it has been reported by Akamigbo. (1984) that silt content is low in most soils of Guinea savanna of Nigeria.

**Chemical properties**

The chemical properties of the soils of study areas are presented in Table 3. Soil reaction was slightly acid to neutral with pH values of the surface soil as 6.3, 6.4, 6.9 and 6.5 for GDM, MTD, ENG and NDY respectively and were classified as slightly acid to neutral. Organic carbon (OC) in GDM ranged from 1.46 to 2.33 g $kg^{-1}$ and rated high. OC in MTD ranged from 3.61 to 7.05 g kg$^{-1}$, and rated very high. OC in ENG ranged from 0.51 to 4.24 g kg$^{-1}$, and rated low to high. OC in NDY ranged from 6.72 to 9.01 g kg$^{-1}$, and rated very high. Organic carbon is an essential component of soil chemical parameter for tropical soils, contributing to aggregate stability, permeability, water holding capacity, nutrient retention, and other desirable soil properties. (Ravindra. *et al.*2017). Total N in the soils of all sites was very low to low. Except in NDY, where available phosphorus was low, other sites had moderate to high values. The cation exchange capacity (CEC) values for all sites were generally low, except for MTD that was moderate. According to (Chude, *et al.* 2011) rating, the concentration of exchangeable $Ca^{2+}$ in GDM, MTD, and NDY were rated to be low, and exhibited the pattern of increased and decreased with the profile depth. While it concentration in ENG was rated to be moderate and increased and decreased with soil depth. The concentration of exchangeable Mg in GDM and ENG were rated to be moderate both in surface and sub-surface horizons and also exhibited increased and decreased pattern with soil depth. While it concentration in MTD and NDY were rated to be low, both in surface and sub-surface horizons and exhibited increased and decreased with soil depth. The concentration of exchangeable K in GDM, MTD, and NDY were rated to be very low both in surface and sub-surface horizons, and also exhibited increased and decreased pattern with soil depth. The concentration of exchangeable Na in GDM, MTD, and NDY were rated to be moderate in both surface and sub-surface horizons, and exhibited increased and decreased with soil depth. While the concentration of Na in ENG was rated to be low, both in the surface and sub-surface horizons, and also exhibited the pattern of increased and decreased with soil depth.

**Table 2: Physical properties of the soils**

| Site | Horizon | Soil Depth (cm) | Sand | Silt (g kg$^{-1}$) | Clay | Textural Class | Bulk density (g cm$^{-3}$) | Total porosity (%) |
|---|---|---|---|---|---|---|---|---|
| GDM | Ap | 0 – 30 | 774 | 160 | 66 | LS | 1.45 | 45 |
| | Bt | 30 – 46 | 614 | 140 | 246 | SCL | 1.50 | 43 |
| | Btv | 46 – 75 | 674 | 200 | 126 | SL | 1.67 | 37 |
| MTD | Ap | 0 – 16 | 681 | 200 | 119 | SL | 1.46 | 45 |
| | Btv1 | 16 – 27 | 601 | 140 | 259 | SCL | 1.63 | 39 |
| | Btv2 | 27- 70 | 641 | 80 | 279 | SCL | 1.57 | 41 |
| ENG | Ap | 0 – 30 | 679 | 146 | 175 | SL | 1.41 | 48 |
| | AB | 30 – 50 | 699 | 146 | 155 | SL | 1.51 | 43 |
| | B1 | 50 – 66 | 619 | 206 | 175 | SL | 1.37 | 48 |
| | B2 | 66 – 85 | 599 | 206 | 195 | SL | 1.30 | 51 |
| | B3 | 85 – 105 | 619 | 206 | 175 | SL | 1.48 | 44 |
| NDY | Ap | 0 – 20 | 721 | 180 | 99 | SL | 1.32 | 50 |
| | Bt1 | 20 – 75 | 761 | 120 | 119 | SL | 1.47 | 45 |
| | Bt2 | 75 – 100 | 721 | 160 | 119 | SL | 1.48 | 44 |

LS=loamy sand, SL= sandy loam, SCL= sandy clay loam.

**Table 3: Chemical properties of soils**

| Areas | Soil Depth (cm) | pH ($H_2O$) | OC | N | P | Ca | Mg | K | Na | EA | CEC | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ($g\ kg^{-1}$) | | ($mg\ kg^{-1}$) | ← | | ($cmol\ kg^{-1}$) | | → | | |
| Gidan Mangoro | 0 – 30 | 6.3 | 1.46 | 0.46 | 12.65 | 2.88 | 0.96 | 0.07 | 0.83 | 0.04 | 8.40 | 56.43 |
| | 30 – 46 | 6.1 | 2.33 | 0.48 | 7.19 | 3.20 | 2.08 | 0.08 | 0.67 | 0.03 | 9.01 | 66.93 |
| | 46 – 75 | 6.2 | 1.46 | 0.36 | 9.51 | 2.40 | 1.12 | 0.07 | 0.58 | 0.04 | 7.11 | 58.65 |
| | 0 – 16 | 6.4 | 7.05 | 0.74 | 14.39 | 2.08 | 0.80 | 0.14 | 0.45 | 0.14 | 14.41 | 24.08 |
| Mutun Daya | 16 – 27 | 6.3 | 3.61 | 0.50 | 20.25 | 2.40 | 0.80 | 0.09 | 0.51 | 0.13 | 17.41 | 21.83 |
| | 27 -70 | 6.4 | 3.93 | 0.52 | 21.41 | 2.40 | 1.44 | 0.09 | 0.61 | 0.10 | 18.85 | 24.08 |
| Enagi | 0 – 30 | 6.9 | 1.87 | 0.34 | 26 | 5.04 | 0.72 | 0.14 | 0.20 | 0.05 | 7.40 | 82.43 |
| | 30 – 50 | 6.5 | 0.85 | 0.56 | 43 | 5.70 | 1.04 | 0.11 | 0.22 | 0.08 | 8.60 | 82.21 |
| | 50 – 66 | 6.9 | 4.24 | 0.46 | 28 | 6.64 | 1.28 | 0.14 | 0.23 | 0.04 | 11.08 | 78.82 |
| | 66 – 85 | 6.6 | 1.19 | 0.56 | 21 | 5.20 | 1.52 | 0.12 | 0.26 | 0.05 | 8.40 | 84.52 |
| | 85 – 105 | 6.4 | 0.51 | 0.23 | 30 | 5.60 | 0.40 | 0.07 | 0.20 | 0.05 | 7.20 | 87.08 |
| Ndayako | 0 – 20 | 6.5 | 6.72 | 0.36 | 9.33 | 1.60 | 0.96 | 0.05 | 0.50 | 0.11 | 10.40 | 29.90 |
| | 20 – 75 | 6.5 | 7.70 | 0.46 | 7.24 | 2.08 | 0.80 | 0.09 | 0.56 | 0.13 | 13.86 | 25.47 |
| | 75 – 100 | 6.6 | 9.01 | 0.42 | 2.83 | 1.92 | 0.96 | 0.05 | 0.53 | 0.15 | 11.88 | 29.12 |

**Land Characteristics/Quality Attributes of the Soils**

Results of land characteristics and soil quality attributes of GDM, MTD, ENG, and NDY essential for suitability evaluation are presented in Table 4. The sites characteristics were based on particle size distribution (texture), effective soil depth, topography, drainage formed, fertility status and nutrient retention status for maize production respectively.

**Table 4: Land characteristics/quality attributes of the sites**

| Parameter | Gidan Mangoro | Mutun Daya | Enagi | Ndayako |
|---|---|---|---|---|
| Mean Temp (°C)(Growing Season) | 26.2 | 26 | 26.4 | 27 |
| Rainfall (mm) | 1256 | 1328 | 1,226.3 | 1,259.5 |
| Dry months | 5 | 5 | 5 | 5 |
| Slope (%) | 3.0 | 4 | 3.0 | 3.0 |
| Soil depth (cm) | 75 | 70 | >100 | >100 |
| Drainage | Mod. | Imperf. | Well | Well |
| Soil texture | LS | SL | SL | SL |
| Soil reaction (pH) | 6.3 | 6.4 | 6.9 | 6.5 |
| Organic carbon (g $kg^{-1}$) | 1.46 | 7.05 | 1.87 | 6.72 |
| Total Nitrogen (g $kg^{-1}$) | 0.46 | 0.74 | 0.34 | 0.36 |
| Phosphorus (mg $kg^{-1}$) | 12.65 | 14.39 | 26 | 9.33 |
| Potassium (cmol $kg^{-1}$) | 0.07 | 0.14 | 0.14 | 0.05 |
| CEC (cmol $kg^{-1}$) | 8.40 | 14.41 | 7.40 | 10.40 |
| Base saturation (%) | 56.43 | 24.08 | 82.43 | 29.90 |
| Flooding | F1 | F1 | F0 | F0 |
| Exchangeable Sodic percentage (%) | 2.70 | 12.35 | 9.88 | 9.99 |
| Gravel (%) | 4 | 4 | 2 | 2 |

F0 = non-flooding, F1 = moderately flooding, F1= Flooding, F3= highly flooding,

**Land Suitability Evaluation for Maize**

The assessment of the fitness of the study sites for maize production followed the suitability criteria laid down by the Sys *et al.* (1993), for both actual and potential suitability. The actual suitability evaluation involved the assessment of the land in its current status, while the potential suitability evaluation was carried out after imposing corrective management measure to correct the limitation (especially fertility related). The outcome of matching the land and environmental requirement (Table 1) with the land characteristics/ soil quality of the sites (Table 4) for each site covered both the actual (current) and potential suitability of the sites after correcting the limitations) and results are presented in Table 5.

**Table 5: Suitability Assessment of the study sites for maize production**

| | Gidan Mangoro | Mutun Daya | Enagi | Ndayako |
|---|---|---|---|---|
| Annual Rainfall | 100 | 100 | 100 | 100 |
| Mean temp (growing season) | 100 | 100 | 100 | 100 |
| Soil drainage (w) | 85 | 60 | 100 | 100 |
| Soil characteristics (s) | | | | |
| Effective soil depth | 85 | 60 | 100 | 100 |
| Soil Texture | 85 | 85 | 85 | 85 |
| Slope | 100 | 85 | 100 | 100 |
| Nutrient availability (f) | | | | |
| Soil reaction (pH) | 100 | 100 | 85 | 100 |
| Topsoil organic carbon | 85 | 100 | 85 | 100 |
| Total N | 100 | 100 | 100 | 100 |
| Available phosphorus | 85 | 85 | 85 | 60 |
| Potassium | 40 | 60 | 40 | 40 |
| Nutrient retention (n) | | | | |
| Base Saturation | 85 | 60 | 100 | 60 |
| Topsoil CEC | 60 | 85 | 60 | 60 |
| ESP | 100 | 100 | 100 | 100 |
| Aggregate Suitability: | | | | |
| **Actual** | **N1fn (21)** | **N1wfn (20)** | **N1fn (22)** | **N1fn (17)** |
| **Potential** | **S3n (31)** | **S3wn (28)** | **S3n (47)** | **S3n (43)** |

S3= Marginally Suitable, N1= currently not Suitable, fn=fertility limitations, wfn=wetness and
fertility limitations, wn=wetness limitation, n=no limitations

The actual suitability indices were 21, 20, 22 and 17% for GDM, MTD, ENG and NDY respectively, suggesting that all the sites were not suitable (N1) for maize production in their current status due to limitations of soil fertility (particularly P and K) and nutrient retention (low organic matter and CEC). Low K content in GDM, ENG and NDY and moderate in MTD was the major fertility limitation. NDY also had moderate P content in the soil. In addition to fertility limitation, the soils of MTD had limitation of wetness (imperfectively drained subsurface) as a result of presence of plinthic horizon which induced perched water-table. The index suitability for MTD was 20% for actual and 28% for potential which translated to currently not suitable (N1) and marginally suitable (S3) respectively. After imposing corrective measures to correct the fertility limitation through application of mineral fertilizer, the index of suitability upgraded to 31, 28, 47 and 43 for GDM, MTD, ENG and NDY respectively. These values corresponded to marginally suitable (S3) for maize production.

## CONCLUSION AND RECOMMENDATIONS

From the results of this study, it can be concluded that climate was not a constraint for the production of maize in the study sites. The low organic matter, phosphorus and potassium content in all the site can be amended by adopting management practices that can encourage return of plant/crop residues into the soil as well as application of mineral fertilizers to improve phosphorus and potassium. Also planting on ridges will corrects problem of improve rooting condition in Mutun Daya.

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# MICROALGAE AS SOIL NUTRIENT ENHANCERS: A REVIEW

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## ABSTRACT
Microalgae, the microscopic photosynthetic organisms have gained considerable attention in sustainable agriculture due to their potential as natural soil nutrient enhancers. This review explores the current research on microalgae applications to improve soil fertility and crop productivity. Microalgae are rich in essential nutrients, such as nitrogen, phosphorus, and potassium, and contain bioactive compounds such as phytohormones and polysaccharides, that enhance soil health, stimulate plant growth and yield, and support beneficial microbial communities. This review further examines the mechanisms by which microalgae contribute to soil nutrient cycling, focusing on their role in nitrogen fixation, organic matter accumulation, and soil structure improvement. Additionally, various methods of microalgae cultivation, application in agricultural settings, cultivation requirements and challenges and limitations were discussed. The findings highlight microalgae's promising role in reducing dependency on chemical fertilizers and advancing sustainable farming practices, emphasizing the need for further research into optimizing microalgae-based soil amendment technologies such as nanoparticles for diverse agricultural systems.

**KEYWORDS**: Microalgae, Sustainable agriculture, Soil nutrient enhancers, Soil fertility, Chemical fertilizers.

## INTRODUCTION
In recent years, the demand for sustainable agricultural practices has intensified, driven by the need to balance increased food production with environmental conservation (Murata *et al*., 2021). Traditional methods of enhancing soil fertility often rely on chemical fertilizers, which, despite their effectiveness, pose several challenges, including soil degradation, pollution, and the disruption of natural nutrient cycles (Suleiman *et al*., 2020). As a result, there is an increasing interest in exploring environmentally friendly alternatives to conventional fertilizers. Among these alternatives, microalgae have emerged as a promising natural solution due to their nutrient-rich composition, ability to grow on non-arable land, and capacity to utilize wastewater, minimizing resource competition with food production (Alvarez *et al*., 2021). Microalgae are diverse, photosynthetic microorganisms capable of producing high biomass and accumulating a variety of nutrients, including nitrogen, phosphorus, potassium, and trace elements essential for plant growth (Alvarez *et al*., 2021). In addition to their nutrient content, microalgae produce

bioactive compounds that can enhance soil microbial activity, improve soil structure, and promote plant health. These characteristics make microalgae an attractive option for use as a bio-fertilizer, soil conditioner, and nutrient amendment in various agricultural systems (Romero-García *et al*., 2022). This article provides a comprehensive overview of the role of microalgae in enhancing soil fertility and supporting sustainable agriculture by discussing the nutrient profile of different microalgae species, their application methods in soil, and the mechanisms by which they influence soil properties and plant growth. Furthermore, it examines the environmental and economic benefits of using microalgae in agriculture, as well as the challenges and limitations that must be addressed to enable their widespread adoption. By exploring recent advances and identifying knowledge gaps, this review seeks to highlight the potential of microalgae as a natural and sustainable alternative to synthetic fertilizers, contributing to the advancement of sustainable agricultural practices.

**General Characteristics of Microalgae**

Microalgae represent a diverse group of photosynthetic microorganisms spanning various taxonomic classifications and are broadly divided into prokaryotic and eukaryotic types. Prokaryotic microalgae, primarily cyanobacteria like *Spirulina* and *Anabaena*, lack a true nucleus, while eukaryotic microalgae, such as *Chlorella* (Chlorophyta) and *Phaeodactylum* (Bacillariophyta), possess a defined nucleus (Iavicoli *et al*., 2022). These microorganisms thrive in diverse aquatic environments and even extreme habitats, underscoring their adaptability (Guldhe *et al*., 2017; Gupta *et al*., 2023). Microalgae serve as primary producers, converting sunlight, carbon dioxide, and water into energy, making them essential to global carbon fixation and oxygen production. Their versatile growth capabilities, allowing autotrophic, heterotrophic, and mixotrophic modes, enhance their potential for large-scale cultivation, even in environments like wastewater and saline waters (Goyal *et al*., 2023).

Nutritionally, microalgae are abundant in macronutrients, including proteins, lipids, and carbohydrates. Some species, such as *Spirulina*, contain high protein levels and essential amino acids, while others, particularly those rich in polyunsaturated fatty acids (PUFAs), offer valuable nutritional benefits for plants and animals (Gupta *et al*., 2023). Additionally, microalgae are high in essential vitamins and minerals that benefit plant growth, such as iron, magnesium, and zinc (Guldhe *et al*., 2017). Beyond their nutritional profile, microalgae produce bioactive compounds that enhance soil and plant health, including antioxidants, antimicrobial agents, and growth-promoting hormones (Holdmann *et al*., 2019). These attributes collectively underscore the promise of microalgae in sustainable agriculture, particularly for soil fertility and health enhancement (Gupta *et al*., 2023).

**Commonly Used Microalgae Species in Agriculture**

Several microalgae species have gained popularity in agricultural applications due to their unique characteristics and potential uses. *Chlorella spp*., a protein-rich green alga, has shown promise as a natural fertilizer, significantly enhancing soil nutrient content, crop yields, and plant growth through improved nitrogen and phosphorus levels (Dineshkumar *et al*., 2020; Gürbüz and Çelik, 2023). Studies also suggest that Chlorella promotes soil microbial diversity and nutrient cycling, supporting its role in sustainable agriculture (Fang and Zhang, 2022; Li *et al*., 2024). Spirulina (*Arthrospira spp*.), known for its high protein content, has been shown to improve soil fertility and crop productivity by enhancing nutrient levels, organic matter, and microbial activity (Lafarga *et al*., 2020; Ranjbar and Abad, 2023). Studies demonstrate that Spirulina applications boost soil structure and nutrient availability, supporting its role as a sustainable biofertilizer in agriculture (Shahzad *et al*., 2023). *Dunaliella salina*, a halophilic microalga, has shown potential as a biofertilizer by enhancing soil nutrient content, microbial activity, and crop yields (Khan *et al*., 2023). Studies highlight its role in increasing nutrient availability and promoting beneficial soil microbes, supporting its use as a sustainable soil enhancer in agriculture (Gupta and Mehta, 2022). *Haematococcus pluvialis* has shown promise as a biofertilizer, enhancing soil nutrients (notably nitrogen and potassium) and boosting plant growth and crop yields (Kim and Lee, 2022). Studies reveal its ability to improve soil microbial diversity, nutrient uptake, and root development, supporting its use in sustainable agriculture (Ali *et al*., 2024). Studies on *Euglena gracilis* have demonstrated its potential as an organic manure and soil enhancer. Mishra and Paliwal (2023) assessed its impacts in agricultural settings and discovered that its incorporation significantly boosted nutrient levels, particularly nitrogen, phosphorus, and potassium; resulting in enhanced plant growth and crop yields. In a similar vein, Sahu *et al*. (2022) explored the effects of Euglena on soil health and microbial activity, finding that its application increased soil organic matter and microbial diversity, which in turn improved nutrient cycling and overall soil fertility. Bhowmick *et al*. (2024) investigated the ability of *Euglena gracilis* to enhance soil quality and plant performance, revealing that its use improved soil structure, increased moisture retention, and promoted root development, all leading to higher crop yields. Furthermore, Choudhary and Kumar (2023) highlighted the advantages of employing it as a biofertilizer, noting that its application enhanced nutrient availability in the soil and positively impacted growth parameters in various crops. Figure 1 shows commonly used microalgae species in agriculture.

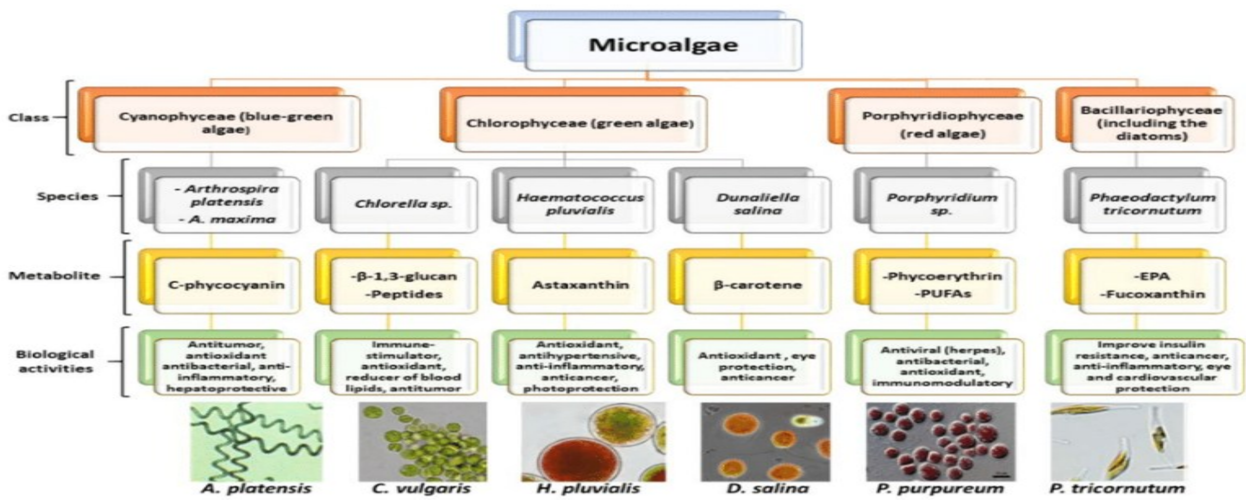


**Figure 1: Commonly Used Microalgae Species in Agriculture**

Source: Gonçalves (2021)

**Growth and Cultivation Requirements for Microalgae**

There are many factors that affect the growth and productivity of microalgae, some of these factors include nutrient availability, light intensity, temperature, pH, salinity, and aeration (Rathod *et al*., 2022). Optimal N:P ratios typically range from 16:1 to 24:1, varying by species. Proper nutrient management supports efficient growth, while strategic limitation can induce production of valuable compounds like lipids. Manipulating nutrient concentrations allows optimization for different purposes (Yadav *et al*., 2020). Light intensity typically ranges from

100-200 µmol photons m^-2 s^-1 for optimal microalgae growth, though requirements vary by species. Excess light causes photoinhibition, while photoperiod preferences differ, with some species thriving under continuous illumination and others preferring light/dark cycles (Rathod *et al*., 2022). Most microalgae prefer temperatures between 20-30 °C, with species-specific variations. Higher temperatures accelerate metabolism but can damage cells, while lower temperatures slow growth but promote valuable compounds like polyunsaturated fatty acids. Climate change makes temperature management increasingly important (Yadav *et al*., 2020). Optimal pH of most species is in the range of 7 – 9 while others such as *Spirulina platensis* tolerate up to pH 11. pH affects nutrient availability, carbon dioxide ($CO_2$) solubility, and photosynthetic efficiency, making it crucial to maintain proper pH for maximizing productivity and creating optimal growing conditions. The $CO_2$ concentrations between 1-5 % enhance productivity compared to atmospheric levels (0.04 %). While increased $CO_2$ stimulates growth, excessive levels can decrease pH, creating acidic conditions that inhibit algal growth and metabolic processes. Effective mixing (aeration) ensures even nutrient distribution, prevents sedimentation, and improves gas exchange. Aeration provides $CO_2$ and removes excess oxygen, which can inhibit photosynthesis if accumulated (Holdmann *et al*., 2019).

**Cultivation Systems of Microalgae**

There are two main types of microalgae cultivation systems, open and closed, and each of these has its own advantages and disadvantages. The most common and economical method for large-scale microalgae cultivation is the use of open systems like raceway ponds, where the growing medium is directly exposed to the air. Evaporation helps regulate temperature, but issues such as aeration, water replacement to offset evaporative loss, and contamination by algal grazers remain its challenges. The main attractive features of these systems are their simplicity, low construction and operational costs, and ease of maintenance (Jebali *et al*., 2021). They also tend to have lower biomass productivity than closed systems do because of lack of light penetration and low $CO_2$ availability (Kumar *et al*., 2022). One way in which open systems reduce costs is using nutrient-rich wastewater as the culturing medium which also provides a mechanism to reduce heavy metal (i.e. lead, nickel, and cadmium) toxicity in the wastewater (Jebali *et al*., 2021). The most popular type of open system are raceway ponds with a depth between 10 and 50 cm, to allow for appropriate illumination, and having a paddle wheel for gas/medium mixing and circulation. A closed system or photobioreactor focuses on optimizing light capture and use a tubular or flat-plate design while controlling evaporation, culturing media, contamination, and temperature. Typically, photobioreactors have higher volumetric productivity and can better capture light than open ponds which rely on natural light (Kumar *et al*., 2022).

The choice between open (in figure 2) and closed (in figure 3) systems depends on various factors, including the microalgae species being cultivated, desired products, local environmental conditions, and economic considerations. For example, in the case of high-value products like nutraceuticals or certain pigments, closed systems are more commonly used because they can better preserve the purity and production conditions (Barros *et al*., 2023). However, for lower-value, high-volume products such as biofuels, or for wastewater treatment where contamination is not nearly as big an issue, open systems may be more appropriate. They are also working on hybrid systems that incorporate open and close cultivation in order to utilize the benefits of both types of systems (Yin *et al*., 2021). With the continuing development of microalgae biotechnology, new cultivation systems will allow for greater efficiency, lower costs, and a wider variety of uses for products derived from microalgae. *Arthrospira spp., Dunaliella spp.,* *Anabaena spp., Phaeodactylum spp., Pleurochrysis spp., Chlorella spp. and Nannochloropsis spp. are typically cultured in open systems while Porphyridium spp., Haematococcus spp. and Tetraselmis spp.* are usually cultured in closed systems (Barros *et al*., 2023). Table 1 shows factors involved in utilizing a system for culturing microalgae and compared between a photobioreactor (closed system) and a raceway pond (open system)

**Table 1: Comparison of Factors for Microalgae Cultivation in Photobioreactors (Closed System) vs. Raceway Ponds (Open System)**

| Factor | Photobioreactor | Raceway Pond |
|---|---|---|
| Space required | Moderate | High |
| Evaporation loss | Low | High |
| CO2 Sparging efficiency | High | Low |
| Maintenance | Difficult | Easy |
| Contamination risk | Low | High |
| Biomass quality | Reproducible | Variable |
| Energy input for mixing | High | Low |
| Operation type | Batch | Batch |
| Setup cost | High | Low |
| Maintaining continuous | Difficult | Difficult |

Source: Mukabane *et al*. (2024)

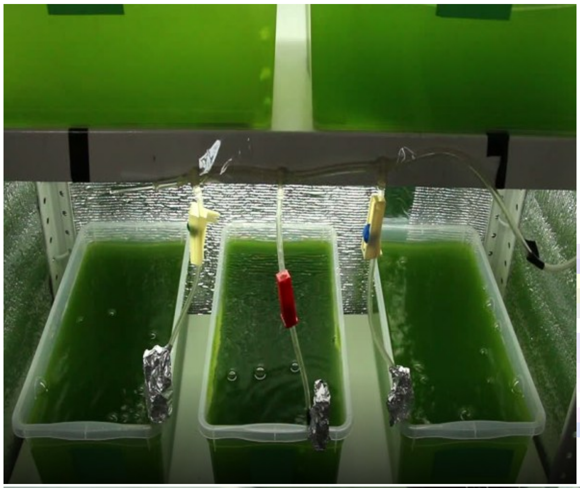

**Figure 2: Open System** **Figure 3: Close System**

Source: Mukabane *et al*. (2024)

**Harvesting Methods for Microalgae**

Harvesting is a critical step in microalgae cultivation, often accounting for 20-30 % of the total production costs. The choice of harvesting method depends on factors such as algae species, cell density, culture volume, and the desired end product (Saad *et al*., 2019). Different harvesting techniques for microalgae and their advantages and limitations are shown in table 4.

**Table 2: Advantages and Limitations of Different Microalgae Harvesting Techniques**

| Harvesting Techniques | Advantages | Limitations |
|---|---|---|
| Sedimentation | Simple and inexpensive; Do not require complex equipment. | Slow process; May result in lower biomass recovery. |
| Floatation | Low-cost method; Short operation time; Low space requirement. | Requires the use of chemical surfactants. |
| Filtration | Cost effective; High biomass recovery. | Requires regular maintenance of membranes; Membrane fouling and replacement increase operational costs. |
| Centrifugation | Rapid and efficient separation technique, High biomass recovery rate; Applicable to almost all microalgae species. | High energy consumption; Possibility of cell damage; Expensive equipment and management cost. |
| Coagulation/flocculation | Aggregates microalgae; It can be used in combination with other techniques for improved efficiency; Cost effective. | Requires the use of chemicals for flocculant formation; Chemicals may be expensive. |
| Electrical based processes | Do not require the use of chemicals; Applicable to a wide range of microalgae species. | High energy consumption and equipment cost. |

Source: Singh and Patidar (2018)

The harvested microalgae biomass undergoes a two-step processing method where it is first subjected to freeze-drying (a preservation technique that removes water through sublimation while maintaining cellular integrity), after which the dried material is mechanically processed through milling equipment to produce a fine powder that can be easily stored and applied in various agricultural applications (Olivares-Molina and Fernández-Ponce, 2022), as illustrated in figure 4.


**Figure 4: Harvested/Freeze Dried/Blended (Powdered) Microalgae**

Source: Olivares-Molina and Fernández-Ponce (2022)

**Nutrient Profile of Microalgae (macronutrients, micronutrients, bioactive compounds and secondary metabolites) and their roles in soil health**

Microalgae are abundant in macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), which are fundamental for soil health. Nitrogen is essential for chlorophyll production and plant growth, phosphorus aids in root development and energy transfer, and potassium enhances plant resilience to stressors such as drought and disease. Together, these macronutrients from microalgae create a nutrient-rich environment essential for plant vitality and soil fertility, making microalgae a valuable agricultural soil supplement (Tan *et al*., 2020). In addition to macronutrients, microalgae provide essential micronutrients and trace elements, including iron, zinc, magnesium, and manganese, which are critical for metabolic activities like photosynthesis and enzyme functions. Iron and zinc support chlorophyll synthesis and enzyme activity, while magnesium is a vital component of chlorophyll itself (Tan *et al*., 2020). This micronutrient profile allows microalgae to create a balanced nutrient supply in the soil, which enhances plant resilience and growth by meeting a broad range of metabolic needs (Kumar *et al*., 2023).

Beyond traditional nutrients, microalgae also provide bioactive compounds and secondary metabolites, such as phytohormones, polysaccharides, and antioxidants. These bioactive compounds can stimulate plant growth and support soil structure. Phytohormones, like auxins and cytokinins, promote root development and cell division, while antioxidants help protect soil microorganisms, fostering a healthy soil microbiome (Gupta *et al*., 2023). These benefits highlight microalgae's role as a soil enhancer, contributing to the sustainability and productivity of agricultural systems (Holdmann *et al*., 2019).

**Table 3: Classes of Bioactive Compounds in Microalgae/Cyanobacteria and their Potential Roles in Agriculture**

| Bioactive Compounds | Biological Activity | Role in Agriculture | Microalgae/Cyanobacteria Sources |
|---|---|---|---|
| **Phenolic Compounds** | Antioxidant, antibacterial, and antifungal | Crop protection against pathogens and various biotic and abiotic stress conditions | *Chlorella vulgaris*, *Isochrysis sp.*, *Botryococcus braunii*, *Odontella sinensis*, *Chaetoceros calcitrans*, *Phaeodactylum tricornutum*, *Isochrysis galbana*, *Tetraselmis suecica*, *Saccharina japonica*, |
| **Carotenoids** | Antioxidant, anti-inflammatory, and anticancer | Crop fortification; Soil bioremediation and fertilization; Crop protection against biotic and abiotic stress conditions | *Spirulina sp.*, *Dunaliella salina*, *Chlorella pyrenoidosa*, *Haematococcus pluvialis*, *Chlorella protothecoides*, *Murielopsis sp.*, *Chlorella zofingiensis*, *Phaeodactylum tricornutum* |
| **Terpenoids** | Antioxidant, antibacterial, and anticarcinogenic | Crop protection against insects and bacteria; Attraction of pollinators; Stimulation of plant growth and development | *Pseudanabaena articulate*, *Sphaerococcus coronopifolius*, *Chondrococcus hornemannii*, *Hypnea pannosa*, *Plocamium cornutum*, *Oscillatoria perornata*, *Planktothricoids raciborskii*, *Thermosynechococcus elongate*, *Portieria hornemann* |
| **Polysaccharides** | Antioxidant, anti-inflammatory, antibacterial; anticoagulant and anticancer | Crop protection against biotic and abiotic stress conditions; Improvement of soil quality; Stimulation of plant growth | *Dunaliella*, *Chlorella*, *Navicula*, *Aphanothece*, *Cylindrotheca*, *Scytonema*, *Arthrospira*, *Rhodella*, *Phaeodactylum*, *Chlamydomonas*, *Porphyridium*, *Nostoc* |
| **Free Fatty Acids** | Antioxidant, antifungal, antiviral, antibiotic, and anticarcinogenic | Crop protection against various biotic and abiotic stress conditions | *Dunaliella*, *Spirulina*, *Chlorella*, *Porphyridium*, *Nannochloropsis*, *Anabaena*, *Scenedesmus* |
| **Phytohormones** | Chemical messengers | Crop response to stress conditions; Regulation of cellular activities in crops | *Chlamydomonas*, *Chlorella*, *Protococcus*, *Scenedesmus*, *Arthrospira*, *Phormidium* |

Source: Singh and Patidar (2018)

## Microalgae as Biofertilizers

The use of microalgae in agriculture offers a range of advantages, not only for the environment but also for the health of the soil and, subsequently, for the crops (Osorio-Reyes *et al*., 2023). In general, microalgae exhibit growth-enhancing properties through three distinct modes, namely biofertilizers, biostimulants, and biopesticides (Parmer *et al*., 2023). In contrast to chemical fertilizers, the introduction of microalgae into the soil as biofertilizers can help to create a more diverse and healthy soil ecosystem, promoting nutrient cycling, and improving soil structure and fertility (Osorio-Reyes *et al*., 2023). Figure 1 provides a comprehensive overview of the main activities linked to microalgae-based products in agricultural practices, highlighting their action mode and impact on crop production.

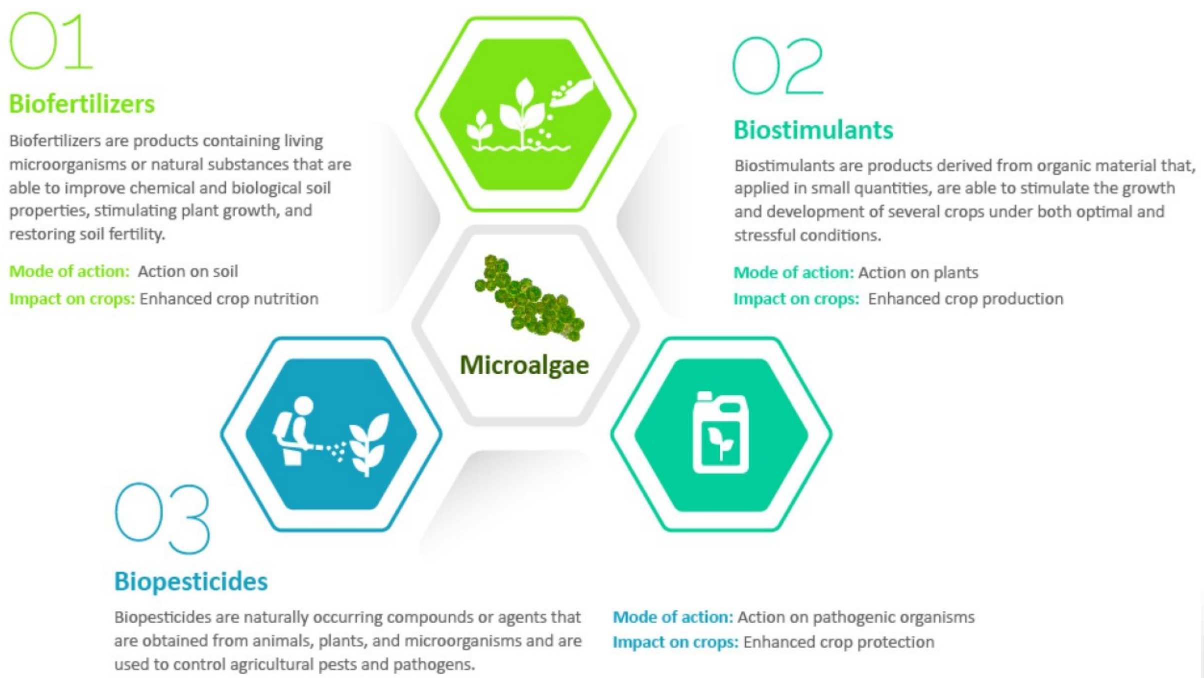


**Figure 5: Classification of the Main Activities Associated with Microalgae in Crop Production**

Source: Gonçalves (2021)

**Application methods for microalgae in soil**

Microalgae can be directly applied to soil as fresh or dried biomass, serving as a natural soil amendment. This method enriches soil with essential nutrients and supports beneficial microbial activity, enhancing soil structure and organic matter content. Direct application is straightforward and cost-effective, making it an accessible way to improve soil health. Foliar spraying (FS) is a commonly employed method for enhancing crop productivity in several crops owing to the faster response of plants to nutrients supplemented compared to other treatments and it enhances the water use efficiency and stomatal functioning of the plants (Arahou *et al*., 2022). Processed microalgae are also used in biofertilizer production, where they are cultivated, harvested, and formulated into products like granules or liquid suspensions. As biofertilizers, they release nutrients gradually and offer bioactive compounds that stimulate plant growth and soil health. These formulations allow precise nutrient management, tailored to specific crop or soil needs. Another approach is to integrate microalgae with traditional fertilizers (organic or synthetic) or even with nanoparticles (Rai *et al*., 2023). By combining with organic fertilizers, microalgae boost organic matter and microbial activity, while with synthetic fertilizers, they improve nutrient efficiency and reduce chemical dependency (Smith and Jones, 2023). In field trials, combining microalgae with nanoparticles has been shown to improve nutrient delivery and bioavailability, enhancing plant uptake and reducing nutrient losses through leaching or volatilization (Rai *et al*., 2023). This synergy supports efficient, sustainable soil and crop management and promotes sustainable soil management.

**Environmental and Economic Benefits of Using Microalgae in Agriculture Over Chemical Fertilizers**

Microalgae can serve as a natural biofertilizer, reducing the need for chemical fertilizers that can harm ecosystems. Algae-based fertilizers release nutrients slowly, allowing plants to absorb them more effectively and reducing nutrient runoff, which is a common issue with synthetic fertilizers. By decreasing fertilizer runoff, microalgae help mitigate water pollution and eutrophication in nearby water bodies, thus promoting healthier ecosystems (Tan *et al*., 2020). Microalgae are efficient in capturing carbon dioxide, a major greenhouse gas. Through photosynthesis, they convert $CO_2$ into biomass, which can then be used in various agricultural applications. This process contributes to carbon sequestration, helping reduce atmospheric $CO_2$ levels. Additionally, using microalgae-based biofertilizers can decrease the greenhouse gas emissions associated with the production and application of conventional fertilizers, particularly those related to nitrogen-based fertilizers (Parmer *et al*., 2023).

Microalgae production for agriculture is economically viable, especially as it can be cultivated on non-arable land and in wastewater, reducing competition for agricultural land and freshwater resources. Furthermore, algae grow rapidly and can be produced throughout the year, offering a steady supply of biofertilizers and biostimulants. For farmers, switching to algae-based inputs can reduce input costs, improve soil health, and enhance crop yields over time. Studies have shown that while the initial setup for algae cultivation may be costly, long-term benefits and reduced dependency on expensive chemical fertilizers create a favourable cost-benefit ratio (Osorio-Reyes *et al*., 2023).

**Previous studies on the potential of microalgae as soil enhancers and crop yield improvers**

The application of microalgae as soil amendments has gained significant attention in recent years due to their potential to enhance soil fertility, improve crop yields, and promote sustainable agriculture. Several studies have explored various aspects of microalgae applications in soil management (Ali *et al*., 2024). Renuka *et al*. (2021) conducted a pot trial on the use of microalgal biomass as a biofertilizer, specifically investigating the effects of *Chlorella vulgaris* on soil nutrient levels and crop yield. The trial was conducted in a controlled greenhouse environment in India and found that soil amended with *Chlorella vulgaris* biomass led to a 23 % increase in nitrogen content and a 17 % rise in phosphorus availability for wheat cultivation, which contributed to a 15 % increase in grain yield. This research underscored the potential of microalgae as a sustainable alternative to chemical fertilizers. Similarly, Xiao *et al*. (2023) carried out field trials in China to investigate the effects of microalgal inoculation on soil physical properties, highlighting the broader applications of microalgal biofertilizers in agricultural systems. Their research demonstrated that the application of Scenedesmus obliquus improved soil aggregate stability by 22 % and water holding capacity by 15 % in sandy loam soils. These improvements were attributed to the production of extracellular polymeric substances by the microalgae. A study by Adame *et al*. (2022) focused on the carbon sequestration potential of soil microalgae in agricultural landscapes. They reported that microalgae biocrusts could sequester up to 5.2 tons of carbon per hectare per year, suggesting a significant role in mitigating climate change while improving soil organic matter content. Kumar *et al*. (2024) explored the use of microalgae for heavy metal remediation in contaminated agricultural soils. Their experiments with Chlorella sorokiniana showed a reduction of up to 50 % in cadmium and 40 % in lead concentrations over a four-month period, demonstrating the potential of microalgae in soil decontamination. Peng *et al*. (2022) investigated the synergistic effects of microalgae and plant growth-promoting rhizobacteria (PGPR) on soil fertility. They found that co-inoculation of *Chlorella vulgaris* with *Azospirillum brasilense* enhanced soil nitrogen content by 35 % and increased maize yield by 20 % compared to individual inoculations.

Singh *et al*. (2021) studied the impact of microalgae amendments on crop drought resistance. Li *et al*. (2023) examined the effects of microalgae inoculation on salt-affected soils. Application of Dunaliella salina reduced soil electrical conductivity by 25 % and increased tomato yield by 18 % in saline soils, indicating the potential of halotolerant microalgae in reclaiming salt-affected agricultural lands. Chen *et al*. (2022) investigated the use of selenium-enriched microalgae as a soil amendment. They found that applying Spirulina platensis biomass enriched with selenium increased soil selenium availability by 40 % and enhanced grain selenium content in rice by 35 %, offering a novel approach to biofortification. Zhang *et al*. (2020) studied the impact of microalgae amendments on soil organic matter decomposition. Their research showed that inoculation with Chlamydomonas reinhardtii accelerated the decomposition of crop residues by 30 %, enhancing nutrient cycling and soil fertility. The collective findings of these studies highlight many advantages of applying microalgae as soil amendments, including bioremediation, stress reduction, soil nutrient enrichment and crop yield improvement. The studies also demonstrate the potential of microalgae to support soil health monitoring and sustainable farming techniques.

**Challenges and Limitations of Using Microalgae in Agriculture**

While microalgae offer significant environmental and economic advantages for agriculture, including reduced dependency on chemical fertilizers and carbon sequestration, several challenges limit their widespread use. Scaling up cultivation remains costly and complex, requiring precise environmental control and substantial energy for processes like drying and harvesting. Large-scale operations may also pose local environmental risks if waste products aren't managed carefully Renuka *et al*. (2021). Application limitations also arise, as microalgae-based fertilizers may not deliver nutrients consistently across all soil types or climates and may not be suitable for all crops. Finally, regulatory and market barriers further complicate the adoption of microalgae in agriculture. Regulatory frameworks for algae-based products are still evolving, and obtaining approvals can be a lengthy and complex process that varies by region. In some cases, restrictions on specific microalgae strains or production methods create further obstacles for producers (Kumar *et al*., 2023). Market development also faces hurdles, as many farmers are unfamiliar with microalgae fertilizers and may hesitate to adopt new practices without clear evidence of their cost-effectiveness and benefits compared to conventional fertilizers. Creating demand and building trust among farmers and consumers will require substantial outreach, education, and demonstration of the long-term benefits of microalgae-based solutions (Parmer *et al*., 2023). Overcoming these challenges through innovation, education, and supportive policies will be key to integrating microalgae into sustainable farming practices.

**Future Directions and Research Needs for Microalgae in Agriculture**

To fully explore the potential of microalgae in agriculture, targeted research and development are essential in optimizing cultivation techniques for cost-effective production. Innovations in photobioreactor design, nutrient recycling, and energy-efficient harvesting methods could help reduce costs, making microalgae a viable option for large-scale agricultural use (Holdmann *et al*., 2019). Developing efficient delivery systems for applying microalgae in various soil types and climates is also crucial. Research should focus on ensuring that algae-based nutrients reach plant roots effectively and sustainably, regardless of environmental conditions. Additionally, long-term studies on soil health and crop productivity are needed to assess the enduring impact of microalgae biofertilizers, potentially demonstrating added benefits like improved soil structure and increased microbial activity (Rai *et al*., 2023). Finally, advances in genetic engineering and biotechnology could significantly enhance microalgae's application in agriculture. By increasing nutrient content, growth rates, or environmental resilience, genetically optimized algae could offer higher-value biofertilizers tailored to specific agricultural needs (Gupta *et al*., 2023). Pursuing these research directions will be instrumental in making microalgae a practical, sustainable solution for the future of farming.

## CONCLUSION AND RECOMMENDATIONS

This review highlights the potential of microalgae as effective soil nutrient enhancers, offering a rich source of essential macronutrients, micronutrients, and bioactive compounds. Key applications methods, including direct biomass use, foliar spraying (FS) biofertilizer production, and integration with existing fertilization methods. It also demonstrates the versatility of microalgae in improving soil fertility, enhancing microbial activity, and promoting sustainable agricultural practices. When combined with advanced technologies like nanoparticles, microalgae can further improve nutrient delivery and reduce chemical input reliance. The application of microalgae in agriculture supports sustainable soil management by reducing the need for synthetic fertilizers and enhancing soil health through organic enrichment and bioactive compounds that foster plant growth. These attributes align with goals for sustainable agriculture, as they help maintain soil biodiversity, improve crop productivity, and minimize environmental impacts. Microalgae thus offer a promising solution for developing resilient and productive agricultural systems, particularly in the face of global challenges such as soil degradation and climate change. In summary, microalgae possess a unique, multifaceted potential to enrich soil nutrients, enhance soil structure, and support sustainable agriculture. Continued research and development are essential to optimize microalgae-based applications and fully harness their benefits for large-scale agricultural practices. By integrating microalgae into soil management, we can move closer to a more sustainable, resilient food production system.

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# PRODUCTION AND ANTIFUNGAL ACTIVITY OF BIOSURFACTANT AGAINST STORED PRODUCT FUNGI

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## ABSTRACT

Fungal contamination in stored agricultural commodities poses significant risks to food security, public health, and economic stability. Traditional methods for controlling spoilage fungi such as Aspergillus, Penicillium, and Fusarium face challenges like environmental pollution and the emergence of resistant strains. This study explores biosurfactants which are biodegradable, eco-friendly molecules produced by microorganisms, as a natural alternative for fungal control. Derived from bacterial isolates in fermented foods, biosurfactants disrupt fungal membranes and exhibit versatile applications in food preservation and sustainability. The study identified bacterial isolates capable of producing biosurfactants with diverse functional properties. In oil drop collapse and oil displacement tests, isolates OS5 and IS5 demonstrated exceptional surface activity, with rapid oil droplet collapse and significant oil displacement (up to 5.0 cm). Emulsification indices ranged from 20% to 65%, with isolates OS5 and IS5 exhibiting superior capacities, making them ideal for industrial applications like bioremediation and detergent production. Additionally, biosurfactants showed antifungal activity, with isolate OS5 demonstrating broad-spectrum inhibition against common contaminants, including Aspergillus niger and Fusarium spp. The findings highlight the two potentials of biosurfactants in *the* environmental and agricultural sectors. These natural compounds offer sustainable solutions for fungal contamination and industrial challenges, reducing reliance on synthetic chemicals. Future research should optimize production and explore structural properties to enhance efficiency and broaden application potential.

**Keywords**: biosurfactant, antifungal activity, stored product, food safety and ecofriendly.

## INTRODUCTION

Fungal contamination in stored agricultural products is a critical issue with significant implications for global food security, economic stability, and public health (Smith *et al.,* 2019). Spoilage fungi, including *Aspergillus*, *Penicillium*, and *Fusarium* species, not only cause physical and nutritional deterioration but also produce mycotoxins, which are toxic secondary metabolites that can contaminate food and pose serious health risks to consumers (Banat *et al.,* 2020). Additionally, fungi can degrade stored products enzymatically, leading to physical damage, off-flavors, and loss of nutritional value (Konishi *et al*., 2017) Furthermore, the growth of fungal mycelium can cause structural changes and produce extracellular enzymes that break down complex carbohydrates, proteins, and lipids. The health risks associated with fungal spoilage of stored products, particularly mycotoxin contamination, cannot be overlooked. Certain fungal species, such as Aspergillus, Penicillium, and Fusarium, are capable of producing mycotoxins, which have been linked to various adverse health effects, including carcinogenic, mutagenic, teratogenic, and immunosuppressive properties (Battilani *et al.,* 2016). Mycotoxins can enter the food chain, leading to human exposure and potential toxicity.

Preventing and controlling fungal spoilage of stored products requires a comprehensive and multi-faceted approach. Good agricultural practices, including proper harvesting, drying, and storage techniques, can minimize fungal contamination at the production stage (Desai & Banat, 2020). Adequate storage conditions, such as maintaining appropriate temperature, humidity, and ventilation, are crucial for inhibiting fungal growth during storage. Proper packaging, including moisture barriers and insect-proof materials, also prevents fungal infestations. The development of eco-friendly and sustainable strategies for food preservation is of utmost importance, Biosurfactants offer a promising alternative to synthetic fungicides as they are biodegradable, non-toxic, and environmentally friendly (Van *et al*., 2017), The production and characterization of biosurfactants from these bacterial isolates can provide valuable insights into their antimicrobial properties, including their effectiveness against spoilage fungi commonly found in stored food products (Rahman, 2018). Biosurfactants are surface-active compounds produced by microorganisms when grown on a carbon source (Ijah *et al.,* 2018). They possess both hydrophobic and hydrophilic regions in their structure, which enable them to reduce the surface tension and interfacial tension between different phases, such as water and oil (Sen *et al.,* 2017). This unique property allows biosurfactants to interact with hydrophobic substrates, including fungal cell membranes, disrupting their structure and function (Maier, 2020). As a result, biosurfactants exhibit antimicrobial activity against several microorganisms, including spoilage fungi (Rufino *et al.,* 2017).

The potential of biosurfactants as natural alternatives to synthetic fungicides for controlling fungal growth and mycotoxin production has gained significant interest in recent years (Crowley *et al,* 2021). Unlike synthetic fungicides, biosurfactants are biodegradable, non-toxic, and environmentally friendly (Torres *et al.,* 2020). They offer a sustainable approach to combat fungal contamination in stored food products, addressing economic and health concerns (Battilani *et al.,* 2016). Exploring the use of biosurfactants produced by bacterial isolates from traditionally fermented foods against stored product spoilage fungi presents a novel and promising research avenue (Cameotra, 2017). Traditionally fermented foods harbor a rich diversity of microbial communities, including bacteria with the ability to produce bioactive compounds. These bacteria have evolved in challenging environments and have developed mechanisms to produce compounds that help them compete with other microorganisms (Banat *et al.,* 2020).

## RESEARCH METHODOLOGY

### Collection of Samples

A variety of fermented food products such as *Kunun zaki*, *Fura*, *Ogi* and *Iru* were obtained from local food vendors in Kure Central market, Minna, Niger State, Nigeria in clean bottles and sterile bags. The samples were labeled appropriately and transported to the Microbiology laboratory, Department of Microbiology, Federal University of Technology, Minna, for the isolation of bacteria.

### Materials

The media used were Minimal Salt Medium, nutrient agar, nutrient broth, and potato dextrose agar were prepared according to the manufacturer's instructions. The media were sterilized by autoclaving at 121°C for 15 minutes and then allowed to cool before dispensing into sterile Petri dishes.

**Isolation of Bacteria Isolates from fermented foods**

Decimal dilutions of each food sample were carried out by transferring 1ml of the sample into tubes containing 9 ml of sterile water and homogenous solution was allowed to occur. The dilution procedure was repeated so that there were a series of six tubes giving serial dilution, $10^{-1}$ to $10^{-6}$. An aliquot of one (1ml) of $10^{-4}$, $10^{-5,}$ and $10^{-6}$ respectively for each sample was withdrawn with a sterile pipette into the of the sterile Petri dish and about 20 ml sterile molten nutrient agar was poured aseptically into the plate containing the aliquot and mixed for 10 seconds. Extreme care was taken so that the medium did not spill or gel on the lid of the Petri dish, The plates were allowed to cool and incubated at 37°C for 24 hours and observed for bacteria growth.

After incubation, pure colonies were obtained from distinct colonies by sub-culturing on nutrient agar and incubated at 37°C for 24 hours. The pure cultures were then grown on nutrient agar slant in MacCartney bottles and stored in a refrigerator. The inoculants for subsequent studies were obtained from the slants.

**Screening for Biosurfactant Production by Isolated Bacteria**

Each bacterial isolate was inoculated into 10 mll of nutrient broth medium and incubated at 37°C for 48 hours, centrifuged at 3000 rpm for 30 minutes where the supernatant was used for biosurfactant screening assays (Rufino *et al.,* 2017).

**Drop collapse test**

The assay was carried out as described by Rufino *et al.* (2017). A drop of the culture supernatant was placed carefully on an oil-coated glass slide and observed after one minute. If the drop of supernatant collapsed and spread on the oil coated surface, it signifies the presence of a biosurfactant (positive) However, if the drop remains after one minute, it was documented as negative. This test was simultaneously carried out on distilled water as a control.

**Oil spreading test**

Using a micropipette, ten microliters (10 µl) of engine oil were added to the surface of 40 ml of distilled Petri dish to form a thin oil layer. 10 µl of the culture supernatant was gently added to the water in the center of the oil layer. After one minute, if biosurfactant was present in the supernatant, the oil was displaced and a clearing zone was formed as described by Rufino *et al.* (2017). The area of displacement was calculated by expressing the cleared zone diameter over the oil surface diameter of the aqueous layer and then multiplying by 100 (Rufino *et al*., 2017).

$$\text{Area of displacement (AOD)} = \frac{Cleared\ zone\ diameter}{Oil\ surface\ diameter} \times 100 \qquad (1)$$

**Emulsification activity (E24)**

The emulsification activities of the biosurfactant solutions were determined by measuring the emulsion index (E24) at 25°C as described by Van *et al*. (2017). A mixture of 4 ml of diesel and 4ml of cell-free extract obtained after centrifugation of sample culture was taken in a test tube and homogenized by vortexing at high speed (6000 rpm) for 2 mins using Stuart auto vortex mixer (AE-11D, Great Britain). The homogenized mixture was then allowed to stand for 24 hours undisturbed. After 24 hours, the height of the stable emulsion layer and the total height of the mixture were measured by using a meter rule; the values obtained were used to calculate the emulsification index (E34), thus:

$$Emulsification\ index\ (E24) = \frac{Height\ of\ emulsifying\ layer}{Total\ height\ of\ solution} \times 100 \qquad (2)$$

**Characterization and Identification of Biosurfactant Producing Bacteria**

The potential biosurfactant-producing bacteria were characterized based on their Gram reaction, biochemical and molecular tests. Some of the biochemical tests are described below following the methods described by Cheesbrough (2006). The isolates were identified by comparing their characteristics with those of known taxa using Bergey's Manual of Determinative Bacteriology.

Isolates were subjected to Gram staining to determine their Gram reaction, revealing the structural differences in their cell walls through coloration under a microscope. Subsequent biochemical tests included the catalase, indole, oxidase, and citrate tests, which provided insights into enzymatic activity, substrate utilization, and metabolic capabilities. Additionally, carbohydrate utilization, motility, urease production, methyl red (MR), and Voges-Proskauer (VP) tests were conducted to assess the bacteria's physiological traits, further confirming their taxonomic identity. These results were compared against the criteria in *Bergey's Manual of Determinative Bacteriology*.

Molecular characterization involved DNA extraction, polymerase chain reaction (PCR), and sequencing. DNA extraction was meticulously performed using Proteinase K and CTAB to ensure high-quality DNA. The extracted DNA was then amplified using specific primers targeting bacterial genes, following a standard thermal cycling protocol. The amplified DNA's integrity was verified through agarose gel electrophoresis, and its concentration was quantified using a nanodrop spectrophotometer. For sequencing, the study used advanced tools such as the Big Dye Terminator v3.1 kit and a Genetic Analyzer, with the sequences processed using bioinformatics tools like BioEdit and MEGA 6 for genetic analysis and identification.

**Production and Identification of Biosurfactant Produced**

The bacterial isolates were incubated with Bonny light crude oil as a carbon source. The potential biosurfactant producing bacterial isolates were inoculated into a sterile Muller Hinton broth and incubated at 37°C for 24 hours, then Iml. of the 24 hours old culture was transferred into 1000mL. Erlenmeyer flask containing mineral salts oil medium of (ljah *et al.,* 2018) ($K_2HPO_4$ (1.8g), $KH_2PO_4$ (1.2g), NH, CI (4.0g), $MgSO_4.7H_2O$ (0.2g), NaCl (0.1g), $FeSO_4.7H_2O$ (0.01g), ImL of Bonny light crude oil, pH 7.4). The production medium was seeded with 3% inoculum and incubated at 37ºC for 48 hours with 150 rpm agitation. The cell free supernatant was used as a crude biosurfactant (Agarry *et al.,* 2018).

The culture was obtained and centrifuged at 3000 revolutions per minute for 15 minutes. After centrifugation, the resulting supernatant liquid was filtered through the Whatman No. 1 filter paper. The cell free supernatant was then concentrated **with** hydrochloric acid to lower its pH to 2. It was then left to sit in a refrigerator overnight to facilitate the complete precipitation of biosurfactant. Further chemical characterization utilized Gas Chromatography-Mass Spectroscopy (GC-MS) to identify specific compounds within the biosurfactant. The analysis involved separating and detecting chemical components under precise conditions, such as programmed temperature changes and helium as the carrier gas. The data were statistically analyzed using SPSS, ensuring robustness and reliability in interpreting the results. This comprehensive approach established a clear profile of biosurfactant-producing bacteria, highlighting their potential applications in industrial and environmental processes.

**Isolation of Fungi from stored products**

Samples of maize, rice, and melon seeds were gathered from multiple stalls in Kure Market. Each sample was placed in sterile polyethylene bags, clearly labelled, and transported to the Microbiology laboratory, Federal University of Technology within four hours to minimize extraneous contamination.

Isolation of fungi began with surface sterilization. Each sample underwent a rinse with sterile distilled water and was subsequently sterilized by immersion in a 1% sodium hypochlorite solution for one minute, followed by three additional rinses with sterile water to ensure the fungi isolated were endogenous to the grains. For fungal culturing, 10 grams of each ground sample (maize, rice, melon) were directly inoculated onto Potato Dextrose Agar (PDA) plates, which were supplemented with 0.1% streptomycin to inhibit bacterial growth. The plates were then incubated at 25°C for 5-7 days under standard fungal growth conditions (Sen *et al.,* 2017).

Following incubation, fungal colonies were observed and then sub-cultured onto fresh PDA plates to obtain pure cultures. The colony morphology such as color, texture, shape, and growth patterns of each isolate was meticulously recorded. Identification of fungal isolates involved microscopic examination. A portion of each fungal colony was stained with lactophenol cotton blue and observed under the microscope, to identify structures like conidia, conidiophores, sporangia, and hyphae. These morphological features were compared to established fungal identification keys and atlases for species confirmation.

## RESULTS AND DISCUSSION

**Table 1: Characterization of isolated fungi from stored product**

| Sample Type | Morphological Characteristics | Microscopic Features | Isolated Fungi |
|---|---|---|---|
| Maize | Black, powdery colonies with radial grooves on PDA; conidia dark | Septate hyphae; conidiophores; terminals in a globes vesicle; supporting phalides, spherical conidia in chains | *Aspergillus niger* |
| | Yellow-green, velveting colonies, rapid growth on PDA | Septate hyphae, conidiophores with rough walls; producing conidia in chains | *Aspergillus flavus* |
| Rice | Blue-green colonies with white periphery; compact texture | Branched septate hyphae; flasked shaped phalides grouped in clusters; elliptical conidia | *Penicillium* spp |
| | Fast growing white to grey cottony colonies | Aseptate coarse hyphae; sporangiophores produce round sporangia | *Mucor* spp |
| Melon | Dark brown to black colonies; dry, velvety texture | Septate hyphae; conidia are large, multicellular with longitudinal septa | *Alternaria* spp |

**Table 2: Oil spread/displacement caused by bacterial isolates**

| Isolates code | Diameter (cm) | Time (s) | |
|---|---|---|---|
| IS1 | 3.0 | 3 | |
| IS5 | 4.8 | 7 | |
| IS8 | 3.1 | 5 | |
| KS3 | 3.0 | 4 | Positive |
| OS5 | 5.0 | 8 | |
| OS6 | 3.8 | 6 | |
| OS7 | 3.0 | 5 | |
| OS8 | 3.3 | 5 | |
| IS2 | 2.3 | 11 | |
| IS3 | 1.5 | 25 | |
| IS4 | 2.0 | 15 | |
| IS6 | 1.4 | 17 | |
| IS7 | 2.4 | 20 | |
| IS9 | 2.8 | 22 | |
| IS10 | 2.3 | 25 | |
| KS1 | 2.3 | 19 | |
| KS2 | 0.5 | 16 | |
| KS5 | 1.5 | 17 | |
| KS4 | 1.8 | 24 | |
| KS6 | 2.0 | 18 | |
| KS7 | 2.3 | 17 | |
| KS8 | 2.7 | 19 | |
| KS9 | 2.2 | 20 | |
| KS10 | 0.5 | 26 | |
| OS1 | 0.3 | 28 | |
| OS2 | 1.5 | 22 | |
| OS3 | 1.5 | 26 | |
| OS4 | 2.3 | 19 | |
| OS9 | 0.7 | 21 | |
| OS10 | 1.2 | 24 | Negative |
| FS1 | 0.5 | 29 | |
| FS2 | 1.2 | 24 | |
| FS3 | 2.1 | 22 | |
| FS4 | 2.5 | 20 | |
| FS5 | 0.8 | - | |
| FS6 | 1.6 | - | |
| FS7 | 2.1 | - | |
| FS8 | 1.4 | - | |
| FS9 | 2.3 | - | |
| FS10 | 0.3 | - | |
| Control | - | - | |

Positive Diameter ≥ 3.0cm within 30 seconds of displacement
Negative Diameter ≤ 3.0cm within 30 seconds of displacement

**Table 3: Emulsification capacity of bacterial isolates**

| Isolates code | Emulsification Index, E24 (%) |
|---|---|
| IS1 | 37.55 |
| IS2 | 45.34 |
| IS3 | - |
| IS5 | 60.51 |
| IS8 | 40.24 |
| OS2 | 37.66 |
| OS3 | - |
| OS5 | 65.33 |
| OS8 | 41.74 |
| KS3 | 57.32 |
| Control | - |

Values are means ± standard error of means for n=2.
Key-: No emulsification

**Table 4: Antifungal activity of biosurfactants on fungi isolated from stored products**

| Isolates code | *Aspergillus niger* | *Aspergillus flavus* | *Mucor spp* | *Penicillium spp* | *Alternaria spp* |
|---|---|---|---|---|---|
| IS5 | - | - | 23.3 | - | - |
| OS5 | 28.9 | 25.9 | 32.6 | - | - |
| KS3 | - | - | - | - | - |

Table 1 shows the identification of fungi isolated from maize, rice, and melon based on their morphological and microscopic characteristics. In maize, *Aspergillus niger* forms black, powdery colonies with dark conidia, while *Aspergillus flavus* displayed yellow-green, velvety colonies. Both species exhibit septate hyphae and conidiophores, with conidia forming in chains. In rice, *Penicillium spp.* is identified by its compact blue-green colonies and elliptical conidia grouped on flask-shaped phialide, while *Mucor* spp. form cottony white-to-grey colonies with aseptate coarse hyphae and sporangia. Meanwhile, *Alternaria spp.*, isolated from melon, shows dark brown, dry colonies with large, multicellular conidia. These findings are crucial for understanding the fungal biodiversity in stored products, particularly the presence of mycotoxin-producing species like *Aspergillus niger* and *Aspergillus flavus*, which pose significant health risks.

In Table 2, the oil displacement activity of bacterial isolates was evaluated, categorizing them as positive or negative based on a diameter threshold of ≥3.0 cm within 30 seconds. Positive isolates, including IS5, OS5, and KS3, demonstrate potent biosurfactant activity, with diameters ranging from 3.0 to 5.0 cm achieved within seconds. In contrast, negative isolates, such as FS1 and OS1, exhibit minimal displacement or slower activity, falling below the threshold. These data highlight isolates like OS5 as promising candidates for producing biosurfactants, which can reduce surface tension, facilitate the breakdown of hydrophobic substances, and have potential applications in bioremediation and enhanced oil recovery.

Table 3 provides further insights into the functional potential of bacterial isolates by measuring their emulsification index (E24). OS5 and IS5 stand out with high indices of 65.33% and 60.51%, respectively, indicating their strong ability to stabilize emulsions. Moderate emulsifiers, such as IS2 (45.34%) and KS3 (57.32%), also show potential for industrial applications. In contrast, isolates like IS3 and OS3 lack emulsifying ability. High emulsification indices are particularly valuable in applications requiring stable mixtures, such as bioremediation of oil spills, formulation of bio-based products, and enhancing the solubility of hydrophobic compounds.

The antifungal potential of biosurfactants is assessed in Table 4, which measures their inhibitory effects on fungi isolated from stored products. OS5 demonstrates broad-spectrum antifungal activity, effectively inhibiting *Aspergillus niger* (28.9%), *Aspergillus flavus* (25.9%), and *Mucor spp.* (32.6%). IS5 shows selective activity against *Mucor spp.* (23.3%) but is ineffective against other fungi. KS3, by contrast, exhibits no antifungal activity. The ability of OS5 to inhibit multiple fungi, particularly mycotoxin producers like *Aspergillus*, positions it as a potential natural antifungal agent for protecting stored products, reducing spoilage, and enhancing food safety.

The integration of data across these tables reveals the multifunctional potential of certain bacterial isolates. OS5, in particular, stands out due to its high oil displacement, strong emulsification capacity, and broad-spectrum antifungal activity. Such isolates hold promise as biocontrol agents for managing fungal contamination in stored products and as bio-based alternatives in industrial applications. For instance, their biosurfactants could be used to protect maize, rice, and melon from spoilage, mitigate the risks of mycotoxins, and facilitate environmentally friendly practices in bioremediation and food preservation.

In conclusion, this study underscores the importance of identifying microbial species with diverse functionalities. The findings pave the way for innovative applications in stored product management, food safety, and industrial processes, particularly through the use of biosurfactants derived from effective bacterial isolates like OS5. Such natural solutions align with sustainable development goals, offering eco-friendly alternatives to synthetic preservatives and chemical surfactants.

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# GROWTH AND YIELD PERFORMANCE OF CUCUMBER (*Cucumis sativus* L.) AS INFLUENCED BY NPK 15:15: 15 AND WATERING LEVEL IN IGBOORA, OYO STATE, NIGERIA

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## ABSTRACT
Fertilizer application and adequate irrigation are essential to improve the growth and yield of crops. Therefore, a pot experiment was set up in the screen house at the Department of Crop Production Technology, Oyo State College of Agriculture and Technology, Igboora to investigate the effects of NPK 15:15:15 fertilizer (NPK) and watering level on growth performance and yield of cucumber. The treatment combinations (of NPK at 50, 100, and 150 kg/ha, and watering levels at 100, 200, and 300 ml) were arranged as a 3 × 3 factorial in a Completely Randomised Design (CRD) with four replicates. Growth parameters such as vine length, leaf area, number of leaves, stem diameter, and yield parameters such as number of fruits and yield were recorded and subjected to analysis of variance. The means were compared using Duncan's Multiple Range Test at a 5% probability level. NPK application at 150 kg/ha produced the highest significant vine length (21.64 cm), leaf area (123.3 cm2), number of leaves (19.22), number of fruits (3.64), and yield of cucumber (8.68 t/ha) while watering level at 200 ml produced the highest significant number of leaves (15.97), number of fruits (2.18) and yield of cucumber (9.97 t/ha). The effect of the interaction of the NPK fertilizer and watering level was significant for vine length, number of fruits, and yield of cucumber. The treatment combination of 200 ml watering level and NPK 15:15:15 fertilizer at 150 kg/ha produced the highest significant effect on the growth and yield parameters of cucumber and was recommended for optimum screen house production of the crop in the study area.
**Keywords**: Cucumber, NPK, Watering level, Growth and Yield

## INTRODUCTION
Cucumber (*Cucumis sativus* L.), is a fruit vegetable belonging to the family Cucurbitaceae. It originated in India and has gained widespread popularity worldwide. Introduced to West Africa by the Europeans in 1940, its cylindrical, green-skinned fruit is commonly consumed raw, cooked, or as a part of salads. In addition to its culinary applications, cucumber is used to produce facial cleansers, body creams, soap, and shampoo. It possesses remedial properties, such as reducing high blood pressure and aiding in treating kidney ailments. During the fruit formation stage and throughout the growth stage, cucumber plants require a significant amount

of water. To ensure enough food supply for the population, the emphasis has been on irrigated agriculture. While surface irrigation systems are simple, the efficient use of water is crucial, and drip irrigation systems have been recommended to improve irrigation efficiency and ensure optimal water use for agriculture. Excessive irrigation can lead to a decrease in crop yield, while insufficient irrigation can cause water stress and reduce production (Sezen *et al*., 2007). Various experiments have demonstrated the positive impact of different drip irrigation frequencies on different crops (Segal *et al*., 2000; Sharmasarkar *et al*., 2001). However, there is a lack of consistency regarding the optimal level of water required for specific cucumbers and under certain conditions. Mulvaney (1999) discovered that the highest yield of cucumbers was obtained on a frequency of every second day. Conversely, Wang *et al*. (2006) found that reducing the irrigation frequency from once a day to once a week resulted in a significant reduction in potato yield. Furthermore, Pitts *et al*. (1991) reported that two drip irrigation frequencies (three times per day and once per day) did not affect tomato yield.

The cultivation of cucumber has been shown to benefit from fertilizers. Inorganic fertilizers, which are chemical compounds made in industries play a crucial role in supplying essential plant nutrients such as nitrogen, phosphorus, and potassium. These fertilizers not only support plant growth but also serve as a soil amendment. Nitrogen, for instance, promotes vegetative growth and aids in photosynthesis, while phosphorus is necessary for stimulating flowering, fruiting, and seed formation. Additionally, potassium enhances starch and sugar formation, thus increasing the strength of the plant (Aujla *et al*., 2007). Cucumber requires a significant quantity of macro and micronutrients, particularly manganese and iron. Research has shown that 100 kg N ha-1 maximizes cucumber fruit length, fruit weight, and vine length, which are indirectly related to yield. However, for minimizing the days to flowering, days to fruit set, and days to fruit maturity, as well as obtaining a higher number of fruits and ultimately higher yield, 80 kg N ha-1 is the most economical dose (Waseem *et al*., 2008). Similarly, an increase in nitrogen application results in maximum fruit length and fruit weight of cucumber (Ahmed *et al*., 2007). Nevertheless, despite the importance of fertilizers and sufficient watering for improved cucumber production, little research has been conducted to examine their combined effects on growth and yield in the study area. Therefore, the objective of this study was to investigate the effects of NPK 15:15:15 fertilizer and watering level on the growth and yield of the crop.

## MATERIALS AND METHODS

The research site was located at a latitude of 6° 20′ N and a longitude of 50° 40′ E, with an elevation of 500 feet above sea level with a humid tropical climate, with a mean annual rainfall of 1762 mm and daily temperature of 26.40°C. It lies within the derived savannah agro-ecological zone in southwestern Nigeria. The study utilized a 3 × 3 factorial arrangement in CRD with four (4) replicates. Thirty-six (36) experimental pots were used, with each containing 5kg of soil. The treatment combinations comprised three levels of NPK 15:15:15 at 50, 100, and 150 kgha-1 and three levels of watering at 100, 200, and 300 ml. NPK fertilizer was applied two weeks after planting using the side-dressing method, while watering was done twice per day (morning and evening) using a graduated beaker.

The soil used in the experiment was collected on arable farmland of the research farm with a soil auger at 0-15 cm, air dried, and sieved with a 2 mm sieve before weighing and filling into the experimental pots. The composite sample was sent to the laboratory for physical and chemical analysis. The soil samples were air-dried for 21 days, crushed, and sieved to remove debris. The hydrometer method was used to determine sample particle size (Bouyoucos, 1962). The total nitrogen of the substrates was assessed using the macro-Kjeldahl method (Jackson, 1958). The pH was determined with a pH meter, while available phosphorus was estimated using the Bray 1 method (Bray and Kurtz, 1945).

Cucumber seeds (Armenian cucumber) were directly seeded into the experimental pots at 2 seeds per pot. Weeding was carried out manually by uprooting as at when due. Watering was done at the required level as scheduled. Data were collected on growth parameters from three weeks after planting. Vine length was measured using a meter rule, the number of leaves was virtually counted, and stem diameter was measured using a Vernier caliper. The leaf area was calculated using the Karaca et al., 2020 model, LA = a + bLW (where a = -6.29, b = 0.85, L – leaf length, W – leaf width). Yield parameters were taken by counting the number of fruits per plant and weighed using the S. Mettler Electronic Compact Balance measuring scale recorded in grams (g). The data collected were subjected to Analysis and Variance (ANOVA). The means were separated using Duncan's Multiple Range Test at a 5% probability level.

## RESULTS

### The pre-planting analysis of the experimental site

The results from the chemical and physical properties of the soil showed that the experimental soil had a pH value of 6.47 (Table 1). Hence, the experimental soil was moderately acidic. The soil was low in essential plant nutrients like nitrogen, phosphorus, and potassium with values of 1.7%, 9.97mg/kg, and 0.36cmol/kg, respectively. The particle size analysis of the soil is 89.4% sand, 5.8% silt, and 4.8% clay. Therefore, the soil textural class was sandy loam.

**Table 1: Physical and chemical properties of experimental soil**

| Elements | Values |
|---|---|
| pH ($H_2O$) | 6.47 |
| **Exchangeable base (Cmol/kg)** | |
| Ca | 3.65 |
| Mg | 0.76 |
| K | 0.36 |
| Na | 0.54 |
| Total N (g/kg) | 1.7 |
| Total Org. C (g/kg) | 8.7 |
| Available P (mg/kg) | 9.97 |
| **Particle size analysis** | |
| Sand (g/kg) | 89.4 |
| Silt (g/kg) | 5.8 |
| Clay (g/kg) | 4.8 |
| Textural class: | Sandy loam |

### Growth performance of cucumber as influenced by NPK fertilizer and watering level

The effects of NPK levels and watering levels on the vine length of cucumber were significant ($P \leq 0.05$) while the interaction effect of NPK levels and irrigation levels was not significant (Table 2) with respect to vine length. The application of NPK at 150 kg/ha produced the highest significant vine length (21.64 cm), followed by NPK at 100 kg/ha (19.13 cm) and NPK at 50 kg/ha (16.38 cm). The watering level showed that 200 ml application produced the highest significant ($P \leq 0.05$) vine length (17.72 cm) compared to 300 ml (15.77 cm) application but had no significant effect from 100 ml (16.18 cm). There was no significant ($P>0.05$) interactive effect for vine length between NPK levels and watering levels.

Moreover, the effects of NPK levels and watering levels were significant ($P \leq 0.05$) for the leaf area while the interactive effect of NPK levels and watering levels was insignificant. The application of NPK at 150 kg/ha produced the highest significant ($P \leq 0.05$) leaf area (123.30 cm2) compared to other application rates. The watering level showed that 200 ml application produced the leaf area (93.76 cm2) did not differ significantly from 100 ml (85.45 cm2) but had a significant effect compared to 300 ml (78.22 cm2) application with respect to leaf area.

The interaction between NPK levels and watering levels was not significant.
Also, NPK levels and watering levels were significant ($P \leq 0.05$) for the number of leaves per plant while the interactive effect of NPK levels and watering levels was not significant. NPK at 150 kg/ha produced the highest significant ($P \leq 0.05$) number of leaves (19.22), followed by NPK 50 kg/ha (15.49) and NPK 100 kg/ha (15.87). The amount of water level applied showed that 200 ml produced the highest significant number of leaves (15.97) compared to 100 ml (13.68) and 300 ml (14.02) application. The interaction effect of NPK levels and watering levels was not significantly different for the number of leaves.

The effects of NPK levels, watering levels, and the interactive effect of NPK levels and watering levels were not significant for stem diameter. The application of NPK 150 kg/ha produced the widest stem diameter (5.97mm) but had no significant effect compared to NPK 100kg/ha (5.89 mm) and NPK 50kg/ha (5.77 mm). The application of watering level showed that 300 ml produced (5.08 mm) stem diameter, but was not significantly different from 100 ml (5.12 mm) and 200 ml (5.30 mm) application. The interaction effect of NPK levels and watering levels was not significant.

**Table 2: Effects of NPK 15:15:15 fertilizer and watering level on growth performance of cucumber in Igboora, Oyo State, Nigeria**

| Treatment | VL (cm) | LA ($cm^2$) | NL | SD (mm) |
|---|---|---|---|---|
| **NPK Effect** | | | | |
| **NPK50** | 16.38b | 92.45b | 15.49b | 5.77a |
| **NPK100** | 19.13ab | 98.96ab | 15.87b | 5.89a |
| **NPK150** | 21.64a | 123.3a | 19.22a | 5.97a |
| **LSD** | 5.07 | 5.53 | 2.96 | NS |
| **Watering Effect** | | | | |
| **100** | 16.18a | 85.45a | 13.68b | 5.12a |
| **200** | 17.72a | 93.76a | 15.97a | 5.30a |
| **300** | 15.77b | 78.22b | 14.02b | 5.08a |
| **LSD** | 1.65 | 10.85 | 1.72 | NS |
| **Interaction** | | | | |
| **LSD** | NS | NS | NS | NS |

Means with the same letter along the column are not significantly different using Duncan's Multiple Range Test at 5% level of probability. VL: Vine length, LA: Leaf area, NL: Number of leaves per plant, SD: Stem diameter

**Yield performance of cucumber as influenced by NPK 15:15:15 fertilizer and watering level**

Furthermore, the effects of NPK levels, irrigation levels, and interaction of NPK levels and watering levels were significant for the number of cucumber fruits and yield (Table 3). NPK application at 150 kg/ha produced the highest significant ($P \leq 0.05$) number of cucumber (3.64) compared to NPK at 100 kg/ha (2.38) and NPK at 50 kg/ha (1.13). Also, the 200 ml watering level produced the highest significant number of cucumber fruits (2.18) compared to 100 ml (1.72) and 300 ml (1.77). The interactive effect of NPK levels and watering levels showed that 200 ml watering level and NPK at 150 kg/ha was significant ($P \leq 0.05$). Application of NPK at 150 kg/ha produced the highest significant ($P \leq 0.05$) fruit yield (8.68 t/ha) compared to NPK at 100 kg/ha (6.21 t/ha) and NPK at 50 kg/ha (5.87 t/ha), while 200 ml watering level produced the highest significant yield (9.97 t/ha) compared to 100 ml (6.68 t/ha) and 300 ml (6.02 t/ha).

**Table 3: Effects of NPK 15:15:15 fertilizer and watering level on yield performance of cucumber in Igboora, Oyo State, Nigeria**

| Treatment | Number of fruits per plant | Yield (t/ha) |
|---|---|---|
| **NPK Effect** | | |
| NPK50 | 1.13c | 5.87b |
| NPK100 | 2.38b | 6.21b |
| NPK150 | 3.64a | 8.68a |
| LSD | 1.07 | 1.95 |
| **Watering Effect** | | |
| 100 | 1.72b | 6.68b |
| 200 | 2.18a | 9.97a |
| 300 | 1.77b | 6.02b |
| LSD | 0.35 | 2.72 |
| **Interaction** | | |
| LSD | 1.24 | 1.25 |

Means with the same letter along the column are not significantly different using Duncan's Multiple Range Test at 5% level of probability.

## DISCUSSION

The application of NPK fertilizer at 150 kg/ha produced significant growth and yield performance compared to NPK application applied at lower rates. This significant increase in growth and yield performance of cucumber treated with NPK fertilizer at 150 kg/ha showed that the fertilizer supplied greater amounts of the major nutrients needed for optimum growth and yield of the crop. The results corroborate the findings of Choudhari and More (2002), who reported that a maximum number of fruits per vine and yields ha-1 (tons) of cucumber plant was produced when treated with 150:90:90 kg NPK ha-1 through fertigation. Moreover, the findings from this study are in line with the report of Watcharasak and Thammasak (2005), who also obtained the highest leaf number, leaf area, and fresh and dry weight of shoot and roots in cucumbers treated with fertigation of 150 mg N L-1. Furthermore, a reduced watering level produced poor growth and yield of cucumber in this study. This agrees with the report of Wang *et al*. (2006) that reducing the irrigation frequency from once a day to once a week resulted in a significant reduction in the yield of potatoes. This observation is in line with the earlier report by NKgapele and Mphosi (2012) that NPK at 120 kg N/ha and intermediate irrigation frequently gave the best performance in most growth and yield parameters of cucumber plants.

## CONCLUSION AND RECOMMENDATION

This study showed that the combined NPK fertilizer application and watering level had a significant effect on cucumber. The NPK effect was significant for the vine length, leaf area, and number of leaves. Therefore, NPK 15:15:15 at 150 kg/ha is hereby recommended to cucumber farmers. The watering level effect was significant for the vine length, leaf area, and number of leaves. Also, the highest yield was obtained at a 200 ml watering level and NPK 15:15:15 at a 150 kg/ha treatment combination. Irrigation at 200 ml twice per day in addition to the application of NPK 15:15:15 fertilizer produced optimum growth and yield of cucumber, and are hereby recommended for farmers in screen house cucumber production in the study area
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# EFFECT OF POULTRY MANURE SOURCES AND LEVELS ON YIELD OF COWPEA IN MINNA

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## ABSTRACT

A field experiment was carried out at the Federal University of Technology, Minna, in the cropping season of 2024 to determine the effect of poultry manure sources and levels on the yield of cowpea. The study was a 2 x 5 x 4 factorial experiment. The experiment was arranged in a Randomized Complete Block Design (RCBD). The treatments consisted of two sources of poultry manure (Deep Liter and Battery Cage Poultry systems) at 0, 5, 10, 15, and 20 t/ha replicated four times. The treatments were applied 2 weeks before planting to ensure proper breakdown of the organic material. The gross plot size was 4m x 4m (16 $m^2$) each, while the net plot size was 45m x 22m (990 $m^2$). Seeds (SAMPEA 20T, Early Maturing and Semi Erect) were planted at the rate of 3 seeds/hill and a spacing of 75cm between the rows and 25cm within the rows and later thinned to 1 plant/stand at 2 weeks after planting (WAP). All plots received a basal dose of N and P at an approved rate of 10kg N/ha and 30kg P/ha. The same quantity of inorganic fertilizer was applied per plot irrespective of the different levels of treatment. Pods were harvested at 12 WAP and sundried. The pods were threshed to separate the grains from the haulm. Data obtained were subjected to Analysis of Variance at a 5% level of probability using Statistix 8.0 statistical software. Duncan multiple range test (DMRT) was used to separate significant differences between means. Results showed that the poultry manure sources did not significantly affect the yield of cowpea. The poultry manure level did not significantly affect the yield parameters. However, the best improvement in yield parameters was observed when 0 t/ha poultry manure was applied regardless of sources. It is therefore recommended that growing SAMPEA 20T with poultry manure should not be encouraged. If, however, there is a need to use poultry manure, the battery cage source should be recommended.

**Keywords:** Cowpea, Poultry Manure, Deep Litter, Battery Cage.

## INTRODUCTION

Cowpea (*Vigna unguiculata*), one of the important legume crops grown globally, plays a vital role in the livelihood of millions of smaller holder farmers who depend on it as a source of economic livelihood and nutritional well-being (Bolarinwa*et al.,* 2021). Cowpea is mainly grown for food, fodder, vegetables, green manure, and cover crops. Cowpea is vegetables (leaves and fresh pods) or grain. In sub-Saharan Africa (SSA), West Africa is regarded as the major cowpea-producing region with 80% of the total regional production reported for Nigeria and Niger at first and second positions respectively for 14 years in a row (Huynh *et al.,*2016). Cowpea is rich in protein and carbohydrate content with high nutritive value and palatability (Ddungu *et al.,* 2015). Despite the importance of cowpeas, their productivity in Nigeria is very low, at less than 600 kg/ha compared with a potential grain yield of over 2000 kg/ha (Boukar *et al.,*2018). This is due to the use of unimproved varieties and poor soil fertility due to land degradation as a result of erosion, desertification, tillage, and unsustainable agricultural practices. Apart from cowpea's nutritional component, the crop has high rates of symbiotic nitrogen fixation and improves soil fertility which can be achieved by litter accumulations that impact organic matter positively. However, the quantity of organic matter accumulated under any cropping system may not be stable over time and may need external applications in the form of animal manures. Studies of Kannan *et al.,* (2005), have shown that poultry manure may be a preferable source of animal manure used in crop production.

Poultry Manure has been used since the earliest civilization for improving soil properties, it is primarily composed of Nitrogen (N), Phosphorus (P), and Potassium (K); it also contains calcium, magnesium, sulphur, and some micronutrients (Kannan *et al.,*2005), which are critical for crop growth and soil fertility. The application of poultry manure has been shown to increase the organic matter content of the soil, which in turn improves its structure, water-holding capacity, cation exchange capacity (CEC), and soil microbial properties (Ayoola & Adeniyan, 2006). The application of poultry manure introduces a substantial amount of organic matter into the soil, which serves as a substrate for microbial activity. This can lead to an increase in microbial biomass, diversity, and activity, all of which are beneficial for soil health and plant growth (Adesodun & Mbagwu, 2008). The objective of the study was to determine the effect of poultry manure sources and levels on the yield of cowpea.

## MATERIALS AND METHODS

### Description of Study Site

The study was conducted at Federal University of Technology, Minna, Niger State. The experimental site is located beside the University Works Department on latitude 9°31'6"N to 9°31'50"N and Longitudes 6°26'26"E to 6°27'6"E. Minna has a sub-humid climatic condition. The annual rainfall is 1284mm, while the mean temperature is 32 oC, the dry season lasts for five (5) months from November to March, while the rainy season extends between April and October. The soils of Minna developed from basement complex rocks ranging from shallow to very deep soils overlying deeply weathered gneisses and magnetite with some underlain by iron pans to varying depths. The soils are mostly sandy in texture. Minna is located in the Southern Guinea savanna zone characterized by vast grassland with few scattered trees and shrubs. Crops are mostly grown under rain-fed conditions. The crops include maize, rice, cowpea, soybean, and groundnut. Crops grown under irrigation during the dry season include rice, maize, and vegetables.

### Treatments and Experimental Design

The study was a 2 x 5 x 4 factorial experiment. The treatments consisted of two sources of poultry manure (Deep Liter and Battery Cage Poultry systems) at 0, 5, 10, 15, and 20 t/ha replicated four times. The treatments were applied 2 weeks before planting to ensure proper breakdown of the organic material. The experiment was arranged in a Randomized Complete Block Design (RCBD)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **REP 1** | DL0 | BC0 | BC10 | DL15 | BC5 | BC20 | BC15 | DL10 | DL20 | DL5 |
| **REP 2** | DL20 | BC0 | BC15 | BC20 | DL15 | BC5 | DL0 | DL10 | BC10 | DL5 |
| **REP 3** | DL20 | BC0 | BC20 | DL10 | BC10 | BC5 | DL5 | BC15 | DL15 | DL0 |
| **REP 4** | BC0 | BC5 | DL15 | DL10 | BC15 | DL0 | DL5 | BC10 | DL20 | BC20 |

*DL: Deep Litter, BC: Battery Cage, 5,10,15,20: Poultry manure application rates (t/ha)*

**Figure 1: Plot Layout**

**Agronomic Practices**

The field was cleared and ploughed using a tractor. The plots were leveled manually using a hoe. The gross plot size was 4m x 4m (16 $m^2$) each, while the net plot size was 45m x 22m (990 $m^2$). Seeds (SAMPEA 20T, Early Maturing and Semi Erect) were planted at the rate of 3 seeds/hill and a spacing of 75cm between the rows and 25cm within the rows at a depth of 5cm according to (Dugje *et al.,*2009). The plants were thinned to 1 plant/stand at 2 weeks after planting (WAP). All plots received a basal dose of N and P at an approved rate of 10kg N/ha and 30kg P/ha. The nutrient was sourced from NPK 20:10:10 and SSP. 0.00072kg (0.72grams) of NPK20:10:10 fertilizer was applied per plant stand i.e 0.07kg (70grams) per plot at planting and 0.00182kg (1.82grams) of SSP was applied per plant stand i.e. 0.175kg (175 grams) per plot by band placement method. The same quantity of inorganic fertilizer was applied per plot irrespective of the different levels of treatment. Weeding was done manually first at 2 WAP, and secondly at 5 WAP to ensure a clean field. Insect pest was controlled using insecticide 5 weeks after planting when flower bud initiation had started. This was to control thrips and early attack of *Maruca* pod borer and ensure good flowering. Pods were harvested at 12 WAP and sundried. The pods were threshed to separate the grains from the haulm.

**Measurement of Crop Yield Parameters**

Pod weight was determined by weighing the pods from each plot and expressing the weight in Kg/ha. Grain yield was determined by weighing the grains from each plot and expressing the weight in Kg/ha. Haulm weight was determined by weighing the haulm from each plot and expressing the weight in Kg/ha.

**Statistical Analysis of Data**

The data were subjected to Analysis of Variance at a 5% level of probability using Statistix 8.0 (Statistix, 2010) statistical software. Duncan multiple range test (DMRT) was used to separate the means.

**RESULTS**

Organic sources did not significantly($p>0.05$) affect pod weight (Table 1). Plants that received poultry manure from battery cages produced heavier pod weights (1187.49 Kg/ha) compared to those fertilized with poultry manure from a deep litter system (1056.25 Kg/ha). The increase as a result of manure from the battery cage system was 12.5%. Haulm weight (Kg/ha) was not significantly($p>0.05$) affected by organic sources (Table 1). Similarly, plants fertilized with battery cage manure produced a heavier haulm weight of 446.88 Kg/ha compared to the haulm weight of 410.94 Kg/ha obtained by deep litter manure. The increase in haulm weight as a result of battery cage manure was 8.52%. Grain yield (kg/ha) was not significantly ($p>0.05$) affected by organic sources (Table 1). Cowpea plants supplied with battery cage manure produced a heavier grain yield of 743.75 Kg/ha compared to a grain yield of 651.56 Kg/ha produced by deep litter manure. The increase in grain yield due to battery cage manure was 14.1%. Regardless of sources, all yield parameters were highest when 0 t/ha of poultry manure was added (Table 1). The addition of poultry manure beyond 0 t/ha only depressed yield parameters with the highest depression obtained at 10 t/ha across all yield parameters observed.

**Table 1: Main Effect of Poultry Manure Sources and Levels on Yield of Cowpea**

| Treatment | Pod Weight (Kg/ha) | Haulm Weight (Kg/ha) | Grain Yield (Kg/ha) |
|---|---|---|---|
| Sources (S) | | | |
| Deep Litter | 1056.25 | 410.94 | 651.56 |
| Battery Cage | 1187.49 | 446.88 | 743.75 |
| Significance | NS | NS | NS |
| Levels (t/ha) (L) | | | |
| 0 | 1332.03 | 457.03 | 859.38 |
| 5 | 1105.47 | 425.78 | 679.69 |
| 10 | 996.06 | 375.00 | 621.09 |
| 15 | 1097.65 | 453.13 | 636.72 |
| 20 | 1078.13 | 433.59 | 691.41 |
| Significance | NS | NS | NS |
| S*L | NS | NS | NS |

**NS = Not Significant**

**DISCUSSION**

As a result of the battery cage system, yield and yield characteristics were improved compared to the deep litter system. This is because of the absence of litter material in the manure obtained from the battery cage system unlike that of the deep litter system with saw dust fortification. This is consistent with the report of Johnson & Clark, (2021), who maintained that the yield of crops fertilized with deep litter system manure was lower than that of battery cage system manure. The deep litter system manure used in the experiment was fortified with sawdust which ordinarily should have a C: N ratio of 400:1 (Söderström & Jones, 2019). This implies that Nitrogen immobilization will increase under deep litter manure of saw dust origin compared to battery cage manure. At the level of manure application, 0 t/ha averagely produced the best yield characteristics observed. This implies that the inherent fertility status of the soil was probably sufficient for yield increase such that a further improvement by application of manure was altering the physiology of the plant by increasing source/sink competition in favor of vegetative growth and at the expense of grain and pod growth (Zhang & Wang, 2020).

## CONCLUSION

The poultry manure sources did not significantly affect the yield of cowpea. Similarly, the poultry manure level did not significantly affect the yield parameters. However, the best improvement in yield parameters was observed when 0 t/ha poultry manure was applied regardless of sources.

## RECOMMENDATIONS

It is therefore recommended that growing SAMPEA 20T with poultry manure should not be encouraged. If, however, there is a need to use poultry manure, the battery cage source is recommended.

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# EFFECTS OF BIOFERTILIZER AND PLANT GROWTH ACTIVATOR ON SOIL HEALTH AND AMARANTH PRODUCTIVITY IN ITAKPE, SOUTHERN GUINEA SAVANNA AGROECOLOGY

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## ABSTRACT

The use of biofertilizers and soil conditioners are alternative and effective means of improving crop yield and soil microenvironment. This study was conducted to investigate the effect of biofertilizers and soil bio-inoculant on the performance, physicochemical and biological properties of Itakpe soil planted with *Amaranthus tricolor* during the cropping period of 2024. Treatments consisted of two biofertilizers; Farmers' friend at 0, 1.0 kg ha$^{-1}$, Maxi grow at 0, 0.5 and 1.0 kg ha$^{-1}$, and soil bio-inoculant (Activator) at 0, 0.5 and 1.0 kgha$^{-1}$ arranged in a Randomized Complete Block Design in three replicates. Number of leaves increased with farmers' friend at all sampling stages. All *Amaranthus* parameters measured increased with increasing application rate of maxi grow. However, increasing maxi grow beyond 0.5 kgha$^{-1}$ does not significantly increase plant height at 8 Weeks after Transplanting (WAT), leaf area at 4 and 6WAT. Most parameters were optimum in plots treated with 0.5 kg ha$^{-1}$ activator. Maximum biomass yield was obtained in plots treated with 1.0 kg ha$^{-1}$ each of maxi grow and activator. Soil analysis shows that farmers' friend increased particle density and soil porosity, soil organic matter, total nitrogen, $Mg^{2+}$, $Ca^{2+}$, total exchangeable bases, exchangeable acidity and effective cation exchange capacity values. Maximum bulk density was obtained in the control plots, though not significantly different from bulk density obtained from plots treated with 0.5 kgha$^{-1}$ of maxi grow. The highest values for most of the soil chemical parameters was obtained with plots treated with 1.0 kg ha$^{-1}$ of maxi grow and activator, but was at par with plots treated with 0.5 kg ha$^{-1}$. Fungi, bacteria population and enzyme activities such as dehydrogenase, alkaline phosphatase, cellulase and protease increased with the application of farmers' friend, maxi grow and activator. Actinomycetes population was not significantly affected by farmers' friend. 0.5 kg ha$^{-1}$ each of maxi grow and activator seemed optimum for microbial populations and enzymatic activities while farmers' friend, maxi grow each at 1.0 kg ha$^{-1}$ + 0.5 kg ha$^{-1}$ of activator is recommended for optimum performance of *Amaranthus*, and improved soil physicochemical characteristics. Higher population of microbes and enzymatic activities as evident in this research may have influenced certain phenological changes resulting in high *Amaranthus* performance and improved soil physical and chemical structure.

**Keywords**: *Amaranthus tricolor,* Microbial activities, farmers' friend, maxi grow, activator, physicochemical, biological properties.

## INTRODUCTION

*Amaranth* is a common plant of immense value as cultivated vegetable in the tropical and subtropical regions. Consisting of 70 species, *Amaranthus tricolor*, popularly called "Red Calaloo" amaranth is known for its high nutritional benefit, i.e., rich source of vitamins and minerals (Clouse *et al*. 2016), high protein content (Siswanti and Khairunnisa 2021; Sarker *et al*., 2015) a high proportion of chlorophyll, Amaranthin and carotenoids as reported by Sarker and Oba (2019). This crop is widely cultivated by most farm families due to its ease of production. It is grown for seed with substantial amounts of biomass. The tropical soil is highly deficient in essential nutrient required for growth of wide arrays of vegetables, thereby necessitating the use chemical fertilizer among vegetable farmers (Anton *et al*., 2023). This effort to increase soil fertility for *amaranth* production degrade the quality of its product (Zhang *et al*., 2010) as heavy fertilizer application into the soil, also affects the soil microclimate and microbial environment by limiting, harming and interfering with optimal enzymatic activities necessary for optimum *amaranthus* growth and development. Additionally, high amount of surface runoff washes sufficient amount of fertilizer and other chemicals which contaminates ground water (Arora, 2015). Incorporating microbial solution towards alleviating these problems enhances production, reduces the residual effect of fertilizers and harmful chemicals in food thus eliminating its threat to human life. The role of microbes in strengthening soil fertility, improving crop yield and quality has been reported in several researches (Ramalakshmi *et al*., 2008; Moreno-Espíndola *et al*., 2018; Mingxing *et al*., 2024). Microbiomes are essential components of plant growth factors, that greatly influence every developmental stage of plant. Optimum microbial activity can be enhanced by application of biofertilizers or plant growth regulators. Biofertilizers are natural materials of plant and/or animal extract containing living micro-organisms. The role of bio-fertilizers in promoting plant growth and development, facilitating the available nutrients in the soil through regulation of soil pH, decomposition of soil organic matter, and influencing other soil physical and chemical properties has been reported (Othman *et al*., 2024). Organic matter has reportedly improved soil structure, porosity, nutrient-holding capacity and has formed substrate as food for beneficial microbes i.e., Phosphate-solubilizing bacteria (PSB) (Singh *et al*., 2013; Prabhu *et al*., 2019;). PSB has reportedly improved soil fertility by solubilizing phosphorus, improving soil porosity, suppressing the growth of harmful soilborne pathogens (Niamat *et al*., 2019).

Previous studies have focused mainly on the comparative impact of organic, mineral and bio-fertilizers in improving growth, development and yield of *Amaranthus*. However, the need to wholistically look at the role of microbiome technology in improving crop performance, soil physical, chemical and biological properties cannot come at a later time than now. Therefore, this study aimed to determine the impact of biofertilizer and soil bio-inoculant on the growth and yield performance, soil physical and chemical properties as well soil microbial population and enzymatic activities within *Amaranthus* rhizosphere in Itakpe environment of Kogi State.

## MATERIALS AND METHODS

### *Experimental Site Description*

This study was carried out during the cropping periods of 2024 at the Itakpe Campus, Kogi State Polytechnic Student Research Farm (Lat. 7º 38'N and Long. 6º 53'E). Itakpe is located within the Southern Guinea Savannah Ecological Zone of Nigeria and it is characterized by annual total rainfall of 1032 mm, average rainfall of about 138.5 mm mostly distributed between the months of April and October. Annual average temperature of 25.1º C Mean monthly minimum and maximum temperature of about 22.78ºC and 28.05ºC respectively. This site has the following soil properties:

**Table I. Soil Properties of the Experimental Site prior to establishment of the trial**

| Soil Properties | Values |
|---|---|
| *Physical properties* | Depth (0 – 30 cm) |
| Sand (%) | 68.04 |
| Silt (%) | 12.7 |
| Clay (%) | 19.26 |
| Textural class | sandy-clay-loam |
| Bulk density ($mgm^{-3}$) | 1.55 |
| Particle density ($mgm^{-3}$) | 1.97 |
| Porosity (%) | 35 |
| *Chemical properties* | |
| pH ($H_2O$) | 5.23 |
| Organic Matter (%) | 1.7 |
| Total Nitrogen (%) | 0.05 |
| Available Phosphorus ($mgkg^{-1}$) | 4.5 |
| Organic Carbon (%) | 0.99 |
| *Exchangeable Cations (meq/100g soil)* | |
| $K^+$ | 1.97 |
| $Mg^{2+}$ | 1.7 |
| $Ca^{2+}$ | 3.54 |
| $Na^+$ | 0.47 |
| E.C (ppm) | 0.46 |
| TEB | 7.27 |
| EA | 1.39 |
| ECEC | 8.66 |
| *Microbial Population (CFU/SFU/g soil)* | |
| Fungi | $3.8 \times 10^3$ |
| Actinomycetes | $6.7 \times 10^4$ |
| Bacteria | $7.9 \times 10^6$ |
| *Enzyme activities* | |
| Dehydrogenase (DH) (µg TPF $g^{-1}$ soil $h^{-1}$) | 55.75 |
| Alkaline Phosphatase (ALP) (µmol p-nitrophenol $g^{-1}$ soil $h^{-1}$) | 118.2 |
| Cellulase (CEL) (µmol equivalent glucose $g^{-1}$ soil $h^{-1}$) | 80 |
| Protease (µmol tyrosine $g^{-1}$ soil $h^{-1}$) | 127.9 |

***Treatments and Experimental Design***

Treatments consisted of two bio-fertilizers; Farmer's friend at 0, 1.0 kg $ha^{-1}$, Maxi grow at 0, 0.5 and 1.0 kg $ha^{-1}$, and soil bio-inoculant (Activator) at 0, 0.5 and 1.0 kg $ha^{-1}$ respectively, obtained from CHC Agritech Africa Nigeria Limited. The treatments were combined factorially, and allotted to every plot using a random number system to prevent biasness. The experiment was laid using a Randomized Complete Block Design. A total of eighteen treatments were used, the experiment was laid in three replicates, a total of fifty-four plots was used each measuring 9.0 $m^2$. Each plot was separated from its adjacent plot by 0.5 m while each replicate was separated from the other with a discard row of 1.0 m apart. Healthy, dry seeds of "Red Calaloo" Amaranth (*Amaranthus tricolor*) obtained from the National Horticultural Research Institute (NIHORT) Ibadan were soaked in warm water at temperature of 50 ◦C for 20 min with continuous stirring, cooled to the temperature of 20 ◦C and left for 4 – 8 hours. Seeds was then raised in the nursery bags and watered in the mornings and nights; other recommended nursery management practices were applied. Sprouted seedlings were transplanted into the prepared plots at 3 – 5 leaf stage. Prior to transplanting, activator was incorporated into the soil immediately after land preparation when humidity level was 90% with sufficient water and left for 14 days to speed up the multiplication of beneficial soil microbes. Farmer's friend and Maxi grow was applied at two weeks after transplanting. Abamectin Benzoate at 30ml/16L of water and 25% carbendazim solution was applied once at 10 days intervals to control stem rot and damping-off disease. Weeding was done regularly to keep the field weed free.

***Soil Sampling and Determination of Physicochemical, biological Properties and Enzymatic Activities of Amaranthus Rhizosphere***

Immediately after harvest, samples of soil were collected from each plot at a depth 0 – 30cm using tabular auger, bulked in an air tight polyethene bags labelled per plot and taken to the laboratory. These samples were analyzed for physical and chemical properties such as percentage sand, silt clay, Bulk Density ($mgm^{-3}$), Particle Density ($mgm^{-3}$), porosity (%), pH, percent organic carbon, organic matter, electrical conductivity (mS/cm), total nitrogen, available phosphorus (mg/kg), potassium, sodium, magnesium, calcium total exchangeable bases, exchangeable acidity and effective cation exchange capacity respectively. The particle size analysis of the soil was carried out using hydrometer method as described by Day (1965), pH ($H_2O$) of the soil samples was measured using a potentiometer in a water-soil suspension (2.5:1) as described by Black (1965), total Nitrogen by Kjedahl method (Bremmer and Malvaney, 1982; IITA, 1975) and Available phosphorus by Bray I method (Bray and Kurtz, 1945). Exchangeable bases by ammonium acetate saturation and Cation Exchange Capacity by ammonium acetate saturation and Cation Exchange by Ammonium Acetate and Extraction and distribution method (Black, 1965). Biological properties of the samples were carried out in the laboratory to ascertain the microbial population in the soil during the growing period of the crop. The direct microscopic method was employed. Samples were dispersed in different agar media and smeared over $25cm^2$ glass slide. 1 ml of Aliquots dilution was smeared in nutrient agar, Martin's Rose Bengal agar and Kenknight's agar as described by Rangaswami (1966), Martin (1950) and Allen (1953) for measurement of bacteria, fungi and actinomycetes population expressed as colony forming units per gram ($CFUg^{-1}$). These glasses were incubated at 28 – 32 ºC for 72 hours (for bacteria), 120 hours (for fungi) and 168 hours (for actinomycetes) respectively.

Samples of soil around the root horizons of Amaranthus were taken from individual plot, placed in a well labelled polythene bags and taken to the lab for determination of enzymatic activities such as dehydrogenase (DH), alkaline phosphatase (ALP), cellulase (CEL) and protease (PRO). Each enzyme activity was determined by spectrophotometric methods as described by García *et al*. (2003).

***Data Collection and Analysis:*** Ten plants were tagged in each plot for measurement of growth and yield data i.e., plant height, number of leaves per plant, stem girth, leaf area per plant and fresh biomass yield every fortnight, beginning from two weeks after transplanting. All data collected (crop and soil) were subjected to Analysis of Variance (ANOVA) using the CropStat package, significantly different treatment means were separated using New Duncan Multiple Range Test (NDMRT) at 5% level of probability.

## RESULTS AND DISCUSSION

### Effect of Biofertilizers and Soil bio-inoculant on Yield Characters of *Amaranthus tricolor*

Some of the parameters were significantly influenced ($P<0.05$) by biofertilizer and soil bio-inoculant at different stages of sampling (Table 1). At 4, 6 and 8 weeks of sampling, plots treated with 1.0 kg $ha^{-1}$ of farmers' friend produced the highest number of leaves consistently when compared with the control plots. Our result corroborates with Rana *et al* (2007) who reported that application of organic material (seaweed extract) resulted in higher plant height, weight and yield in lettuce. At 4 weeks of sampling, leaf area obtained with zero application of farmers' friend was higher. Plant height, stem girth at all sampling stages, Leaf area at 6 and 8 Weeks After Transplanting (WAT) were not also significantly affected by farmers' friend. Maxi grow significantly improved all the characters at all sampling stages with application of 1.0 kg $ha^{-1}$ producing highest yield consistently. Plots treated with 0 kg $ha^{-1}$ of maxi grow consistently produced the lowest characters. Plots treated with 0.5 and 1.0 kg $ha^{-1}$ of activator produced heights at 4WAT, stem girth at stem girth at 8WAT, number of leaves and leaf area at 4, 6 WAT that were statistically at par. However, other characters increased with increasing rate of activator up to 1.0 $kgha^{-1}$. This result correlates with the report of Jjagwe *et al*. (2020). Significant improvement in parameters measured in this research is evident in the fact that biofertilizers has proven tract of enhancing nutrient uptake, improving soil structure, and resistance to pests and diseases. Several authors have reported significant improvement of growth and yield of crops with organic fertilizer (Abduljebbar *et al*., 2023).

Farmers' friend did not significantly influence fresh biomass yield (Table 1). However, biomass yield obtained from applying 1.0 kg $ha^{-1}$ of maxi grow and activator respectively were significantly highest (27.82 and 53.85 t $ha^{-1}$). Yield obtained from plots treated with 0.5 kg $ha^{-1}$ and 0 kg $ha^{-1}$ of activator and maxi grow respectively were statistically at par. Colla *et al* (2017) also reported improved fresh and dry weight, number of leaves and head diameter from foliar application of organic fertilizer.

**Effect of Biofertilizers and Soil Bio-inoculant on Soil Physical Properties after harvest of *Amaranthus tricolor***

Particle analysis shows that biofertilizer and soil bio-inoculant rates significantly ($P<0.05$) improved soil physical properties (Table 2). However, percentage sand, silt and clay were not significantly influenced by the treatments. Bulk density was not significantly influenced ($P>0.05$) by farmers' friend and activator. however, it decreased by 11.56% when treated with 1.0 $kgha^{-1}$ maxi. This may be due to the fact that biofertilizers enhance organic matter decomposition, forming chelates by building more organic compounds, enhancing the proliferation of beneficial microorganism that improve water percolation, nutrient uptake, gas exchange, and root growth (Meng *et al*., 2019). The results corroborate with Arunrat (2020) who highlighted the importance of reduced bulk density to soil health. Reiterating that heavy compaction resulting from higher bulk density reduces water, nutrient infiltration and microbial activities. Patel *et al*. (2024) has reported reduced bulk density with increasing farm yard manure and biofertilizers in soil planted with chickpea. Maxi grow had no significant influence on particle density. However, farmers' friend increased particles density of the soil (2.54 $mgm^{-3}$) when compared with the control plots. Particle density obtained with activator at 0.5 and 1.0 kg $ha^{-1}$ (2.65, 2.79 $mgm^{-3}$) were statistically at par, though higher than the control. Improved particle density in the present study was influenced by rapid organic matter decomposition. Abeje *et al*. (2023) reported that robust soil organic matter often improves aggregate stability and total soil porosity, reducing compactness and increasing soil pore spaces. This confirms our result obtained with bulk density. It can be further stressed that bulk density inversely varies with porosity. This result also correlates with Candemir and Gulser (2011). Farmers' friend and activator increased soil porosity. Application of 1.0 kg $ha^{-1}$ increased soil porosity from 42.45 – 49.65 %. Similarly, activator increased porosity from 45.53 to 50.19 %. This relates to the fact that organic matter often lowers soil compaction, thus improving soil porosity and permeability for both water and nutrient. This aligns with the reports of Yazdanpanah *et al*. (2016), Shah *et al*. (2022) and Vasu *et al*. (2021) who observed that biofertilizers and organic manures improves soil structure, enhances soil microbial activities viz-a-viz Phospho-bacteria and Rhizobium increases soil organic carbon. Meng *et al*. (2019) also reported a decreased bulk density and increased the total porosity upon application of manure.

**Effect of Bio-fertilizers and Soil Bio-inoculant on the Soil Chemical Properties after harvest of *Amaranthus tricolor***

Application of the treatments significantly increased the soil pH. however, farmers' friend slightly decreased pH (Kcl) of the soil by 1.33%. Application of 1.0 kg ha$^{-1}$ of maxi grow increased pH ($H_2O$) by 4.53%, pH (Kcl) by 2.74 %. Similarly, activator increased pH in $H_2O$ and Kcl solution by 4.51 and 4.29 % respectively. Giving the original soil pH of 5.23, application of treatments caused a shift towards neutral value from strong acidity. This is because soil bio inoculants may have released cations into the soil which speeds up organic matter decomposition. This conforms with the assertion of Butterly *et al*. (2013) who reiterated that $H^+$ are neutralized during organic matter decomposition by addition of Ca and Mg ions thus causing a shift in soil pH. Similar observation has been made by other authors (Suryantini 2007). Berger *et al*. (2013) had reported reduction in pH of saline soils upon application of biofertilizers. This report was also in line with Abdallah *et al*. (2021) who opined that decline in soil upon addition of biofertilizers are due to the formation of organic acids in the course of organic matter decomposition. Farmers' friend and maxi grow did not significantly affect organic carbon. This negates the report of Nisha *et al*. (2007) who found increased organic carbon and organic matter contents of poor soils upon application of organic fertilizer. In our present study, plots treated with 0.5 kg ha$^{-1}$ of activator produced the highest organic carbon. This increase may be due to higher organic matter resulting from the addition of biofertilizer and soil bio-inoculant. The increase in organic carbon upon application of organic materials, humic acids and biofertilizers has been reported by many authors (Angelova *et al*., 2013; Jangir *et al*., 2017; Patel *et al*., 2024). Zeynep (2020) found increased organic carbon content upon the addition of biofertilizers. This was supported by Son *et al*. (2007).

Zhao *et al*. (2016) also reported that increased organic carbon improves porosity through release of organic substances from biofertilizers. Organic matter was increased by treatments. Farmers' friend produced organic matter higher than the control. Maxi grow and activator produced the highest organic matter (2.21 and 2.59 %) at 0.5 kg ha$^{-1}$, this did not differ significantly from values obtained when treated with 1.0 kgha$^{-1}$. Control plots had the lowest organic matter throughout. This is an indication that biofertilizers contain high content of organic matter. Organic matter has effectively expanded soil biodiversity and improved microbial activities of the soil thereby improving soil microclimate (Albiach *et al*., 2000). Long term effect of compost manure has also been reported to improve soil organic matter content, resulting in robust microorganism populations and enzymatic activities (Chang *et al*., 2007). Total nitrogen increased as a result of farmers' friend, maxi grow and activator application. Highest nitrogen (0.75%) was obtained when 1.0 kg ha$^{-1}$ was applied, this was at par with Nitrogen at 0.5 kg ha$^{-1}$. Similarly, higher N (0.34 %) was obtained with maxi grow at 0.5 kg ha$^{-1}$. Farmers' friend also increased N from 0.16 to 0.34 % whereas available phosphorus was not affected. This result is in agreement with Li *et al*. (2017) and (Jangir 2017) who found higher N with biofertilizers and organic manure.

**Table 1. Effect of Bio-fertilizers and Soil Bio-inoculant on Growth Characters of *Amaranthus tricolor* in Itakpe Environment during the 2024 Cropping Season.**

| Treatments | Plant height (cm) | | | Stem girth (cm) | | | Number of leaves | | | Leaf area ($cm^2$) | | | Fresh Biomass (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sampling periods (Weeks After Transplanting) | | | | | | | | | | | | |
| Farmers Friend ($kgha^{-1}$) | 4 | 6 | 8 | 4 | 6 | 8 | 4 | 6 | 8 | 4 | 6 | 8 | |
| 0 | 32.32 | 59.21 | 70.67 | 6.13 | 11.16 | 20.30 | $25.63_b$ | $31.62_b$ | $61.64_b$ | $133.20_a$ | 169.72 | 162.04 | 20.20 |
| 1.0 | 27.75 | 47.70 | 59.28 | 5.45 | 12.0 8 | 23.05 | $29.62_a$ | $38.20_a$ | $63.74_a$ | $31.33_b$ | 172.01 | 194.36 | 23.40 |
| Significance$_{0.05}$ | ns | ns | ns | ns | Ns | ns | * | * | * | * | ns | ns | ns |
| SE (±) | 3.30 | 4.84 | 4.16 | 0.45 | 0.90 | 1.78 | 1.01 | 1.71 | 4.84 | 9.33 | 9.00 | 14.79 | 0.11 |
| Maxi grow ($kgha^{-1}$) | | | | | | | | | | | | | |
| 0 | $15.38_b$ | $34.58_b$ | $55.13_b$ | $3.31_c$ | $6.65_c$ | $11.38_c$ | $13.66_c$ | $17.73_c$ | $36.06_c$ | $63.33_b$ | $136.55_b$ | 152.58 | $18.33_b$ |
| 0.5 | $27.71_b$ | $50.35_b$ | $65.53_{ab}$ | $5.91_b$ | $12.88_b$ | $25.46_b$ | $32.56_b$ | $41.50_b$ | $64.18_b$ | $169.88_a$ | $191.30_a$ | 193.01 | $19.60_b$ |
| 1.0 | $47.01_a$ | $75.43_a$ | $74.28_a$ | $8.15_a$ | $15.20_a$ | $28.18_a$ | $36.65_a$ | $45.50_a$ | $87.83_a$ | $163.58_a$ | $184.75_a$ | 189.01 | $27.82_a$ |
| Significance$_{0.05}$ | * | * | * | * | * | * | * | * | * | * | * | ns | * |
| SE (±) | 4.04 | 5.93 | 4.97 | 0.5 | 1.11 | 2.18 | 1.24 | 2.09 | 5.93 | 11.43 | 11.03 | 18.11 | 0.29 |
| Activator ($kgha^{-1}$) | | | | | | | | | | | | | |
| 0 | $14.93_b$ | $25.22_b$ | $30.19_b$ | 4.30 | $10.66_b$ | $17.20_b$ | $18.77_b$ | $32.55_b$ | 35.22 | $69.38_b$ | $145.28_b$ | 159.35 | $19.73_b$ |
| 0.5 | $35.15_a$ | $39.40_b$ | $40.82_b$ | 3.91 | $12.74_b$ | $19.09_a$ | $23.87_a$ | $40.23_a$ | 43.59 | $187.15_a$ | $190.20_a$ | 194.71 | $20.84_b$ |
| 1.0 | $43.62_a$ | $64.34_a$ | $67.46_a$ | 4.53 | $15.33_a$ | $24.20_a$ | $21.81_a$ | $38.16_a$ | 48.72 | $180.33_a$ | $192.60_a$ | 196.31 | $53.85_a$ |
| Significance$_{0.05}$ | * | * | * | ns | * | * | * | * | * | * | * | ns | * |
| SE (±) | 2.21 | 4.78 | 5.93 | 0.02 | 1.6 | 1.8 | 1.1 | 3.24 | 2.96 | 10.37 | 15.46 | 24.3 | 0.67 |

*Means followed by the same letter(s) within the same column are not significant at 5% level of probability. ns = not significant, * = significant at 5% level of probability.*

**Table 2. Effect of Bio-fertilizers and Soil Bio-inoculant on Soil Physical properties after harvest of *Amaranthus tricolor* in Itakpe Environment during the 2024 Cropping Season.**

| Treatments | Sand (%) | Silt (%) | Clay (%) | Bulk Density ($mgm^{-3}$) | Particle Density ($mgm^{-3}$) | Porosity (%) |
|---|---|---|---|---|---|---|
| Farmers Friend ($kgha^{-1}$) | | | | | | |
| 0 | 68.33 | 17.28 | 24.43 | 1.40 | $2.19_b$ | $42.45_b$ |
| 1.0 | 68.69 | 17.23 | 24.11 | 1.35 | $2.54_a$ | $49.65_a$ |
| Significance$_{0.05}$ | ns | Ns | Ns | ns | * | * |
| SE (±) | 0.25 | 0.03 | 0.22 | 0.03 | 0.17 | 0.84 |
| Maxi grow ($kgha^{-1}$) | | | | | | |
| 0 | 68.95 | 17.07 | 24.08 | $1.47_a$ | 2.53 | 43.03 |
| 0.5 | 68.04 | 17.43 | 24.56 | $1.40_{ab}$ | 2.65 | 47.08 |
| 1.0 | 67.48 | 16.33 | 19.21 | $1.30_b$ | 2.71 | 47.00 |
| Significance$_{0.05}$ | ns | Ns | Ns | * | Ns | ns |
| SE (±) | 0.74 | 0.56 | 2.96 | 0.08 | 0.14 | 2.31 |
| Activator ($kgha^{-1}$) | | | | | | |
| 0 | 68.63 | 16.70 | 24.65 | 1.59 | $2.49_b$ | $45.53_b$ |
| 0.5 | 69.07 | 13.42 | 27.51 | 1.58 | $2.65_a$ | $50.18_a$ |
| 1.0 | 68.55 | 13.81 | 27.60 | 1.57 | $2.79_a$ | $50.19_a$ |
| Significance$_{0.05}$ | ns | Ns | Ns | ns | * | * |
| SE (±) | 0.28 | 1.79 | 1.67 | 0.01 | 0.15 | 0.95 |

*Means followed by the same letter(s) within the same column are not significant at 5% level of probability. ns = not significant, * = significant at 5% level of probability.*

**Table 3. Effect of Bio-fertilizers and Soil Bio-inoculant on the Soil Chemical Properties in Itakpe Environment during the 2024 Cropping Season.**

| Treatments | pH ($H_2O$) | pH (Kcl) | OC | OM | TN | EC | Av. P | $Na^+$ | $K^+$ | $Mg^{2+}$ | $Ca^{2+}$ | TEB | EA | ECEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | | | (mS/cm) | (mg $kg^{-1}$) | meq/100g soil | | | | | | |
| Farmers Friend ($kgha^{-1}$) | | | | | | | | | | | | | | |
| 0 | 5.74 | $5.24_a$ | 0.96 | $1.66_b$ | $0.16_b$ | $0.52_a$ | 4.39 | 0.38 | $1.93_a$ | $2.10_b$ | $3.36_b$ | $6.67_b$ | $1.19_b$ | $8.13_b$ |
| 1.0 | 5.99 | 5.17b | 1.32 | $2.28_a$ | $0.34_a$ | $0.51_b$ | 3.73 | 0.51 | $1.33_b$ | $1.47_a$ | $3.95_a$ | $8.36_a$ | $1.43_a$ | $9.55_a$ |
| $Significance_{0.05}$ | ns | * | ns | * | * | * | ns | ns | * | * | * | * | * | * |
| SE (±) | 0.08 | 0.02 | 0.13 | 0.22 | 0.06 | 0.003 | 0.23 | 0.05 | 0.21 | 0.22 | 0.21 | 0.59 | 0.08 | 0.50 |
| Maxi grow ($kgha^{-1}$) | | | | | | | | | | | | | | |
| 0 | $5.73_b$ | $5.10_b$ | 1.00 | $1.72_b$ | $0.16_b$ | 0.48 | $3.46_b$ | $0.39_b$ | $1.44_b$ | $1.61_b$ | $3.47_b$ | $6.99_b$ | $1.23_b$ | $8.37_b$ |
| 0.5 | $5.81_{ab}$ | $5.33_a$ | 1.28 | $2.21_a$ | $0.25_{ab}$ | 0.51 | $3.43_b$ | $0.47_a$ | $1.89_a$ | $2.01_a$ | $3.88_a$ | $7.74_{ab}$ | $1.38_a$ | $9.03_{ab}$ |
| 1.0 | $5.99_a$ | $5.24_{ab}$ | 1.08 | $1.86_{ab}$ | $0.34_a$ | 0.52 | $4.81_a$ | $0.46_{ab}$ | $1.72_c$ | $1.84_{ab}$ | $3.72a_b$ | $8.17_a$ | $1.29_{ab}$ | $9.40_a$ |
| $Significance_{0.05}$ | * | * | ns | * | * | ns | * | * | * | * | * | * | * | * |
| SE (±) | 0.07 | 0.06 | 0.14 | 0.15 | 0.05 | 0.01 | 0.46 | 0.03 | 0.13 | 0.11 | 0.12 | 0.34 | 0.04 | 0.30 |
| Activator ($kgha^{-1}$) | | | | | | | | | | | | | | |
| 0 | $5.98_b$ | $5.36_b$ | $1.12_b$ | $1.93_b$ | $0.22_b$ | $0.44_b$ | $3.12_c$ | 0.45 | $2.45_a$ | $1.93_b$ | $3.76_b$ | $7.97_c$ | $1.39_c$ | $8.25_b$ |
| 0.5 | $6.11_{ab}$ | $5.54_{ab}$ | $1.50_a$ | $2.59_a$ | $0.56_{ab}$ | $0.46_{ab}$ | $3.74_b$ | 0.47 | $1.83_b$ | $2.19_{ab}$ | $4.08_{ab}$ | $8.69_b$ | $1.83_b$ | $9.14_{ab}$ |
| 1.0 | $6.25_a$ | $5.59_a$ | $1.36_{ab}$ | $2.34_{ab}$ | $0.75_a$ | $0.48_a$ | $4.96_a$ | 0.37 | $2.05_{ab}$ | $2.69_a$ | $4.47_a$ | $10.08_a$ | $2.25_a$ | $10.93_a$ |
| $Significance_{0.05}$ | * | * | * | * | * | * | * | ns | * | * | * | * | * | * |
| SE (±) | 0.07 | 0.07 | 0.11 | 0.19 | 0.15 | 0.01 | 0.54 | 0.03 | 0.18 | 0.22 | 0.21 | 0.62 | 0.25 | 0.78 |

*Means followed by the same letter(s) within the same column are not significant at 5% level of probability. ns = not significant, * = significant at 5% level of probability.*
*OC = % Organic Carbon, OM = % Organic Matter, TN = Total Nitrogen, EC = Electrical Conductivity, Av. P = Available Phosphorus, Ca = Calcium, Na = Sodium, K = Potassium Mg = Magnesium, TEB = Total Exchangeable Bases, EA= Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity.*

**Table 4. Effect of Bio-fertilizers and Soil bio-inoculant on Soil Biological Activities under *Amaranthus* cropping in Itakpe Environment during the 2024 Cropping Season.**

| Treatments | Soil Microbial population ($g^{-1}$ soil) | | | Soil Enzymatic Activities | | | |
|---|---|---|---|---|---|---|---|
| | Fungi $x10^6$ cfu | Actinomycetes $x10^4$ cfu | Bacteria $x10^3$ cfu | Dehydrogenase µg $TPFg^{-1} h^{-1}$ | Alkaline Phosphatase µ mol p-np $g^{-1} h^{-1}$ | Cellulase µ mol glucose $g^{-1} h^{-1}$ | Protease µ mol tyrosine $g^{-1} h^{-1}$ |
| Farmers Friend ($kgha^{-1}$) | | | | | | | |
| 0 | $7.05_b$ | 9.69 | $11.03_b$ | $58.07_b$ | $124.8_b$ | $80.49_b$ | $133.12_b$ |
| 1.0 | $7.99_a$ | 9.83 | $12.33_a$ | $61.24_a$ | $127.3_a$ | $81.00_a$ | $136.75_a$ |
| $Significance_{0.05}$ | * | ns | * | * | * | * | * |
| SE (±) | 0.26 | 0.52 | 0.91 | 2.24 | 1.76 | 0.36 | 2.56 |
| Maxi grow ($kgha^{-1}$) | | | | | | | |
| 0 | $4.86_b$ | $7.48_a$ | $10.45_b$ | $58.11_b$ | $121.4_b$ | 81.13 | $129.80_b$ |
| 0.5 | $5.93_a$ | $7.38_{ab}$ | $11.23_a$ | $64.38_{ab}$ | $130.4_a$ | 86.90 | $140.42_a$ |
| 1.0 | $5.27_{ab}$ | $6.23_b$ | $11.33_a$ | $68.16_a$ | $133.9_a$ | 86.72 | $143.11_a$ |
| $Significance_{0.05}$ | * | * | * | * | * | Ns | * |
| SE (±) | 0.31 | 0.40 | 0.27 | 2.93 | 3.72 | 1.89 | 12.06 |
| Activator ($kgha^{-1}$) | | | | | | | |
| 0 | $5.37_b$ | $7.55_b$ | $8.08_c$ | $76.19_c$ | $143.2_b$ | $80.56_b$ | $143.60_b$ |
| 0.5 | $6.35_{ab}$ | $9.43_{ab}$ | $12.14_b$ | $80.32_b$ | $145.5_{ab}$ | $89.01_a$ | $147.03_{ab}$ |
| 1.0 | $6.92_a$ | $9.85_a$ | $15.53_a$ | $84.04_a$ | $148.9_a$ | $93.45_a$ | $150.21_a$ |
| $Significance_{0.05}$ | * | * | * | * | * | * | * |
| SE (±) | 0.45 | 0.70 | 2.15 | 2.26 | 1.65 | 3.78 | 1.91 |

*Means followed by the same letter(s) within the same column are not significant at 5% level of probability. ns = not significant, * = significant at 5% level of probability.*

Activator may have regulated soil to pH favorable for optimum microorganism activities resulting in availability of nutrients for plant uptake. Additionally, higher organic carbon may imply N availability (Angelova *et al*., 2013). Das *et al*. (2017) had argued that application of organic fertilizers speeds microbial activities and population to release N into the soil. Maxi grow and activator increased soil available phosphorus by 39 and 58.9 % respectively as control plots consistently produced the lowest P levels. This is in agreement with Mijwel (2018) who obtained higher P levels by adding biofertilizers to the soil. Higher microbial activities are required to make P available for plant uptake and this is achieved through biofertilization and organic manures (Prabhu *et al*., 2019). $K^+$ decreased with the application of farmers' friend and activator but slightly increased with maxi grow. Maximum $K^+$ was obtained with control plots for farmers' friend and activator. However, 0.5 kg $ha^{-1}$ maxi grow produced the highest $K^+$ value (1.89 mg $kg^{-1}$). Significant changes in the N, P and K content of the soil may have resulted from the high N, P & K content in the bio-fertilizer used in this experiment. Decrease in K level in this study is similar to the report of Jangir *et al*. (2017) who found no significant variation in soil available K with varying biofertilizers. Angelova *et al*. (2013) argued that K content of the soil can be improved by compost and other ameliorants. Electrical Conductivity was affected by treatments. Farmers' friend decreased EC value by 1.92%, while activator increased EC values by 9.1%. Higher EC value (0.48 (mS/cm) was obtained with activator at 1.0 kg $ha^{-1}$. Chandra *et al*. (2021) asserted that formation of organic acids resulting in high degradation of organic matter could increase EC of the soil. Exchangeable Acidity and Effective Cation Exchange Capacity increased with increasing farmers' friend. Control plots for farmers friend produced lower EC (1.19 meq $100g^{-1}$) and ECEC (8.83 meq $100g^{-1}$).

This also corresponds with the result of Gonzalez *et al*. (2010) who found higher EC values in high organic material of different sources. This was supported by Atiyeh *et al*. (2002) who concluded that EC of soil depends on the nature of organic material applied to the soil. Our result corresponds with Zeynep (2020) who found increasing CEC with the application of biofertilizers. Maxi grow had no significant effect on EC, Alakhdar *et al*. (2020) had argued that EC values are decreased in saline soils when biofertilizers are used because they are best in regulating soil pH. however, for EA and ECEC, increasing maxi grow and activator beyond 0.5 kgha$^{-1}$ does not cause any significant changes. Abeje (2023) found an ECEC values moderate for crop growth in soils without biofertilizer treatments, hence any little change in soil reaction may have caused an increase in ECEC values. EA and ECEC values of 1.29 and 9.40 meq 100g$^{-1}$ was obtained for maxi grow while 2.25 and 10.93 meq 100g$^{-1}$ for activator respectively. Miller *et al*. (2016) had reported that there is often an increase in negatively charged sites on carboxyl and phenolic groups due to rapid organic matter decomposition that often raises CEC. Farmers' friend at 1.0 kg ha$^{-1}$ increased $Mg^{2+}$ and $Ca^{2+}$ significantly (1.47 and 3.95 meq 100g$^{-1}$) when compared with the control. Similarly, maxi grow and activator produced highest $Ca^{2+}$, $Na^{+}$ and $Mg^{2+}$ (2.01, 0.47 and 3.88 meq 100g$^{-1}$) when 0.5 kg ha$^{-1}$ of the solution was used. This did not differ significantly from values obtained with plots treated with 1.0 kg$^{-1}$ maxi grow. Similar result was obtained when activator was applied. $Na^{+}$ was not affected by farmers' friend and activator. Higher cations present in the soil may be attributed to application of biofertilizers. This result aligns with the report of Zeynep (2020) who found high content of $Ca^{2+}$, $Mg^{2+}$ and $K^{+}$ in the soil treated with biofertilizer. Kim *et al*. (2016) maintained that exchangeable cations such as $Mg^{2+}$, $Ca^{2+}$ $K^{+}$, $N^{a+}$ and high P levels have close relationship with soil bacteria and microbial biodiversity. Total Exchangeable Bases was increased consistently by treatments. Maximum TEB was obtained at 1.0 kg ha$^{-1}$ each of farmers' friend maxi grow and activator. Control plots were consistently lower in TEB. Yasa *et al*. (2022) obtained higher exchangeable bases from soil treated with biofertilizer which he attributed to the dynamics of the inputs (Nur-Qursyna and Adzmi 2020).

**Effect of Bio-fertilizers and Soil Bio-inoculant on Soil Microbial Population and Enzymatic Activities during the growing season of *Amaranthus tricolor* in Itakpe Environment**

Table 4 shows that microbial load and enzymatic activities increased with increasing application of farmers' friend. Fungal and bacterial population were highest (7.99 x$10^{6}$ CFU and 12.33 x$10^{3}$ CFU) when 1.0 kg ha$^{-1}$ of farmers' friend was applied. This result aligns with the report of Fitriatin *et al*. (2021) who obtained significant increase in population of Phosphorus solubilizing bacteria and fungi up to 11.70 x $10^{9}$ CFU g$^{-1}$ and 10.67 x $10^{4}$ CFU g$^{-1}$ in soil planted with paddy rice. Patel *et al*. (2024) also obtained maximum bacterial load up to 12.33 x$10^{6}$ CFU from application of organic and bio-fertilizer containing rhizobium and phosphorus solubilizing bacteria to soil planted with chickpea. Higher microbial population is due to the release and multiplication effect of biofertilizers applied to the soil. As reported by Bhardwaj *et al* (2014), biofertilizers raises availability of nutrient and creates healthy environment for microbes to thrive. This is reflected in the performance of amaranth as observed in the present study. Robust bacterial population has been reported to increase nutrient uptake (Bargaz *et al*., 2018; Zhang *et al*., 2019). Phosphorus solubilizing bacteria has been reported to increase P uptake in plants (Niamat *et al*., 2019). Enzymatic activities such as dehydrogenase, alkaline phosphatase, cellulase and protease were highest in plots treated with 1.0 kg ha$^{-1}$ of farmers' friend (Table 4).

Although Actinomycetes was not significantly affected (P>0.05) by farmers' friend. Similar observations were made with maxi grow and activator. Ramalakshmi *et al*. (2008) found significant increase in fungal population in biofertilizers inoculated soils in his study, he discovered that population of actinomycetes increased during cropping periods. This confirms our result obtained with maxi grow and activator where bacteria, actinomycetes and fungi populations were significantly increased. Microbial populations and enzymatic activities were though highest in plots treated with 1.0 kg ha$^{-1}$ each of maxi grow and activator, but results did not differ significantly from plots treated with 0.5 kg ha$^{-1}$ of maxi grow and activator. Plots treated with 1.0 kg $ha^{-1}$ of activator produced 84.04 μg $TPFg^{-1}$ $h^{-1}$ dehydrogenase, 148.9 μ mol p-np $g^{-1}$ $h^{-1}$ Alkaline Phosphatase, 93.45 μ mol glucose $g^{-1}$ $h^{-1}$ cellulase, and 150.21 μ mol tyrosine $g^{-1}$ $h^{-1}$ protease while plots treated with 1.0 $kgha^{-1}$ of maxi grow produced 68.16 μg $TPFg^{-1}$ $h^{-1}$ dehydrogenase, 133.9 μ mol p-np $g^{-1}$ $h^{-1}$ Alkaline Phosphatase, and 143.11 μ mol tyrosine $g^{-1}$ $h^{-1}$ protease. Cellulase was not significantly affected by maxi grow. Control plots consistently had lowest microbial population and enzymatic activities throughout the period of the study. The result may be due to the fact that biofertilizers speeds up organic matter decomposition, rapid multiplication of beneficial microbes which improves activities of soil enzymes. This is confirmed in the findings of Laxman *et al*. (2017), who concluded that broad spectrum application of macro nutrients to plants and introduction of microorganisms into the soil through foliar methods could optimize biological activities of dehydrogenase, phosphatases and urease enzymes. Increased Alkaline phosphatase, protease and decreased cellulase activities observed in this present study conforms with the report of Moreno-Espíndola *et al*. (2018) on amaranth. Patel *et al*. (2024) also confirmed that inclusion of the *fabaceae* family into cropping system could increase dehydrogenase activities, due to greater nutrient retention (Mandal *et al*., 2020). Chang *et al*. (2007) found that optimum enzyme activity and increasing microbial population is synonymous to continuous application of organic manure and biofertilizers to the soil. Microbial and enzymatic activities have been reported to influence phenological changes in Amaranth and improve soil structure of optimum crop performance. Fuentes-Ponce *et al*. (2016) confirmed that dehydrogenase activity is a sensitive agronomic indicator. In a report by Moreno-Espíndola *et al*. (2018), higher N, soil organic carbon was observed in the rhizosheath soil of Amaranth crop during flowering and post-harvest seasons, higher microbial biomass carbon and decreased soil water holding capacity was observed in loose soil after harvest of amaranth. Spohn & Kuzyakov (2013) reported that higher Alkaline Phosphatase activity influenced flowering in Amaranth where soil percolation is high and this could impact positively on leaf area.

## CONCLUSION

This study shows that the use of biofertilizers and soil bio-inoculants improves the performance of *Amaranthus tricolor*, soil physical, chemical and biological properties. Foliar application of biofertilizers and inoculants such farmers' friend, maxi grow and activator at 1.0, 1.0 and 0.5 kg $ha^{-1}$ respectively seemed optimum for crop parameters such as number of leaves, plant height, stem girth leaf area and biomass yield. similarly, physical and chemical properties such as bulk and particle density, porosity, soil organic matter, total nitrogen, available phosphorus, $K^{+}$, $Mg^{2+}$, $Ca^{2+}$, electrical conductivity, total exchangeable bases, exchangeable acidity and effective cation exchange capacity performed optimally with 1.0, 0.5 and 0.5 kg $ha^{-1}$ farmers' friend, maxi grow and activator respectively. microbial population (bacteria, fungi and actinomycetes) and enzymatic activities (Dehydrogenase, Alkaline Phosphatase, Cellulase, Protease) were also optimum at this level of treatments. These treatments were reflected in the crop performance and soil microclimate environment such as improved crop growth and biomass yield, aggregate stability and total soil porosity, soil reaction and organic matter, macronutrient availability and uptake. This finding therefore provides insights into the importance of microbiome solution in sustainable food and agroecosystem. Therefore, application of farmers' friend, maxi grow and activator at 1.0, 1.0 and 0.5 kg $ha^{-1}$ respectively is thus recommended for maximum soil physical, chemical and biological activities and *Amaranthus* performance in Itakpe environment.

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# EFFECT OF RHIZOBIUM INOCULATION ON SOIL PHYSICAL AND CHEMICAL PROPERTIES OF ALIERO AND SOKOTO SUDAN SAVANNA ZONE OF NIGRIA

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## ABSTRACT

Field trials were conducted simultaneously during 2024 wet season at Kebbi State University of Science and Technology University Research Farm Aliero (latitude $13^0$ 01N and longitude $5^0$ 15E), and Dry Land Teaching and research farm Usmanu Danfodiyo university Sokoto (latitude $12.34^0$ 01N and longitude $4^0$ 15E).in order to study the effect of Rhizobium inoculation on soil physical and chemical properties of Aliero and Sokoto Sudan savannah zone of Nigeria. The trial consisted of two composite samples each (before and after) which were analysed in laboratory for physical and chemical properties. The result revealed that Sokoto, pH increased from 6.73 to 6.90, organic matter from 2.56% to 3.09%, nitrogen from 1.06% to 1.12%, and phosphorus from 0.36% to 0.39%. Calcium and potassium levels also rose from 3.12 to 3.90 and 0.13 to 0.17, respectively. Conversely, in Aliero, pH decreased significantly from 6.82 to 5.84, and organic matter dropped from 1.01% to 0.50%, while nitrogen increased from 0.76% to 0.98% and phosphorus from 0.24% to 0.28%. This study demonstrates the potential of Rhizobium inoculation in enhancing soil fertility in the Sudan Savanna zone of Nigeria, with distinct outcomes in Sokoto and Aliero.

**Key words:** Rhizobium, Inoculation, Soil, Physical and Chemical Properties.

## INTRODUCTION

The sustainability of agricultural productivity in the Sudan Savanna zone of Nigeria, particularly in Aliero and Sokoto, is closely tied to soil fertility. In these regions, leguminous crops play a vital role in the cropping systems, contributing to soil nitrogen enrichment through biological nitrogen fixation (BNF). The total nitrogen fixation in the world is estimated to be about $1.75 \times 10^{11}$ Kg, of which symbiotic nitrogen fixation in legumes accounts for about $8.0 \times 10^{10}$ Kg by fixing, on average, 20–200 kg N fixed $ha^{-1}$ $year^{-1}$, and the other near half is industrially fixed while producing N fertilizers (about $8.8 \times 10^{10}$ Kg) (Shah *et al.,* 2021). Biological nitrogen fixation (BNF) through rhizobia–legume symbiosis is, thus, the best alternative and a more sustainable process by a group of symbiotic bacteria, so-called rhizobia, which fix the atmospheric N2 and make the fixed nutrient available to the host legume and other crops in the cropping system (Stagnari*et al.,* 2017). Increments in crop yield following nitrogen-fixing legumes arises from the role of this system in modifying the activity of soil organisms; the chemical or physical characteristics of the soil; and/or through breaking the cycles of diseases, insects, and other pests (Wani*et al.,* 1995). The use of legumes in agricultural systems and utilization of associated BNF systems provides economically feasible and environmentally sound ways of decreasing external inputs and improving the soil nutrient content and, hence, can be suggested for the nutrition of sustainable agriculture (Kebede, 2020).

The Sudan Savanna zone of Nigeria faces challenges of soil nutrient depletion, particularly nitrogen, which is essential for plant growth. Conventional fertilizers, while effective, are often expensive and inaccessible to many farmers in Aliero and Sokoto. This has led to declining crop yields, food insecurity, and environmental concerns associated with over-reliance on chemical fertilizers. Rhizobium inoculation offers a cost-effective, eco-friendly alternative to replenish soil nitrogen. However, its effectiveness in the specific ecological and soil conditions of the Sudan Savanna zone remains under-researched. Addressing this knowledge gap is crucial for developing region-specific strategies to improve soil fertility and agricultural productivity. The objective of this study was to evaluate the effect of Rhizobium inoculation on soil physical and chemical properties in Aliero and the Sokoto Sudan Savanna zone of Nigeria.

## MATERIALS AND METHODS

### Soil samples collection

Following land preparation, but prior to planting, and immediately after harvesting composite soil samples at the depth of 0f 0-15 and 15-30cm were collected from the experimental site in a zigzag mode, and sub-samples were taken for physical and chemical analysis. The soil properties determined included soil pH, % organic matter, % Nitrogen, % Moisture content, Bulk Density, N, P, Ca, K, Na, % Sand, % Silt, % Clay and Texture.

### Samples Determination

The soil pH was measured electrometrically in 1:1 (weight/volume) soil: water suspensions in accordance with the procedure described by Thomas (1996). Ca, K and Na were determined by flame photometer. Total nitrogen was determined by the Kjeldah method as described by Okalebo*et al.,* (1993). Available phosphorus was determined by the Olsen method in accordance with the procedure described by Juo (1979). Particle size distribution was determined by the hydrometer method as described by Gee and Bauder (1986) and textural classes of the soils were determined by the United States Department of Agriculture procedure (USDA, 1975). Bulk density was determined by the procedure describe by Campbell, 1994. And moisture content was determined by oven drying method.

## RESULTS

The results highlight the effects of rhizobium inoculatin on soil of Sokoto and Aliero Sudan Savanna zone of Nigeria. In Sokoto, the pH increased slightly (6.73 to 6.90), indicating a move toward more neutral conditions, which supports better nutrient availability. Organic matter also increased significantly (2.56% to 3.09%), reflecting enhanced soil fertility, likely due to improved biological activity from nitrogen fixation. This is further supported by the increase in nitrogen content (1.06% to 1.12%) and phosphorus levels (0.36% to 0.39%). Calcium levels rose markedly (3.12 to 3.90), along with potassium (0.13 to 0.17), indicating enhanced nutrient reserves. Electrical conductivity also showed an increase (3.12 to 3.90 $\mu S\ cm^{-1}$), which is indicative of higher ionic activity in the soil. While these improvements occurred, the texture remained sandy with minor changes in silt content (0.72% to 2.16%).

**Table 1: Soil Physical and chemical properties**

| Sample | pH | % O.M | N (ppm) | P (ppm) | EC μ cm$^{-1}$ | Ca (ppm) | K (ppm) | Na (ppm) | % Sand | % Silt | % Clay | Texture |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sokoto Before | 6.73 | 2.56 | 1.06 | 0.36 | 3.12 | 3.12 | 0.13 | 0.03 | 93.52 | 0.72 | 5.76 | Sand |
| Sokoto After | 6.90 | 3.09 | 1.12 | 0.39 | 3.90 | 3.90 | 0.17 | 0.02 | 92.80 | 2.16 | 5.04 | Sand |
| Aliero Before | 6.82 | 1.01 | 0.76 | 0.24 | 0.25 | 0.25 | 0.05 | 0.02 | 92.08 | 3.60 | 4.32 | Sand |
| Aliero After | 5.84 | 0.50 | 0.98 | 0.28 | 0.26 | 0.26 | 0.11 | 0.02 | 92.08 | 3.60 | 4.32 | Sand |

In Aliero, the effects were less favorable, with the pH dropping significantly (6.82 to 5.84), indicating increased acidity, which may hinder nutrient availability. Organic matter content decreased substantially (1.01% to 0.50%), suggesting a loss of fertility, potentially due to soil degradation or insufficient organic input. Despite these changes, nitrogen levels increased (0.76% to 0.98%), likely reflecting rhizobium's role in nitrogen fixation. Phosphorus content also rose slightly (0.24% to 0.28%), while calcium and electrical conductivity remained almost unchanged (0.25 in both cases). Potassium levels showed a modest increase (0.05 to 0.11). The soil texture remained constant with no changes in sand, silt, or clay proportions.

These findings align with previous studies highlighting the role of rhizobium inoculation in improving soil fertility through biological nitrogen fixation and increased availability of essential nutrients like phosphorus and potassium. Studies have shown that legumes such as groundnut, when inoculated with effective rhizobium strains, contribute to higher soil organic matter and nutrient availability, particularly in sandy soils common to semi-arid regions (Argow 2017 and Gabasawa, 2021). The significant improvements observed in Sokoto may be attributed to better baseline soil conditions and a more favorable environment for rhizobium activity. Sandy soils with adequate organic matter content, as seen in Sokoto, provide better aeration and support rhizobium proliferation, leading to enhanced nitrogen fixation and nutrient cycling (Shikha*et al.,* 2023).

## CONCLUSION

This study demonstrates the potential of Rhizobium inoculation in enhancing soil fertility in the Sudan Savanna zone of Nigeria, with distinct outcomes in Sokoto and Aliero. In Sokoto, Rhizobium inoculation improved soil properties, including pH, organic matter, nitrogen, phosphorus, calcium, and potassium levels, reflecting its capacity to support sustainable agriculture in favorable conditions. Conversely, the results in Aliero highlight the challenges of declining pH and organic matter, indicating that Rhizobium inoculation alone may not suffice in areas with suboptimal baseline soil conditions.

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# INFLUENCE OF POTASSIUM AND SODIUM CHLORIDES CONCENTRATIONS ON GROWTH AND YIELD OF TOMATO (*Solunum lycopersicum* L.) IN SUDAN SAVANNAH

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## ABSTRACT
An experiment was conducted at Kebbi State University of Science and Technology, Aliero, Teaching and Research Fadama Farm located at Jega, during the 2023/2024 dry season, to assess the effects of different concentrations of salts on the growth and yield of tomato. The experiment consists of four treatments including control which were designated as ($SA_1$=NaCl (5g), $SA_2$=NaCl (10g), $SB_1$=KCl (5g), $SB_2$=KCl (10g), and $S_0$= (0g) laid out in Randomized Complete Block Design (RCBD) replicated three times. The nutrient content in the soil was also assessed which comprised Soil Particle size, pH, O.C (Organic Carbon), T.N(Total Nitrogen), Exchangeable K, Na, Ca and Mg before the commencement of the research and after. Data collected on growth parameters encapsulated are thus; Plant height and number of branches per plant while yield parameters included flowering percentage %, Mean fruit diameter, Marketable yield (t ha$^{-1}$), and Total yield t ha$^{-1}$. Data collected were subjected to analysis of variance (ANOVA) and significant differences were separated using least significance difference (LSD) at a 5% probability level. The results on soil nutrients revealed a significant difference before and after the application of the treatments, while growth and yield parameters were statistically the same exceptfor plant height which differed significantly. On plant height at 6WAT, $SB_1$ treatment recorded the highest value (26.587cm), followed by $SA_2$ (25.26cm) and $S_0$ (25.23cm) while $SA_1$ and $SB_1$ revealed the lowest values of 21.63cm and 22.847cm, respectively.
**Keywords:** Potassium, Chloride, Sodium chloride, Plant height, Tomato, leaf length, Soil nutrient

## INTRODUCTION
The tomato originated from the tropics of central and South America, extending from Mexico, Ecuador through Chile and it is introduced to Europe to where it was improved further before reaching the United State and Asia (Choudhury, 1970). Following its introduction into Spain in the 6$^{th}$ century, it was dispersed throughout Africa (De Lannoy, 2001). In Nigeria tomato is widely grown in Guinea savanna mostly in the wet season and Sudan savanna in the dry season under irrigation (Adelana, 1977). Tomato is produced commercially. in 1994, its world production stood at about 70 million metric tons from 2.7 million hectares, but the bulk of the production came from temperate countries, and only about 11% was from the tropics (Rafi, 1996). The average yield of tomatoes was 9.88tha$^{-1}$ in Thailand, 9.44tha-$^{1}$ in the Philippine, 14.84tha$^{-1}$ in India 52.82tha$^{-1}$ in Japan, 54.97tha$^{-1}$ in U.S.A and 45.14tha$^{-1}$ in the Netherland (Anonymous, 1993). In Africa, the highest yield was obtained in South Africa (76.25tha$^{-1}$) and the least was from Angola (3.7tha$^{-1}$). The average yield in Nigeria is about 7.0tha$^{-1}$around the year 2005. (FOASTAT, 2015).

Tomato *(Solunum lycopersicon*) is an herbaceous annual crop belonging to the family solanaceae. The stems are creeping covered with sing hairs and glandulous. Although tender when young, they tend to become woody with age (De Lannoy, 2001). There are two types of growth habits depending on the cultivar, tomato with an indeterminate growth habit have a main stem which extends regularly while issuing a cluster of flower on average after every 3 leaves. Tomato with determinate growth habit have a main stem that stops growing and produces a terminal inflorescence after having issued 2-3 trusses of flower separated by 1,2 or 3 leaves (Adelana, 1977). The leaves are compound and alternate, with varying degree of indentation and incision. Auxiliary bud develops in the leaf axis. Tomato autogamous (In breeding). The plant is unaffected by photoperiod in the flowering, but in relatively long days they grow faster and fruit have a high dry matter content (De Lannoy, 2001). The fruit is a berry, which comes from variety of shapes, round and smooth, sometime slightly flattened and ribbed, cordate, elongated (cylindrical or ovoid) or even pear-shaped. Each fruit contains 50-100 seeds, which makes it possible to extract an average of 2-6g of seed per kilogram of fruit (Villareal, 1980).

In term of composition, the edible part of a tomato represents around 94% of the total weight of the fruit. It contains 93.8g, of water, 1.2g of protein, 4.8g of carbohydrate (including 0.7g of cellulose), 7mg calcium, 0.6mg of iron, 0.5 mg of carotene 0.06mg thiamine, 0.04mg riboflavin, 0.06mg niacin and 23mg vitamin C as well as energy value of 83kg (20kcal)/100g (De Lannoy, 2001). In addition to expanding export potential and providing income to its growers, tomato supplies vitamins and minerals in human diet (De Lannoy, 2001; Zhang, 1999; Villareal, 1980). Tomatoes are rarely eaten fresh, consumes, globally prefer to use them as cooked (paste) in the preparation of soups. In Nigeria the crop gained a wide popularity and acceptance where it holds promise as source of raw material for pure (canned paste) as tomato along with culinary utilization in home of most Nigerian families. However, soil salinity is a major problem in both arid and semi-arid regions of the world for agricultural production (Epstein *et al.,* 1980). Inthese regions, the shortage of water and hot dry climate often results in high salt concentration. Salinity is a complex environmental constraint that presents two components. On osmotic components due to the decrease in the external osmotic potential of the solution, an ionic component linked to the alleviation of ions that become toxic at high concentrations (Na, Cl, $SO_4$, $CO_3$, and $HCO_3$), and a stress induced decrease in the content of essential elements such as K and Ca. A salt induced increase in the polyamine or proline content of tomato has been reported in various species of tomato (Aziz *et al.,* 1999).

An accumulation of ions in plant tissues can affect membrane selective permeability, thus altering the uptake of some ions by the tomato plant (Khan *et al.,* 1997). Chloride ion have been reported to be more toxic than Na in some species of tomato (Shannon *et al.,* 1994). Plant tissue culture is a technique useful for nutrition research and monitoring stress tolerance to salinity of plant species over a short period. A new variety of species has been tested in plant culture to examine the different environmental conditions concerning salinization, in vitro culture techniques are reported to be reliable and quick methods for examining salinity stress (Cano *et al.,* 1998). The effects of sodium chloride (NaCl) on some plants have been studied using in vitro techniques (Demir and Kocacaliskan, 2002). Similar results were obtained by (Lutt *et al.,* 1996; Khaya *et al.,* 2002) who reported that high salt concentrations of increase the membrane permeability of sensitive vegetable crops such as tomato lettuce and cabbage. In a recent study, because of this mechanism described above, a high level of proline was accumulated in the leaves of tomato plants grown under high salinity. This is because of the adaptive strategy against osmotic stress, proline accumulation is a less adaptive response in plant tissue under salt stress. It has also been proposed recently that the multi-component effects of salt stress reduce fruit yield and quality of the tomato plant (Saied *et al.,* 2005). Therefore, this research work aimed at investigating the effects of different levels of NaCl and KCL on growth and yield of tomatoes in the Sudan savanna agro-ecological zone of Nigeria.

## MATERIALS AND METHODS

The research was conducted at the Teaching and Research fadama farm of the Kebbi State University of Science and Technology, Aliero, located at Jega, Kebbi State, during the cool dry season. Jega is located between Longitude 4°23'E and Latitude 12°11'N in Kebbi State. The experiment consists of two levels of NaCl and KCL and also with Control. The treatments were coded as $SA_1$, $SA_2$, $SB_1$, $SB_2$, and $S_0$. These were also designated as $SA_1$=NaCl (5g), $SA_2$=NaCl (10g), $SB_1$=KCl (5g), $SB_2$=KCl (10g) and $S_0$=(0g). The treatments were laid down in randomized complete block design (RCBD) and replicated three times. A total land area of 17.8x14.6m was marked out for an experiment and subdivided into gross plots measuring 3.2x3.2m. An area of 1m wide was left between the gross plots and 1.5m between blocks. Tomato (Roma VF) seedlings were raised in the nursery and transplanted at six leaves growth 5 weeks after sowing). A week before transplanting, the experimental site was plowed and harrowed. Basal application of fertilizer NPK (15:15:15) at 300kg/ha was worked in the soil. All the beds were irrigated and allowed to drain to field capacity. After 24 hours, the seedlings were transplanted at a spacing of 45x45cm. The water was slightly supplied to ensure seedling establishment. The treatments were exposed 2 weeks after transplanting.

The tomato was irrigated every three days. All the plots were manually weeded three times in the growing season. The plants were sprayed against whiteflies, aphids, fruit worms and other pests with karate at the rate of 0.75l/ha 4 weeks after transplanting at $6^{th}$ and $7^{th}$ weeks at the rate of 0.8l/ha. Agronomic parameters obtained were Plant height, Number of branches per plant, Mean fruit diameter, flowering percentage %, Marketable yield $tha^{-1}$and Total yield tons $ha^{-1}$. Prior to the commencement of the research work, soil samples were collected at the experimental site using an auger to establish the status of the available soil nutrients. A total number of 15soil samples were obtained, the samples were air-dried, crushed, and sieved. The sieve soil samples were analyzed for particle size, pH, Organic Carbon (O.C), Total N, available, Exchangeable Calcium (Ca), Magnesium (Mg), Potassium (K), and Sodium (Na). The same parameters were also obtained after the harvest to monitor any changes due to the treatments being applied. Standard laboratory procedures for the soil analysis were followed during the soil sample analysis.

## RESULTS AND DISCUSSION

### Plant Height

As shown in Table 1. The influence of different concentrations of NaCl and KCl on plant height of tomato at 3WAT was statistically the same. Although $SA_2$ which was the treatment that received (10g) of NaCl recorded the tallest plant compared to $SA_1$ and $SB_2$ which reveals and respectively while$SA_1$ and $S_0$ recorded the shortest plant and respectively. However, the case was reversed at 6WAT. Because a significant effect was realised as a result of the application of the treatments. $SB_1$ produced the tallest tomato plant as compared to $SA_2$ and $S_0$ which produced similar plant height. Moreover, $SA_1$ and $SB_2$ treatments recorded the shortest plant. This is inline with (Cerda *et al.,* 1995). Who reported that salt concentration has a detrimental effect on the growth of tomatoes.

### Number of branches per plant

The result of the effects of salt concentrations on the number of branches per plant is presented in Table 1. The result indicated that the treatment did not produce any significant effect on the branch number of tomatoes at 3WAT. Although the treatment $S_0$ with (0g) produced more number of branches per plant whereas $SB_2$ and $SA_1$ revealed. However, the treatment $SA_1$ and $SB_1$ which received (5g) of NaCl and KCl concentrations, recorded fewer branch numbers. However, at 6WAT, the case was similar because the result revealed that no influence of treatment on branch number but it was observed that $SB_2$ and $SA_1$ produced high branch numbers, which was greater compared to treatment $SA_2$, $SB_1$ and $S_0$ which recorded. Moreover, this is in agreement with (Cuarter and Fernandez, 1999) who reported that tomato is relatively tolerance to a region that is exposed to salinity.

**Table 1. Influence of Treatment on Growth Attributes of Tomato Plant**

| | Plant Height (cm) | | Number of Branch/Plant | |
|---|---|---|---|---|
| Treatments | 3WAT | 6WAT | 3WAT | 6WAT |
| $SA_1$ | 9.82 | $21.63^{b}$ | 2.58 | 4.33 |
| $SA_2$ | 12.76 | $28.26^{ab}$ | 3.83 | 3.00 |
| $SB_1$ | 12.72 | $26.59^{a}$ | 2.75 | 3.75 |
| $SB_2$ | 12.67 | $22.85^{ab}$ | 4.42 | 4.75 |
| $S_0$ | 11.88 | $25.23^{ab}$ | 6.26 | 3.41 |
| **Sig.** | NS | * | NS | NS |
| **LSD $_{0.05}$** | **6.26** | **3.41** | **2.44** | **1.58** |

***Within a treatment group mean followed by the same letters (S·) are not significantly different at 5% level of using LSD NS = not significant 5% level of significance.***

**Table 2. Influence of Salt Treatment on Yield Attributes of Tomato Plant.**

| | | | No. of fruit/plant | | | |
|---|---|---|---|---|---|---|
| Trt | Flowering% | Mean fruit diameter | 6WAT | 8WAT | Mkt yld | T.yld |
| $SA_1$ | 11.33 | 3.72 | 2.75 | 7.33 | 17.29 | 28.96 |
| $SA_2$ | 16.33 | 3.88 | 2.67 | 6.50 | 17.13 | 29.63 |
| $SB_1$ | 13.00 | 3.91 | 3.00 | 8.08 | 22.25 | 37.42 |
| $SB_2$ | 12.33 | 4.10 | 2.08 | 5.75 | 16.54 | 27.63 |
| $S_0$ | 15.00 | 4.19 | 4.58 | 10.50 | 25.08 | 35.08 |
| **Sig.** | NS | NS | NS | NS | NS | NS |
| **LSD $_{0.05}$** | **7.92** | **0.76** | **2.55** | **5.29** | **19.53** | **2.29** |

***Within a treatment group mean followed by the same letters (S·) are not significantly different at 5% level of using LSD NS = not significant 5% level of significance.***

**Flowering Percentage (%)**

The result of flowering percentage of tomato plant as influenced by the treatment applied as presented on Table 2. It was obviously observed that No significant effect was realised due to the application of the treatment. However, $SA_2$ treatment which received lesser amount of NaCl produced more flowers 16.33%as compared to $S_0$ while $SA_1$, $SB_1$, and $SB_2$ recorded fewer flowers due to the application of salt.

**Mean Fruit Diameter**

The result is presented on Table 2—continuous the influence of salt on the fruit diameter of the tomato plant. No significant effect was observed as a result of the application of salt. However, the treatment designated as $SB_2$ and $S_0$ had a bigger fruit size when compared to $SA_1$, $SA_2$, and $SB_1$ which recorded similar fruit sizes. Similarly, there is no clear trend on the effects of salt on the fruit diameter of tomatoes, but this could be due to the tolerance of tomato plants in the soil that are exposed to salinization.

**Number of Fruit per Plant**

The result on number of fruit per plant as showed on Table 2. No significant difference was observed due to application of the treatment, both at 6WAT and 8WAT. Similarly, $S_0$ treatment produced more fruit number at 6WAT compared to $SB_1$ which out yield while $SA_1$, $SA_2$ and $SB_2$ revealed fewer fruit number per plant. Similar case was observed at 8WAT. $S_0$ treatment produced a greater number of fruit than $SB_1$ and $SA_1$ which recorded.

**Marketable Yield tha-$^1$**

The result on marketable yield tha-$^1$ as presented on Table 2. No significant influence was observed due to the application of salt as treatment. Although $S_0$ which received (0g) of salt had recorded relatively higher marketable yield tha-$^1$than that of $SA_1$ and $SA_2$ which reveals the same number of marketable fruits. Similarly, $SB_1$ and $SB_2$ treatments recorded the lowest value of marketable yield. However, this contradicts with Chapagain *et al*., (2003) who reported that salt enhances the quality of tomato fruits. This could be due to the nutrients imbalance ~~caused~~ by salinity.

**Total Yield (tha$^{-1}$)**

As shown in Table 2. The results revealed that the treatment does not significantly affectstotal tomato yield. However, the results indicated clearly that the treatment $SB_1$which had lowest quantity of KCL produced more yield tha-$^1$ as compared to $S_0$ which was the control, the least yield were recorded in $SA_1$, $SA_2$ and $SB_2$ treatments.

**Initial Physico-chemical Properties of the Soil in the Experimental Site**

Table 3 shows results on the Physico-chemical properties of the experimental site before transplanting and application of the treatment. The result reveals that the textural class of the soil was sandy loam. Particle size distribution of clay was low (13%) silt also low (10%) and 77% sand are the dominant particle. The sandy loam texture indicates that the soil was suitable for tomato production. Soil organic carbon in the site was high (0.21%), total Nitrogen was also high (0.35%) available phosphorus was medium (14.00 mg kg -1). Exchangeable calcium (Ca) and Mg were 4.55 (medium) and 0.65 cmol (+) kg -1, respectively. Exchangeable potassium (K) and sodium (Na) were low at 0.140 and 0.18 cmol (+) kg -1, respectively. The soil reaction was tested strongly acidic (4.50). Except for the pH, generally, the soil at the experimental site had good physic-chemical properties for the production of most crops.

**Table 3: Physiochemical Properties of Surface Soil (0-15cm) at the Experimental Site Before Transplanting and Application of Treatments.**

| Parameters | Values |
|---|---|
| Particles | |
| Clay | 13 |
| Silt | 10 |
| Sand | 77 |
| Textural class | Sandy Loam |
| O.C (%) | 0.205 |
| TN (%) | 0.350 |
| **Exchangeable (cmol (+) kg$^{-1}$)** | |
| $Ca^{+}$ | 4.55 |
| $Mg^{+}$ | 0.65 |
| $K^{+}$ | 0.140 |
| $Na^{+}$ | 0.18 |
| PH $CaCl_2$ (1:2.5) | 4.40 |

**Table 4. Some Chemical Properties of the Soil at the Depth of (0-15cm) after Harvest of Tomato.**

| Treatments | pH | O.C (%) | TN (%) | $Ca^{+}$ | $Mg^{+}$ | K | $Na^{+}$ |
|---|---|---|---|---|---|---|---|
| | | | | cmol(+) kg$^{-1}$ | | | |
| $SA_1$ | $5.02^{a}$ | $0.32^{d}$ | $0.05^{e}$ | $5.13^{c}$ | $1.53^{c}$ | $0.28^{a}$ | $0.53^{b}$ |
| $SA^2$ | $4.47^{b}$ | 0.32d | $0.09^{a}$ | $5.10^{c}$ | $0.08^{e}$ | $0.28^{a}$ | $2.17^{a}$ |
| $SB^1$ | $5.13^{a}$ | $0.47^{a}$ | $0.06^{c}$ | $7.17^{b}$ | $3.07^{a}$ | $0.27^{a}$ | $0.23^{c}$ |
| $SB^2$ | $5.13^{a}$ | $0.40^{c}$ | $0.06^{d}$ | $8.27^{a}$ | $3.05^{b}$ | $0.27^{a}$ | $0.23^{c}$ |
| $S_0$ | $5.10^{a}$ | $0.43^{b}$ | $0.07^{b}$ | $3.60^{d}$ | $0.48^{d}$ | $0.23^{b}$ | $0.30^{c}$ |
| **Sig.** | * | * | * | * | * | * | * |
| **LSD $_{0.05}$** | **0.261** | **0.172** | **0.006** | **0.262** | **0.015** | **0.024** | **0.185** |

*Within a treatment group, means followed by the same letter (s) are not significantly different at 5% level using LSD. Ns= not significant; *= significant at 5% level of significance.*

**CONCLUSIONS AND RECOMMENDATIONS**

In this study, it was observed that lower NaCl and KCl concentrations favour the accumulation of some nutrients contents of the soil such as Total Nitrogen and most of the soil contents present in the soil that are very vital in Tomato production. However, the soil with lower salt concentration favours the growth and yield of Tomato under good managementand favourable environmental conditions.Therefore it can be concluded that under a sandy clay loam soil, salt concentrations should be kept as low as possible to favour the growth and development of the Tomato during the dry season.

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# EFFECT OF DIFFERENT TYPES OF ORGANIC MANURES ON GROWTH AND YIELD OF CARROT (*Daucus carota* L.)

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## ABSTRACT
The experiment was conducted at the Research Farm of the Faculty of Agriculture, University of Maiduguri, Borno state (Latitude 11.4$^0$ N, Longitude 13.05$^0$ E) during the 2017/2018 dry season to evaluate the effect of different types of organic manures on the productivity of carrot. The treatments consisted of six organic sources of nutrition which comprises of $T_1$ cow dung at 18t/ha, $T_2$ poultry manure 10t/ha, $T_3$ sheep dung 20t/ha, $T_4$ goat dung 15t/ha, $T_5$ farm yard manure 25t/ha and $T_6$ control (0t/ha). The experiment was laid out in randomize complete block design (RCBD) with three replications. The result of the experiment showed that growth parameters such as plant height (24.70 cm), leaf number (31.13) were higher in plot treated poultry manure at 10t/ha than the rest of the nutritional source treatments. The result further showed that yield components such as root length (13.20cm), root diameter (2.53cm), percentage marketable tubers (92.33), and total yield/ha (14.667kg/ha) were also higher in poultry manure treated plots than the rest of the manures used. Based on the results obtained from this experiment, it could be concluded that application of poultry manure at 10t/ha should be recommended for carrot production.
**Keywords:** Carrot, organic, manures; growth; and yield

## INTRODUCTION
Carrot (*Daucus carota* L.) is a cool season crop which belongs to the *Apiaceae* family. It is a biennial plant in nature. Carrot are native to central Asia and were domesticated in ancient Persia over 1,000 years ago. The wild ancestors of carrots likely originated in Greater Iran, which is now Iran and Afghanistan. Today this vegetable is cultivated in many countries throughout the world such as America, Europe, South-West Africa (Rutrazky *et al*., 1999). In all these countries, carrot is one of the vegetables cultivated for their high nutritional value (Al-Harbi *et al*., 1997; Munro and Small, 1997). At first, it grows a rosette of leaves while building up the enlarged tap root. The crop is tolerant to soil pH of 5.5 - 6.5 and it requires a deep and well drained loamy soil with high amount of organic matter (Yayock *et al*., 1988). Fast growing varieties mature within three months (90 days) of sowing of the seed, while slower maturing varieties takes four months (120 days) to reach harvest maturity. It is one of the most important crop cultivated through the world for its edible root. The United Nation's Food and Agricultural Organization (reports that world production of carrot for the calendar year 2013 was 37.2 million tons and almost half (45 %) of this was grown in China. Africa's global share of production is estimated at 1,054 metric tons (Anon, 2013).

In Nigeria, estimated production is reported to have stood at 23,000 metric tons from 27,500 hectares of land. FAO, (2003) reported carrot yield, are generally low in Nigeria, even under good crop management, compared to yields in Europe and elsewhere. For instance, Sarkindiya *et al.,* 2006) reported obtaining yields of up to 14-23t ha-1 of carrot in Sokoto, Nigeria. While in Europe, average yields ranging from 30-60 t/ha have been reported (Anon, 2013). The root of carrot contains high quantities of alpha and beta-carotene, and a good source of Vitamin K and vitamin B, it is an excellent source of carotene a precursor of vitamin A and fibre in the diet (Handelman, 2001). It also contains abundant amounts of nutrients such as protein carbohydrates, fibre and folic acid. Despite the importance of carrot in human life, its production has been persistently low in most parts of the world. However, the main causes of low yields are associated with inadequate knowledge on new production methods and appropriate agronomic principles. Generally, most carrot growers use inorganic fertilizer to realize higher yields as opposed to the unfertilized fields (Dauda *et al.,* 2008). The excessive use of inorganic fertilizers as a source of nutrients has however, been associated with human health problems and environmental degradation through pollution (Arisha and Bardisi, 1999). In addition, the rising costs of inorganic fertilizers have made them too expensive to most resource. Poor scale farmers used organic substrates such as manures and compost can provide significant quantities of nutrients for crop growth and development and have a constant effect on the soil for long time (Eghball *et al*., 2004).

The application of manures improves soil fertility and increases crop yield. It makes both macro and micro nutrients available to plants and also improves soil structure and enhances root growth. Manures also promote the activities of soil microorganisms which convert organic matter into humans and promote plant growth (Dupriez and Deleener, 2008). This study was therefore carried out to determine the effect of different organic manures on growth and yield of carrot.

## MATERIALS AND METHODS

### Experimental Site

The experiment was carried out at the Teaching and Research Farm of the Faculty of Agriculture, University of Maiduguri, Borno State, Nigeria on (latitude 11.4°N, longitude 13.05°E and altitude of approximately 350 m above sea level) between December, 2017 to March, 2018.

### Source of Seeds

The seeds were obtained from pioneer seed company at shop No. B33, Dantata Shopping Complex, Kano Nigeria.

### Treatments and Experimental Design

The experiment consisted of six (6) treatments control (To), cow dung ($T_1$), poultry manure ($T_2$), sheep dung ($T_3$), goat dung ($T_4$), farm yard manure ($T_5$) laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Plot size measured 2 m x 1 m which gave a gross size of 2 $m^2$ and plots within blocks were separated using 0.5m space and blocks (replications) were separated by 1 m in order to allow free movement. The total land area of 75 $m^2$and net plot of 1x 0.5m were used for the experiment.

### Land Preparation

The site for the experiment was cleared using hoe and rake to remove weeds, stones and other unwanted materials in the site. Thereafter, manure was applied at various rates which includes cow dung (18 t/ha), poultry manure (10 t/ha), sheep dung (20 t/ha), goat dung (18 t/ha), and farm yard manure (25 t/ha) which were applied two weeks before sowing. The site was then irrigated to field capacity and seeds were sown by drilling at the depth of 1cm and spacing of 10cm between rows was used.

**Data collection**

**Plant height (cm)**

The measurement was done using a 30cm ruler, from the ground level to the apex of the plant. The result was recorded in centimeters (cm). Three (3) tagged plants from the net plots were used.

Their heights were measured and the average computed. This was done fortnightly.

**Number of Leaves/Plant**

This involved counting the total number of leaves/plant. Three (3) tagged plants from the three middle rows were used for this operation. All the leaves of the three (3) tagged plants were counted, the average number computed and the value recorded as the number of leaves/plant and it was done fortnightly.

**Mean Diameter of Carrot Tubers at Harvest**

The measurement of the mean diameter of carrot was taken using vernier caliper at the centre of the carrot tuber. This was done using the three (3) tagged plants. The diameter of the tubers from the three plants were averaged and recorded at harvest.

**Fresh Weight of Carrots Tubers per Plot at Harvest**

This was taken by measuring the fresh of carrot tubers per plot using a weighing scale or weighing balance to determine the weight of carrot tubers per plot at harvest.

**Tuber Length (cm)**

The root length of carrot was also measured using 30cm ruler. The three (3) tagged plants from the net plot were used for this operation.

**Percentage (%) of Marketable Carrot Tubers at Harvest**

This was evaluated by counting the total number of fresh carrots with good quality (carrot tubers with diameter > 2mm) divided by the total number of the carrot tubers per plot multiply by 100.

$$\%\text{of marketable carrot} = \frac{\text{Number of marketable carrot}}{\text{Total number of carrots/plot}} \times 100$$

**Percentage (%) of Non-marketable Carrot Tubers at Harvest**

This was taken by counting the number of non-marketable carrot tubers per plot and dividing it by the total number of carrot tubers per plot multiplied by 100

$$\%\text{ of non-marketable carrot} = \frac{\text{Number of non-marketable carrot}}{\text{Total No. of Carrots/plot}} \times 100$$

**RESULTS AND DISCUSSIONS**

**Effect of Different Organic Manures on Plant Height**

The effect of different organic manures on plant height shows that there was significance difference amongst the different manures used (Table 1). Poultry manure gave the highest plant height (24.70 cm) and the control gave the least height (11.83cm). This could be attributed to the ability of the poultry manure to release the required nutrients faster than the other manures used which resulted in faster cell division that gave rise to highest plant height than other manures used. Similar findings were reported by Uddain *et al*., (2010) with the application of 25 t/ha of poultry manure in carrot.

**Effect of different organic manures on number of leaves per plant**

The effects of different organic manures on number of leaves per plant is presented in Table 2. The result shows that there were significant differences in number of leaves as a result of different organic manure treatments. Poultry manure gave the highest number of leaves per plant and the control gave the least number of leaves per plants throughout the period of the experiment. These findings is also similar to the work of Kumar *et al*., (2009), and Uddain *et al*., (2010) who both discovered that poultry manure releases nutrients faster than other manures used and this could result in faster cell division in crops, faster growth rate as well efficient capture of light for photosynthesis.

**Effect of different organic manures on root length, root diameter, percentage of marketable and non-marketable tubers per plot and total tuber yield/ha**

The effect of different organic manures on tuber length, diameter, percentage marketable and non-marketable tubers and total tuber yield/ha showed that there was significant effect of different organic manures on these parameters (Table 3). Poultry manure gave the highest tuber length (13.10cm), tuber diameter (2.53cm), percentage marketable tuber per plot (92.33%) and total tuber yield ha-l (14.667kg) and the control gave the least values of tuber length (5.73cm), tuber diameter (1.13cm), percentage marketable tuber per plot (46.00%) although have the highest value of non-marketable tuber per plot (54.00%), total tuber yield ha-1 (5,833kg). The highest value in relation to tuber length, tuber diameter, tuber yield/ha, percentage marketable tubers could be attributed to source/sink relationship because when the nutrients released as a result of application of poultry that resulted in higher vegetative from the source can lead to higher assimilates been channeled to sink. Similar findings were reported by Ahmad *et al*., (2005), Kumar *et al*., (2009), Uddain *et al*., (2010) with the application of poultry manure that increased these parameters compared to other manures used.

**CONCLUSION**

In conclusion, poultry manure is more favorable for growth and yield of carrot. This is because it produced the highest growth, and yield parameters.

**RECOMMENDATION**

From the results of the study, poultry manure is recommended for the production of carrot in the study area.

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**Table 1: Effect of different organic manure on plant height (cm)**

| | Plant Height (cm) 4 | 8 | 12 |
|---|---|---|---|
| | Weeks After Sowing (WAS) | | |
| **Treatments** | | | |
| Cow dung | 5.97b | 11.93b | 20.67b |
| Poultry manure | 7.47a | 15.80a | 24.70a |
| Sheep dung | 5.90b | 12.87b | 19.53bc |
| Goat dung | 5.23c | 10.73b | 17.67d |
| FYM | 4.80c | 11.73b | 18.47cd |
| Control | 3.13d | 6.80c | 11.83c |
| SE ± | 0.1574 | 0.70 | 0.41 |

Mean followed by the same letter (s) in the same column are not significantly different (P<0.05) according to Duncan's Multiple Range Test (DMRT).

Keys: WAS = Weeks after Sowing, FYM = Farm yard Manure.

**Table 2: Effect of different organic manures on number of leaves per plant**

| | Number of Leaves 4 | 8 | 12 |
|---|---|---|---|
| | Weeks After Sowing (WAS) | | |
| **Treatments** | | | |
| Cow dung | 7.20b | 14.13ab | 25.07b |
| Poultry manure | 8.50a | 16.23a | 31.13a |
| Sheep dung | 6.20c | 3.23b | 21.17bc |
| Goat dung | 6.07c | 12.97b | 20.20c |
| FYM | 5.27d | 13.17b | 19.67c |
| Control | 3.27e | 7.40c | 13.43d |
| SE ± | 0.13 | 0.73 | 1.32a |

Mean followed by the same letter (s) in the same column are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test (DMRT).

Keys: WAS = Weeks after Sowing, FYM = Farm yard Manure.

**Table 3: Effect of different organic manures on root length, root diameter, percentage of marketable and non-marketable tubers per plot and total tuber yield/ha**

| Treatments | Tuber length (cm) | Tuber diameter (cm) | Marketable tuber (%) | Non- marketable tuber (%) | Yield (t/ha) |
|---|---|---|---|---|---|
| Cow dung | 11.23ab | 1.93bc | 81.67b | 18.33c | 12b |
| Poultry manure | 13.20a | 2.53a | 92.33a | 7.67d | 14.6a |
| Sheep dung | 9.60b | 2.00c | 80.3bc | 19.67bc | 11.3b |
| Goat dung | 10.20b | 2.03b | 80.00bc | 20.00bc | 12b |
| FYM | 9.90b | 1.87c | 77.00e | 23.00b | 12b |
| Control | 5.73c | 1.13d | 46.00d | 54.00a | 5.8c |
| SE ± | 0.67 | 0.05 | 1.32 | 1.32 | 5.4. |

Mean followed by the same letter (s) in the same column are not significantly different ($P<0.05$) according to Duncan's Multiple Range Test (DMRT).

# EVALUATION OF FALL ARMYWORM (*SPODOPTERA FRUGIPERDA*) INCIDENCE AND MORPHOLOGICAL TRAITS OF MAIZE (*ZEA MAYS* L.) GENOTYPES IN NIGER STATE, NIGERIA

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## ABSTRACT
Fall Armyworm (FAW) (*Spodoptera frugiperda*) is a major invasive insect pest threatening maize (*Zea mays* L.) production in sub-Saharan Africa, including Nigeria. This study evaluated the incidence of FAW infestation and its effect on the morphological traits of 14 maize genotypes across two locations in Niger State, Nigeria: Minna and Mokwa. The trials were conducted using a randomized complete block design with three replications. FAW incidence was recorded as the percentage of plants showing signs of infestation, while morphological traits such as plant height and leaf area were measured. Data collected were subjected to analysis of variance and means were separated using Duncan multiple range test. Results showed significant variation in FAW incidence among genotypes. Highly susceptible genotypes such as NGBO 2854 and NGBO 2864 exhibited FAW incidences of up to 100% in Minna and 87% in Mokwa. Conversely, genotypes such as NGBO 2864, NGBO 2898, and NGBO 2249 demonstrated superior morphological performance with plant heights exceeding 170 cm and leaf areas above 660 cm², indicating resilience under FAW pressure. The environmental influence was evident, with Mokwa favoring slightly better growth for some genotypes. Genotypes NGBO 2864, NGBO 2898, and NGBO 2249 were identified as promising candidates for breeding programs aimed at developing FAW-resistant maize varieties.
**Keywords**: Genotype; resistance; army worm, infestation

## INTRODUCTION
Maize is scientifically known as *Zea mays* L., which holds a paramount position as a staple food crop and plays a fundamental role in the local diet, forming the basis of many traditional dishes and serves as a primary source of nutrition for the population (Chiriboga *et al.,* 2024). Maize cultivation in Niger State is not only essential for food security but also contributes significantly to the livelihoods of many smallholder farmers in the region as it generates income for farmers through sales of maize grain and related products (Akhigbe *et al.,* 2021). Fall Armyworm (FAW), *Spodoptera frugiperda* is an invasive insect pest that has caused significant damage to maize production globally, particularly in sub-Saharan Africa since its introduction in 2016 (Chiriboga *et al.,* 2023). Nigeria, being one of the first countries in Africa to report the presence of FAW in 2016, has been severely impacted by the pest (Ajiboye *et al.,* 2023). The invasion of FAW in Nigeria has led to substantial economic losses for farmers and threatens the country's food security (Ajiboye *et al.,* 2023).

The FAW larvae feed voraciously on maize plants, causing extensive damage to the leaves. This feeding behaviour results in defoliation, where the leaves are consumed or damaged, affecting the plant's ability to photosynthesize effectively. Reduced leaf area due to FAW feeding can hinder the plant's capacity to produce energy through photosynthesis, leading to stunted growth and compromised plant health (Day *et al.,* 2017). Elucidating the mechanisms of resistance and understanding the genetic factors involved can inform the development of more effective and durable resistance strategies. Screening and evaluating a diverse set of maize genotypes under artificial infestation conditions can help identify resistant lines and guide breeding efforts (Balint-Kurti, 2015). The urgency of this study is underscored by the critical need to enhance maize production resilience against FAW in Niger State. Therefore, the objective of this study was to assess the incidence of FAW infestations and to identify maize genotypes that exhibit resistance to FAW in Niger State, Nigeria.

## MATERIALS AND METHODS

The experiment was a multi-locational maize evaluation at the teaching and research farm of the Department of Crop Production, Federal University of Technology, Minna and IITA sub-station Mokwa during the 2024 rainy season. Fourteen maize genotypes were evaluated for Fall armyworm infestation. At each location, the trials were replicated thrice in a randomized complete block design. Land preparation was done manually by making ridges of 8 meters long arranged in a single-row plot. A combination of nitrogen (N) at the rate of 120kg/ha, phosphorus (P) at the rate of 60kg/ha as $P_2O_5$, and potassium (K) at the rate 40kg/ha as $K_2O$ was applied basal to promote optimal growth and development and the remnant dose as top dressing 8 weeks after planting. Data on the incidence were recorded as the percentage of plants showing signs of FAW infestation (NACGRAB, 2020). Plant height, leaf length, leaf width and leaf area were measured to assess the overall growth and health of the plants. Data collected were subjected to analysis of variance and means were separated using Duncan multiple range test.

## RESULTS

The mean incidence of fall armyworm (FAW) across 14 maize genotypes at 8WAS is shown in Table 1. Genotypes NGBO 2854 and NGBO 2864 had the highest FAW incidence, with infestation rates of 100% in Minna and 87% in Mokwa. This consistent vulnerability indicates these genotypes lack inherent resistance to FAW and may not be ideal for cultivation in FAW-prone areas. Genotypes NGBO 7517 and NGBO 2346 showed intermediate levels of FAW infestation, with incidence rates ranging between 53% and 93% depending on the location. For most genotypes, FAW incidence was either equal or slightly higher in Mokwa compared to Minna, indicating that environmental factors at Mokwa (e.g., temperature, humidity, or pest dynamics) may exacerbate infestation levels. The effect of fall armyworm infestation on the morphological traits of 14 Maize Genotypes is shown in Table 2. Several genotypes exhibited robust morphological traits despite FAW infestation, indicating potential tolerance. NGBO 2864 achieved the tallest plant height (172cm in Minna and 131cm in Mokwa) and relatively high leaf area values, suggesting good growth potential under FAW pressure. NGBO 2898 and NGBO 2249 also showed superior performance, with leaf areas exceeding 670 cm² in Minna and 750 cm² in Mokwa. This demonstrates their ability to sustain growth and photosynthetic capacity despite FAW attack. Genotypes like NGBO 7514 and NGBO 3254 displayed average plant heights and leaf areas. For instance, NGBO 7514 had a plant height of 123 cm and a leaf area of 618 cm² in Minna, decreasing slightly in Mokwa. These genotypes are moderately tolerant and could be improved through breeding programs. Genotypes NGBO 2346 and NGBO 7517 exhibited significantly lower values for plant height and leaf area across both locations. For example: NGBO 7517 recorded a leaf area of only 273 cm² in Minna, among the lowest in the study, indicating reduced photosynthetic capacity under FAW pressure.

**Table 1: Mean Incidence of Fall Armyworm Across 16 Maize Genotypes at Two locations**

| Genotypes | Locations | |
|---|---|---|
| | Minna | Mokwa |
| NGBO 7514 | 93[ab] | 80[a] |
| NGBO 3254 | 80[ab] | 80[a] |
| NGBO 2854 | 100[a] | 87 [a] |
| NGBO 2346 | 73[bc] | 73 [a] |
| NGBO 2289 | 80[ab] | 80 [a] |
| NGBO 7517 | 53[d] | 60 [a] |
| NGBO 5505 | 86[ab] | 60 [a] |
| NGBO 2370 | 80[ab] | 80 [a] |
| NGBO 2251 | 100[a] | 73 [a] |
| NGBO 2249 | 93[ab] | 73 [a] |
| NGBO 2898 | 93[ab] | 80 [a] |
| NGBO 2864 | 100[a] | 87 [a] |
| NGBO 7760 | 93[ab] | 67 [a] |
| TSN 5110 | 60[cd] | 60 [a] |
| Mean | 6.01 | 8.7 |

Means with the same letter(s) within the genotypes group, are not significantly different using Duncan multiple range test.

**Table 2: Effect of Fall Armyworm infestation on morphological traits of 16 Maize Genotypes at Two location**

| Genotypes | Minna | | Mokwa | |
|---|---|---|---|---|
| | Plant height | leaf Area | Plant height | leaf Area |
| NGBO 7514 | 123[cd] | 618[ab] | 106[ab] | 673[bc] |
| NGBO 3254 | 137[bcd] | 665[a] | 96[ab] | 717[abc] |
| NGBO 2854 | 135[bcd] | 596[ab] | 131[a] | 719[abc] |
| NGBO 2346 | 83[e] | 406[cd] | 83[b] | 411[e] |
| NGBO 2289 | 131[bcd] | 478[bc] | 130[ab] | 648[bcd] |
| NGBO 7517 | 69[e] | 273[d] | 122[ab] | 530[e] |
| NGBO 5505 | 121[cd] | 603[ab] | 121[ab] | 560[cde] |
| NGBO 2370 | 110[d] | 504[abc] | 115[ab] | 504[de] |
| NGBO 2251 | 147[abc] | 511[abc] | 139[a] | 726[abc] |
| NGBO 2249 | 124[cd] | 666[a] | 98ab | 858 [a] |
| NGBO 2898 | 157[ab] | 677 [a] | 123[ab] | 777[ab] |
| NGBO 2864 | 172 [a] | 577[ab] | 131 [a] | 660[bcd] |
| NGBO 7760 | 147[abc] | 660[a] | 124[ab] | 754 [ab] |
| TSN 5110 | 140b[cd] | 600 [ab] | 140 [a] | 632[bcd] |
| Mean | 9.5 | 51.8 | 14.1 | 51.9 |

Means with the same letter(s) within the genotypes group, are not significantly different using Duncan multiple range test

## DISCUSSION

The significant differences in FAW incidence observed in this study underscore the genetic variability among the maize genotypes. Some genotypes demonstrated lower FAW damage, indicating inherent resistance mechanisms. These findings align with previous studies emphasizing the role of genetic diversity in pest resistance (Chormule *et al.*, 2022). Genotypes NGBO 2864 and NGBO 2898 stand out as promising candidates due to their superior growth and moderate FAW incidence rates. These traits make them suitable for breeding programs aimed at developing FAW-resistant varieties. Resistant genotypes often express traits such as antibiosis, antixenosis, or tolerance which can reduce pest colonization and damage (Tambo *et al*., 2020) The variation in performance between Minna and Mokwa highlights the role of environmental factors. Seasonal variations, natural enemies and agricultural practices may affect pest dynamics (Goergen *et al.*, 2016). Mokwa's conditions seem more favorable for higher leaf area in some genotypes (NGBO 2249, NGBO 2898), which could improve resistance through enhanced photosynthesis. Genotypes like NGBO 2854 and NGBO 2864, despite good growth characteristics, require significant improvement in resistance to FAW. Conversely, NGBO 2864 and NGBO 2898 combine moderate resistance and favorable growth traits, making them strong candidates for further trials.

## CONCLUSION

The promising genotypes (NGBO 2864, NGBO 2898, and NGBO 2249) demonstrate both growth resilience and moderate resistance, making them ideal candidates for advancing FAW resistance research and maize breeding in FAW-prone regions. However, the influence of environmental conditions, as observed in Mokwa, must also be considered in genotype selection and management strategies.

## RECOMMENDATIONS

Genotypes such as NGBO 2864, NGBO 2898, and NGBO 2249 which demonstrate superior performance under FAW pressure, should be prioritized in breeding programs to develop maize varieties with enhanced resistance and growth traits.

Susceptible genotypes like NGBO 2854 and NGBO 2864 require enhanced pest management strategies, including the application of integrated pest management (IPM) techniques, to mitigate FAW infestation during cultivation.

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# EFFECTS OF RHIZOBIA INOCULATION ON GROWTH AND YIELD OF GROUNDNUT (*Arachis hypogaea* L.) VARIETIES IN THE SUDAN SAVANNAH LOCATION OF NIGERIA

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## ABSTRACT

*Field trial was conducted at Kebbi State University of Science and Technology University Research Farm Aliero–during 2024* rainy *season, to assess the effect of Rhizobium inoculation on growth and yield of groundnut varieties. The treatments consisted of factorial combination of four varieties of groundnut (*SAMNUT *23, 24, 25, Ex-Aliero) and four rhizobium inculation levels (0, 300, 600 and900 g ha$^{-1}$) laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Data were collected on Canopy height, Leaf Area, Number of nodules plant$^{-1}$, Number of pods Plant$^{-1}$, Pod yield, Seed yield and 100 kernel weights. The results obtained revealed that both growth and yield parameter were found high by 900g ha$^{-1}$ inoculation level. Among the varieties, SAMNUT 25 was found to show the highest in all the parameters obtained. From the results obtained, it can be concluded that in Aliero, Kebbi state of Nigeria which falls within the Sudan Savannah agro-ecological zone, SAMNUT 25 variety and 900g ha$^{-1}$ inoculation level yields better. Therefore, Samnut 25 variety in conjunction with 900g ha$^{-1}$ Rhizobium application could be selected for increased Groundnut production in the study area.*

**Key words:** Rhizobium, Inoculation, Varieties, Groundnut, Sudan Savanna

## INTRODUCTION

Groundnut (*Arachis hypogaea* L.) or peanut is one of the important legume crops of tropical and semi-arid tropical countries of the world, where it supplies edible oil and vegetable protein (Abdulkadir *et al.,* 2021). It is a significant food for human nutrition due to its valuable nutrients contents such as oil, protein, carbohydrates and vitamins. Peanut seeds contain 43-55% oil, 25-28% protein 18% carbohydrate along with abundant mineral elements such as K, Ca, Mg, P and S. Besides, it is rich in vitamins like A, B (Niacin, Inositol) and E (Tocopherol) (Ferrin and Halis, 2020). The groundnut cultivation area in the world is 26.3 million ha, the production is 45.5 million tons with an average yield per hectare of 1740 kg (Ferrin and Halis, 2020). China, India, Nigeria, USA, Sudan, Tanzania, Argentina and Myanmar are considered as the first countries in the world's peanut production according to the data of 2017 (FAO, 2017). The productivity of groundnuts varies from 3500kg ha$^{-1}$ in the United States of America to 2500 kgha$^{-1}$ in South America, 1600 kg ha$^{-1}$ in Asia and less than 800 kg ha$^{-1}$in Africa. According to Abdulkadir *et al.* (2021), groundnut yields in Africa are lower compared to the average world yields. In Nigeria average yield are much lower (0.6-0.7 t ha$^{-1}$), and this is a serious challenge in the African farming system (Abdulkadir *et al.* 2021). Groundnut can grow in poorly fertile and rain-fed conditions. This may explain why yield in some countries, such as India and Nigeria, are lower than in Brazil or Argentina, even though it is grown over a larger area in the former countries (FAO 2018). As a result, in countries where groundnut is grown in nutrient-poor conditions, farmers are unable to increase yield (Gunri *et al.,* 2017).

Despite the yield potential of groundnut in Nigeria, the yield in farmer's field especially in the savannah is relatively low. This could be attributed to some factors like-drought, weeds, pests and diseases, low soil fertility among others in which fertility problem posses a serious threat to crop productivity. The increasing cost of inorganic fertilizers is making farmers to shy away from using it and look for alternatives. Again, inorganic fertilizers have the tendency of causing rapid degradation of agricultural soils. Excessive application or improper management of these fertilizers can result in water pollution, leading to eutrophication of water bodies and adverse effects on aquatic ecosystems (Jnana *et al.,* 2021). Organic fertilizers on the other hand release nutrients slowly and may not meet the immediate nutrient requirements of groundnut plants during critical growth stages. Reliance on a narrow range of groundnut varieties with similar genetic backgrounds can increase susceptibility to pests, diseases, and environmental stresses, limiting resilience and adaptability.

In regions like the Savannah, where there is a need to intensify agricultural production to meet growing food demands. Rhizobium inoculation will offer a sustainable pathway for increasing groundnut yields without exacerbating environmental degradation or compromising long-term soil fertility. Rhizobium bacteria have the unique ability to fix atmospheric nitrogen into a form that can be utilized by plants. Groundnuts, being leguminous plants, form symbiotic relationships with Rhizobium, allowing them to access atmospheric nitrogen, thus reducing the need for synthetic nitrogen fertilizer (Abd-Alla *et al.,* 2023). The objective of this study is to determine the effect of rhizobium inoculation on growth and productivity of groundnut varieties.

## MATERIALS AND METHODS

### Experimental Sites

Field trial was conducted during 2024 rainy season at Kebbi State University of Science and Technology University Research Farm Aliero (latitude $13^0$ 01N and longitude $5^0$ 15E), 350m above sea level in the Sudan savannah agro ecological zone of Nigeria.

### Treatment and Experimental Design

The treatment consisted of factorial combination of four groundnut varieties namely; Samnut23, Samnut 24, Samnut-25 and Ex-Aliero-and four rates of inoculant (0g, 300g, 600g and 900gha$^{-1}$) which were laid out in a Randomize Complete Block Design (RCBD) with three replications.

### Field layout

The dimension of the individual plot was 4m x 4m (16 m$^2$). There was pathway of 0.5m between the adjoining plots within the blocks and 1.5m distance between the blocks. The net plot area was 2m X 1.5m (3.mm$^2$).

### Seed Inoculation and Sowing

Seed was inoculated by dissolving a sticker material in to 200ml of warm water. The dissolved sticker was then added to the seeds and then mixed until uniformly coated. Then 100g of inoculant was added to the Seeds, mixed until seeds are uniformly covered with the inoculants. The inoculated seed were allowed to set with the sticker for 10 minutes by covering it with a cloth. The inoculated seed was sown at a spacing of 50cm between row

(Inter row spacing) and 20 cm within rows (Intra row spacing), and 2-3 seeds was sown per hole using dibble method.

**Data Collection**

Canopy height (cm) was measured from the ground to top of the main axis of the pre tagged plants at 4, 8 and 12 weeks after sowing (WAS). Leaf area-was determinined by measuring the length of each fully expanded leaf from the base to the tip, as well as the breath. Number of Nodules Plant$^{-1}$ was determined by gently removing the samples plant, the plants were then washed on a sieve under flowing water and then placed on a paper towel in the shade to air-dry for 2-3 days. The nodules were then counted while they are still intact on the roots from the crown to the tip. Pod yield was determined by weighing the harvested pods from each plot. The number of pods from five randomly selected plants from each net plot was counted. 100 Kernel weight was determined by weighing randomly counted 100-grains from each plot. Seed yield was determined by shelling pod yield from each net plot.

**Data-Analysis**

The data obtained was subjected to analysis of variance (ANOVA) using SAS where treatments shows significant differences (DMRT) was used to separate the Mean at 5% level of probability.

**RESULTS AND DISCUSSION**

**Table 1: Plant Height of Groundnut Varieties as influence by Rhizobium Inoculation at Aliero during 2024 Rainy Season**

| **Treatments** | **Canopy Height (cm)** | | |
|---|---|---|---|
| **Rhizobium Level (g)** | **4WAS** | **8WAS** | **12WAS** |
| 900 | 14.00 | 25.09 | 34.59$^{a}$ |
| 600 | 14.58 | 23.92 | 31.85$^{ab}$ |
| 300 | 14.31 | 28.17 | 35.17$^{a}$ |
| 0 | 14.03 | 25.00 | 29.50$^{b}$ |
| S.E ± | 0.67 | 11.19 | 5.58 |
| **Varieties** | | | |
| SAMNUT 23 | 12.76$^{b}$ | 24.06$^{b}$ | 31.52$^{b}$ |
| SAMNUT 24 | 15.88$^{a}$ | 28.76$^{ab}$ | 35.42$^{b}$ |
| SAMNUT 25 | 15.14$^{a}$ | 31.62$^{a}$ | 42.44$^{a}$ |
| Ex-Aliero | 13.16$^{b}$ | 17.75$^{c}$ | 21.67$^{c}$ |
| S.E ± | 0.79 | 10.10 | 8.21 |
| **Interaction** | | | |
| **R x V** | NS | NS | NS |

Means followed by the same letter (s) in the treatment group are not significantly different at 5% level using DMRT. *= Significant at 5%, NS = not significant WAS = Weeks after sowing.

**Table 2: Leaf Area and No. of Nodules$^{-1}$ of Groundnut Varieties as influence by Rhizobium Inoculation at Aliero during 2024 Rainy Season**

| Treatments | Leaf Area (cm) | | | No. of Nodules Plant$^{-1}$ |
|---|---|---|---|---|
| **Rhizobium Level (g)** | **4WAS** | **8WAS** | **12WAS** | |
| 900 | 7.9$^{a}$ | 8.47 | 8.63 | 57.50$^{a}$ |
| 600 | 8.14 | 7.91 | 6.87 | 47.69$^{b}$ |
| 300 | 7.66 | 9.05 | 8.63 | 37.46$^{c}$ |
| 0 | 8.14 | 8.36 | 7.75 | 34.88$^{c}$ |
| **S.E ±** | **0.58** | **7.19** | **5.58** | **2.55** |
| **Varieties** | | | | |
| SAMNUT 23 | 7.52$^{b}$ | 8.43$^{b}$ | 31.52$^{b}$ | 37.67$^{d}$ |
| SAMNUT 24 | 9.62$^{a}$ | 9.61$^{ab}$ | 35.42$^{b}$ | 42.08$^{c}$ |
| SAMNUT 25 | 8.82$^{ab}$ | 9.89$^{a}$ | 42.44$^{a}$ | 52.98$^{a}$ |
| Ex-Aliero | 5.85$^{b}$ | 5.99$^{c}$ | 21.67$^{c}$ | 44.79$^{b}$ |
| **S.E ±** | **0.58** | **6.81** | **6.18** | **2.10** |
| **Interaction** | | | | |
| **R x V** | **NS** | **NS** | **NS** | **NS** |

Means Followed by the same letter (s) in the treatment group are not significantly different at 5% level using DMRT. *= Significant at 5%, NS = not significant WAS = Weeks after sowing.

**Table 3: Number of Pods per plant, Pod Yield, Seed Yield and 100 Kernel Weight of Groundnut Varieties as influence by Rhizobium Inoculations at Aliero during 2024 Rainy Season**

| Treatment | No. of Pods Plant$^{-1}$ | Pod Yield (T ha$^{-1}$) | Seed Yield (T ha$^{-1}$) | 100 Kernel Weight |
|---|---|---|---|---|
| **Rhizobium Level(R) (g)** | | | | |
| 900 | 37.08 | 3.92$^{a}$ | 3.10$^{a}$ | 33.29 |
| 600 | 35.17 | 3.72$^{a}$ | 3.03$^{a}$ | 32.71 |
| 300 | 35.67 | 2.70$^{b}$ | 2.21$^{b}$ | 35.79 |
| 0 | 32.67 | 2.83$^{b}$ | 2.45$^{b}$ | 34.54 |
| **S.E ±** | **38.65** | **0.29** | **0.27** | **9.34** |
| **Varieties (V)** | | | | |
| SAMUT 23 | 25.58$^{b}$ | 2.30$^{c}$ | 1.83$^{c}$ | 39.21$^{b}$ |
| SAMNUT 24 | 28.67$^{b}$ | 3.02$^{b}$ | 2.62$^{b}$ | 35.63$^{a}$ |
| SAMNUT 25 | 34.33$^{a}$ | 3.50$^{a}$ | 3.03$^{a}$ | 38.71$^{a}$ |
| Ex-Aliero | 52.00$^{a}$ | 1.53$^{d}$ | 1.12$^{d}$ | 22.79$^{b}$ |
| **S.E ±** | **33.65** | **0.21** | **0.24** | **8.34** |
| **Interaction** | | | | |
| **R x V** | NS | NS | NS | NS |

Means Followed by the same letter (s) in the treatment group are not significantly different at 5% level using DMRT. *= Significant at 5%, NS = not significant WAS = Weeks after sowing.

**Varietal Response**

Results revealed significant effect (P≥0.05) of variety on canopy height. The highest canopy height was recorded by SAMNUT 25 in all the weeks followed by SAMNUT 24 and SAMNUT 23 respectively as compared with Ex Aliero which recorded the lowest. The differences observed among the four varieties SAMNUT 23, SAMNUT 24, SAMNUT 25, and EX-Aliero on canopy height could be attributed to their genetic make-up. Khan *et al.* (2002) affirmed that differential growth of crops under similar environmental conditions is normally the result of differences in the genetic make-up of these crops (Ayoub, 2014). Significant ($P \leq 0.05$) variation among the groundnut varieties was observed on leaf area and number of nodules plant$^{-1}$ (Table 2). Wider leaves were obtained from SAMNUT 25 than the other varieties except with SAMNUT 24 at 4 and 8 WAS only. The variety EX-Aliero consistently produced the least leaves in this study. The production of more nodules was obtained with SAMNUT 25 compared to the other varieties. The enhanced nodulation in SAMNUT 25 can be linked to its efficiency in forming a symbiotic relationship with Rhizobium, an essential trait for nitrogen fixation. According Gabasawa *et al.,* (2014), effective Rhizobium-legume symbiosis is critical for optimizing plant growth and nitrogen assimilation.

Significant ($P \leq 0.05$) variation was observed among the groundnut varieties on pod plant$^{-1}$, pod yield, Seed yield and 100 kernel weight (Table 3). SAMNUT 25 and Ex-Aliero produced similar more pods per plant compared to the other varieties. Furthermore, SAMNUT 25 produced the highest pod yield and seed yield than the other varieties. In terms of kernel weight, similar heavier kernels were produced by SAMNUT 24 and SAMNUT 25 compared to SAMNUT 23 and Ex-Aliero, respectively. This result shows that improve varieties has the ability of withstanding different environmental condition due it genetic modification which can result high yield production. The low yield resulted by Ex-Aliero could be as result of poor germination encountered after sowing. The results also emphasize the economic advantage of selecting high-yielding varieties like SAMNUT 25 for groundnut production, as higher yields translate to increased profitability for farmers. This result validates the claim by Olarenwaju *et al.,* (2014) that genetic differences significantly influence yield potential.

**Effect of Rhizobium**

There was no significant effect ($P>0.05$) of Rhizobium inoculant application on canopy height in this study except at 12 WAS, such that the application of 300 to 900g ha$^{-1}$produced significantly similar taller plants than the 0g ha$^{-1}$(Table 1). Rhizobium inoculation is known to supply higher N. This attribute of Rhizobium would have enhanced faster node formation and quicker release of nutrients for plant uptake, which might have translated into better growth of the plant. This result was similar to the finding of Omwocha, (2020), who demonstrated that Rhizobium inoculated treatments had the highest plant height in his research conducted on soybean. The delayed effect observed in this study suggests that the benefits of inoculation are more pronounced in later growth stages when nitrogen demand is higher. Significant ($P \leq 0.05$) variation among the Rhizobium inoculant application was observed on number of nodules plant$^{-1}$ (Table 2). The production of more nodules was obtained with 900g ha$^{-1}$ followed by 600g ha$^{-1}$ compared to the other levels which recorded statistically the same. This result indicated that higher Rhizobium inoculant levels promote better nodulation, thereby enhancing nitrogen fixation and plant growth and yield (Asente *et al.,* 2020). Significant ($P \leq 0.05$) variation was observed among the Rhizobium inoculant application on pod yield and Seed yield (Table 3). 900g and 600g ha$^{-1}$ produced similar more pods yield compared to the other varieties which reported statistically the same. The results critically show that higher level of inoculation help in supplying enough nutrient for the crop performance particularly in the nutrient deficient soil. Similar result was reported by Mohammed *et al.,* (2023).

## CONCLUSION

This study has revealed that the application of Rhizobium inoculum (900 $gha^{-1}$) enhanced the yield of groundnut in the study area. However, variety SAMNUT 25 has out-yielded other varieties. From the results obtained, it may be concluded that, Samnut 25 variety could be selected in conjunction with 900 $gha^{-1}$ of Rhizobium for increased groundnut production in Aliero, Kebbi state of Nigeria.

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# EFFICACY OF BIODEGRADABLE AROMATIC PLANT EXTRACTS IN MANAGING ROOT-KNOT NEMATODES (*MELOIDOGYNE INCOGNITA*) INFESTATION IN GARDEN EGG (*SOLANUM MELONGENA* LINNAEUS)

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**ABSTRACT**
Eggplant (*Solanum melongena* Linnaeus.) is the fifth most commercially significant *solanaceous* crop. It is one of the widely planted commercial vegetable crops worldwide. Root-knot nematode (RKN) disease comes first among the diseases and pests infecting eggplant, and the losses caused by it exceeded 50% and estimated to be 100 billion dollars annually. The study Location is between (latitude 9º 37 N and longitude 6º 28 E) in southern guinea savanna Agroecological zone of Nigeria at the screen house of the Teaching and Research Farm of the Department of crop production Federal University of Technology Minna, Niger state. The experimental design for this study includes Extract Types, Concentration, Replicates. The types of extracts tested are *Eucalyptus* leaf, *Eucalyptus* bark, Neem leaf, and Neem bark. Each extract will be applied at five concentration levels: 0% (control), 25%, 50%, 75%, and 100%. The Treatments combination is a 4 × 5 factorial experiment, arranged in Completely Randomized Design (CRD), each treatment combination was replicated three times. The study was conducted in a screenhouse during wet season. The control group consist of plants left untreated to serve as a baseline for comparison. This design ensures a robust assessment of the efficacy of the extracts under varied conditions. This study aims to evaluate the efficacy of Eucalyptus globulus and Azadirachta indica extracts in controlling root-knot nematode (*Meloidogyne incognita*) infestation in garden egg (*Solanum melongena*). It also seeks to identify optimal extract concentrations for promoting plant growth and compares the effects of *Eucalyptus* leaf, Eucalyptus bark, Neem leaf, and Neem bark extracts on plant height and yield. The research explores these botanical extracts as eco-friendly alternatives for nematode management.as done by drenching the egg masses into a grove close to the root of the plant, while the extracts were also applied directly to the plant by drenching. Growth and yield data were subjected to Analysis of variance. The result revealed that *Eucalyptus* bark has the highest plant height of (57.00cm), indicating potentials growth promotion, *Eucalyptus* leaf and neem bark have similar plant height (50.86 and 50.20 cm), also the result shows that Neem leaf has the shortest plant height (43.53 cm). 0%, 25%, 75% and 100 % concentration (49.83 - 51.75 cm), indicate that there is no significant (P≥0.05) growth inhibition and 50% concentrations has significantly shortest plant height (17.33 cm), suggesting phytotoxicity, *Eucalyptus* leaf extract promote yield and neem leaf and bark extract inhibits yield. The concentration effect at 25% optimizes yield.100% concentration has a positive effect but may lead to phytotoxicity.
**Keywords**: Efficacy, Neem, Eucalyptus, Eggplant, Botanical extract, Growth promotion.

## INTRODUCTION
Nematodes are the most prevalent animals that live in soil. Nematodes that parasitize plants greatly reduce the value of agricultural crops worldwide. Root-knot nematodes Pathogens of several different crops called *Meloidogyne* spp, *Meloidogyne incognita*, *M. javanica,* and *M. arenaria* are three species of root-knot nematodes that have been reported to be associated with the root-knot disease of eggplant worldwide (Das *et al.*, 2021). A 50% yield loss and shoot growth reduction occurred when eggplants were inoculated with 4.7 and 3.2 *M. javanica* eggs and juveniles/g soil respectively. *Meloidogyne* is regarded to be the most

important genus affecting many plant species (Abu-Gharbiah, 2010), and the losses caused by it exceeded 50% and estimated to be 100 billion dollars annually. Four species of *Meloidogyne* are wide-spread in the world, which are *M. javanica*, M. *incognita, M. hapla and M. arenaria* (Menjivar *et al.,* 2012).

Globally, garden egg is known as eggplant with the general botanical name *Solanum melongena.* Eggplant exhibits a relatively short stature as opposed to arboreal growth patterns. The plant's foliage stands out for its substantial size, rough lobes, and dimensions of 10 to 20 centimeters in length and 5 to 10 centimeters in width (Sharma and Kaushik, 2021). procedures that maintain a pest population by using either individual strategies or combination strategies at a level where the nematodes are unable to cause a detectable decrease in the yield (both qualitatively and quantitatively) of a crop that could have a detrimental effect on the health of both humans and animals. Nematode management can be roughly classified into: cultural control, chemical control, biological control, integrated management, etc., according to (Oka,2010). The phytochemical properties of *Eucalyptus globulus* leaves and bark water extract are Qualitative phytochemical (bioactive compounds) testing indicated that aqueous extracts of *Eucalyptus globulus* leaves and bark contain alkaloids, flavonoids, glycosides, terpenoids, steroids, saponins and reducing sugars. Aqueous extract eucalyptus leaves are free of cardiac glycosides and anthraquinones while aqueous bark extract also have no chlorophyll and carbohydrates. Our results are identical to those described by the presence of these phytochemical compounds in plant material suggests that their extracts have potential medicinal value in the prevention and/or treatment of specific diseases. (Rasyid. *et al,.*2020).

Research has shown that *Azadirachta indica* is rich in a wide range of compounds such as Nimbin (triterpene) has shown to have antipyretic, fungicidal, antihistamine and antiseptic properties. Also, Nimbin is associated with anti-inflammatory and antioxidant effects, therefore reducing damage by mitigating the production of reactive oxygen species. (Naik *et al*.,2014)

## MATERIALS AND METHODS

### Study location, collection and preparation of plants materials

The research was carried out at the screenhouse of the Teaching and Research Farm of the Department of crop production Federal University of Technology Minna, Niger state. Location is between (latitude 9º 37 N and longitude 6º 28 E) in southern guinea savanna Agroecological zone of Nigerian. Eggplant seeds were obtained from local farmers in Kure Ultra-Modern market Minna Niger state.

### Collection of materials

*Eucalyptus globulus* (Gum tree), and *Azadirachta indica* (Neem), leaves and bark were collected from mature trees at Gidan Kwano Campus, Federal university of Technology Minna. Loamy soil from the Teaching and Research Farm was collected and sterilized at 180°c (350F) for 30-45 minutes using heat treatment. Eggplant seedlings were raised in plastic nursery tray in the screenhouse for four weeks before transplanting. Two seedlings were transplanted which was later thinned to one per polythene bag and two-kilogram 2kg of sterilized soil was used per polythene bag (30 and 40 cm in size).

### Collection of nematodes egg masses

Egg masses of *Meloidogyne incognita* (Root-knot nematodes) were collected from infested tomato roots cultured in the departmental screenhouse. The plant was uprooted carefully and taken to laboratory in a polythene bag. The roots were thoroughly washed under running water to remove soil and debris. The cleaned roots were also cut into small pieces and placed in a shallow Petri-dish and observed under light microscope, the egg masses were then collected into a measuring cylinder. The extracted egg masses were poured into the extractions dish with 100 ml of water and used within 1-2 hours, Precaution was taken to use the egg masses prior to inoculation.

**Preparation of different concentrations of crude extracts**

Five concentrations of *Eucalyptus globulus* (Gum tree) and *Azadirachta indica* (Neem) leave and bark crude extracts at (0 %, 2 5%, 50 %, 75 % and 100 %) were prepared as described by Bello *et al*., 2012.

S (100%): undiluted standard concentration solution (S).

S/1 (75%): to each volume of standard stock solution 'S', equivalents volume of distilled water will be added.

S/2 (50% concentration) to each volume of standard stock solution (S) equivalent volume of distilled water will be added.

S/3 (25% concentration) to each volume of standard stock solution (S) equivalent volume of distilled water will be added.

C: (0% concentration) control which will be distilled water.

**Preparation of leaves and bark extracts**

Two kilograms (2kg) of leaves and bark from **Eucalyptus globulus** (gum tree) and **Azadirachta indica** (neem) were harvested, thoroughly washed, separated from the stalks, and cut into small pieces. The chopped plant materials were blended with 100 ml of water for 4 minutes to form a paste. This paste was transferred to an electric blender, where 1 liter of distilled water was added and blended as part of the required 6 liters of distilled water. The mixture was left to sit for 24 hours before being filtered through muslin cloth. The resulting solution was designated as the standard concentration ("S"). To inhibit bacterial growth, 10 drops of streptomycin sulfate were added to the extracts.

**Inoculation of nematodes egg masses and application of crude extracts**

Ten (10) Egg masses of *Meloidogyne incognita* (Root-knot nematode) were inoculated into each polythene in the screenhouse. Inoculation was done by creating a grove 2cm deep from the base round each Eggplant seedling, the egg masses will be applied in the groves. The extracts were also applied directly using drench method of application into the soil with the extract solution 2-3 times weekly. The 20 Treatments combination, is a 4 × 5 factorial experiment, each treatment was randomly assigned to the experimental units, in a Completely Randomized Design (CRD), each treatment was replicated three 3 times per treatment combination, making a total of 60 experimental units.

**RESULTS AND DISCUSSION**

**Effect of Botanicals extracts and concentrations on plant height, and number of leaves**

Table 1 shows the effects of different plant extracts (*Eucalyptus globulus* bark*, Eucalyptus globulus* leaf, Neem bark, and Neem leaf) and extract concentrations (0 %, 25 %, 50 %, 75 %, and 100 %) on the plant height and number of leaves of eggplants. The tallest plants were observed with the *Eucalyptus globulus* bark extract, achieving a mean height of 57.00 cm, suggesting its potential as a growth promoter. Similar plant heights were recorded for *Eucalyptus globulus* leaf and Neem bark extracts, at 50.86 cm and 50.20 cm, respectively,

**Table1: Effect of Botanicals extracts and concentrations on plant height, and number of leaves at 8 weeks after transplanting**

| Botanical | Plant Height (cm) | Number of Leaves |
|---|---|---|
| *Eucalyptus Globolus leaf* | $50.86^{ab}$ | $21.60^{a}$ |
| *Eucalyptus Globolus bark* | $57.00^{a}$ | $19.20^{a}$ |
| *Azadirachta indica* Neem leaf | $43.53^{ab}$ | $14.80^{b}$ |
| *Azadirachta indica* Neem bark | $50.20^{ab}$ | $21.20^{a}$ |
| LSD | 8.19 | 4 .22 |
| Concentrations (%) | | |
| 0% | $49.83^{a}$ | $19.41^{ab}$ |
| 25% | $51.75^{a}$ | $22.16^{a}$ |
| 50% | $53.33^{a}$ | $17.33^{b}$ |
| 75% | $47.00^{a}$ | $19.75^{b}$ |
| 100% | $48.8^{a}$ | $17.33^{b}$ |
| LSD | 9.16 | 4.72 |

Means in column followed by different letters are significantly different ($P \leq 0.05$) using (LSD) least significant differences

while the Neem leaf extract produced the shortest plants, with a mean height of 43.53 cm. Across the concentration treatments, 0%, 25%, 75%, and 100% concentrations resulted in comparable plant heights (49.83–51.75 cm), indicating no significant ($P \geq 0.05$) growth inhibition. However, the 50% concentration produced significantly shorter plants (17.33 cm), suggesting potential phytotoxic effects at this level. This may be attributed to the presence of bioactive compounds such as essential oils and flavonoids. In contrast, neem leaf extract exhibit growth inhibition properties, potentially due to azadirachtin content. This statement is also in agreement with the report by (Saleem *et al*., 2018) oil extracts are the most typical used form of Neem and its in-depth phytochemical analysis has confirmed the presence in high amounts of triterpenes, flavonoids and saponins, while other components such as catechins and nimbins, seem to be present in lower amounts other metabolites found in Neem extracts are: limonoids, tannins, alkaloids, terpenoids, reducing sugar, catechins, sterols and gallic acid. *Eucalyptus globulus* leaf and neem *Azadirachta indica* bark have the highest mean number of leaves (21.60) and 21.20 cm), indicating potentials growth promotion. While *Eucalyptus* bark has no significant (P≥0.05) effect (19.20). Neem leaf has the lowest mean number of leaves (14.80), suggesting growth inhibition. The concentration level at 25 % has the highest mean number of leaves (22.16), indicating optimal growth 0%, 75 % concentrations had no significant effects (19.41,19.75). 50% 100% concentrations have significantly lower mean number of leaves (17.33) therefore suggesting phytotoxicity. *Eucalyptus globulus* leaf extracts promote growth at various concentrations, while neem leaf *Azadirachta indica* extract inhibits growths, particularly at higher concentrations. The 25% concentration mitigates Neem leaf extracts inhibitory effects.

**Table: 2 Effect of botanicals extracts and concentration on number of branches, stem girth and yield at first harvest of garden egg**

| Botanicals | Number of Branches | Stem girth | Yield at first Harvest |
|---|---|---|---|
| ***Eucalyptus globulus leaf*** | $8.13^{b}$ | $3.60^{b}$ | $3.60^{b}$ |
| ***Eucalyptus globulus bark*** | $8.33^{ab}$ | $4.00^{b}$ | $2.86^{ba}$ |
| **Neem leaf *Azadirachta indica*** | $9.80^{ba}$ | $4.13^{a}$ | $2.26^{b}$ |
| **Neem bark *Azadirachta indica*** | $10.00^{a}$ | $3.73^{ab}$ | $2.26^{b}$ |
| **LSD** | 1.80 | 0.41 | 0.74 |
| **Concentration (%)** | | | |
| **0%** | $9.33b^{a}$ | $4.00^{ab}$ | $2.16^{c}$ |
| **25%** | $10.91^{a}$ | $3.83^{ba}$ | $3.25^{a}$ |
| **50%** | $8.66^{b}$ | $4.08^{a}$ | $2.75^{ba}$ |
| **75%** | $8.66^{b}$ | $3.83^{ba}$ | $2.25^{bc}$ |
| **100%** | $7.75^{a}$ | $3.58^{b}$ | $3.08^{ba}$ |
| **LSD** | 2.02 | 0.46 | 0.83 |

Means in column followed by different letters are significantly different ($P \leq 0.05$) using (LSD) least significant differences.

**Effect of botanicals extracts and concentration on number of branches, stem girth and yield at first harvest of garden egg**

Table 2 shows the effects of different plant extracts (*Eucalyptus globulus* bark*, Eucalyptus globulus* leaf, Neem bark, and Neem leaf) and extract concentrations (0 %, 25 %, 50 %, 75 %, and 100 %) on the number of branches, stem girth, and yield at first harvest. *Azadirachta indica* bark produce the highest mean number of branches (10.00), indicating potentials growth promotion while neem leaf and *Eucalyptus globulus* bark have no significant ($P \geq 0.05$) effects while *Eucalyptus* leaf has the lowest mean number of branches (8.13), suggesting growth inhibition. Also 25% concentration had the highest mean number of branches (10.91), indicating optimal growth. While 0% concentration has an intermediate effect (9.33). 50 %,75 %, and 100 % concentrations have significantly lower mean number of branches (8.66, 8.66, and 7.75) thereby suggesting to have phytotoxicity. Neem leaf has the highest mean stem girth (4.13 cm), indicating potentials growth promotion. *Eucalyptus* bark and Neem bark extracts have no significant($P \geq 0.05$) effects.

*Eucalyptus* leaf extracts had the lowest mean stem girth (3.60 cm) suggesting growth inhibition. On the other hand, 50 % concentration has the highest mean stem girth (4.08 cm), indicating optimal growth. 0 %, 25 %, while 75 % concentrations have no significant ($P \geq 0.05$) effects. 100 % concentration has significantly lower mean stem girth (3.58 cm) suggesting phytotoxicity. *Eucalyptus* leaf extracts produced the highest mean yield (3.40), indicating potential growth promotion. While *Eucalyptus* bark has an intermediate effect (2.86). Neem leaf and neem bark have the lowest mean yield (2.26), suggesting growth inhibition. On the other hand, 25 % concentration produced the highest mean yield (3.25), indicating optimal growth. 100 % concentration had a similar effect (3.08). 0 %, 50 %, while 75 % concentration have significantly $P \leq 0.05$ lower mean yield (2.16, 2.75 and 2.25), suggesting suboptimal growth.

**DISCUSSION**

The study shows that the botanical effect on the growth parameters of E*ucalyptus globulus* leaf extract promotes plant height, number of leaves, and stem girth. Neem leaf extracts results to lower number of leaves and number of branches. While on the concentration effects 25 % optimizes plant height, number of leaves, and number of branches. 50 %, and 100 % concentration exhibits phytotoxicity, reducing plant growth. 0% concentrations have suboptimal growth. On the yield parameters of the botanicals *Eucalyptus* leaf extract promotes yield and neem leaf and bark extract inhibits yield. The concentration effect at 25 % optimizes yield,100 % concentration has a positive effect but may lead to phytotoxicity. 0 % concentration exhibits suboptimal growth.in summary *eucalyptus* leaf extract has growth-promoting properties, neem leaf and bark extract have growth-inhibiting properties. Thus, the above observation is in accordance with the report by (Rasyid. *et al,.*2020). *Eucalyptus globulus* leaves, as well as its bark, are rich in pentacyclic triterpenic compounds. Betulonic, betulinic, oleanolic, ursolic, 3-acetyloleanolic and 3-acetylursolic acids and β-amyrin have been identified in the bark and leaves. Optimal concentration of botanicals extracts is crucial for maximizing growth and yield.

## CONCLUSION

The study investigates the effects of *Eucalyptus globulus* and Neem leave and bark extracts and concentrations on morphological parameters and yield of greenish eggplant (*solanum melongena)* the findings from the research work revealed that the application of aqueous extracts of *Eucalyptus* leaves and bark, Neem leaves and bark promoted morphological growth and increased the yield of Eggplant which was an indication that the extracts reduced the population and infestation of root knot nematodes on the plants while reduction in morphological growth and yield of Eggplant resulting from the application of Neem leaf extracts indicated that there was little effect on the control of root knot nematode , therefore *Eucalyptus* leaf extracts performed better than Neem leaf extracts.

## RECOMMENDATIONS

*Eucalyptus* leaf extracts can be used as a natural plant growth promoter in particularly for Eggplants. *Eucalyptus* leaf extracts can be prepared by collecting fresh leaves and grinding or blending it to paste, and mixing it with clean water. Drenching method of application can be use simply by applying the solution as a soil drench around the base of the plants. Application should be at every three days' interval depending on the plant growth stage and environmental conditions. Neem leaf and bark extracts should be used with caution and at optimal concentrations, farmers should start with a lower concentration and gradually increase base on plant response. *Eucalyptus* leaves are cost effective alternative to synthetic chemicals. *Eucalyptus* trees are widely available in Nigeria, making it easily accessible to farmers. Further research is necessary to explore the biochemicals mechanisms driving botanicals natural extracts effects. Optimization of natural plant extracts concentrations for specific plants species is crucial.

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# EFFECT OF FRUIT COLOUR, PLANT AGE AND WEED CONTROL ON THE VIABILITY AND VIGOUR OF PEPPER (*Capsicum frutescens.* L) SEEDS

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## ABSTRACT

This study investigated the effects of fruit maturation stages, mother plant age, and weed management practices on seed quality traits of "Sombo" pepper (*Capsicum frutescens*). Conducted in the Southern Guinea Savanna region of Nigeria, the research used a randomized complete block design (RCBD) with three replications. Red fruits produced the best outcomes, Heaviest and longest fruits, larger girths and higher seed counts per fruit, Heavier seeds (per fruit and per 100 seeds), Lowest seed moisture content. Superior seed viability traits, including Higher germination percentage, best germination rate and index and longest mean germination time. For Mother Plant Age and Weed Management, the factorial experiment considered six harvesting ages (85–120 days) and five weed control protocols. Effective weed management (e.g., Butachlor or hoeing schedules) influenced fruit and seed quality. Conclusively, harvesting red fruits, combined with optimal weed control, significantly enhanced fruit weight, size, seed quality, and viability. This highlights the importance of maturity and cultivation practices for maximizing seed production in *Capsicum frutescens*.

**Key words:** Fruit colours, Pepper, plant age, viability and weed management

## INTRODUCTION

Pepper is a significant commercial crop used as a vegetable, spice, and in processed foods, ranking third globally among vegetables after tomato and onion (Mustapha et al., 2021). It is widely cultivated in sub-Saharan Africa, with Nigeria being the second-largest producer of pepper in Africa, after tomato (Abu et al., 2020; Mustapha et al., 2021). In Nigeria, farmers often market fresh peppers immediately after harvest, while some are sundried for storage and sale, though some still rot. The color of pepper fruits is a key factor influencing consumer preference, as plants use color to attract pollinators and seed distributors, impacting their commercial value (Jung et al., 2023). Domestication and breeding have resulted in a variety of fruit colors, with unripe peppers varying in shades from green to purple, brown, and black. In modern cultivars, ripe fruits are primarily red, yellow, or orange. Pepper plants undergo developmental phases, transitioning from juvenile to reproductive stages (Mustapha et al., 2021). Weeds, which compete with crops for resources like light, moisture, and nutrients, are a major challenge in pepper production (Gharde et al., 2018). These weeds can significantly reduce plant vigor and yield, particularly in pepper plants, which have a shallow root system, making them more vulnerable to weed competition (Peter and Nathan, 2014). Weed control is therefore a critical concern for both commercial and subsistence pepper farmers (Bullock, 2011).

Seed quality, influenced by factors such as the mother-plant's nutrition and seed age, is essential for pepper production. Farmers often collect seeds from fruits at various stages of maturity, leading to non-uniform germination and seedling emergence (Mustapha et al., 2021). Research by Ibrahim et al. (2018) suggests that seeds from fully ripened fruits have better germination and storage potential, though this may not apply to all pepper cultivars, such as "Sombo." Currently, seeds from fruits of different positions on the plant are often mixed, disregarding variations in seed quality. The aim of this study is to assess the variation in seed quality from different stages of fruit maturation and different mother-plant ages, as well as the effects of weed management on seed viability. These research will contribute to improving seed handling practices and enhancing the quality of pepper seeds for better agricultural outcomes (Kim et al., 1994).

## MATERIAL AND METHODS

### Study Location

The experiment for seed production was sited at the Teaching and Research Farm of Horticulture Department, Federal University of Technology, Minna (9° 34' N and 6° 32' E) while seed viability and longevity test was carried out in the Laboratory of Department of Crop Production, Federal University of Technology, Minna (9° 40'N and $6^0$ 30'E) in the Southern Guinea Savanna region of Nigeria.

### Source of Planting Material

Fruits of "Sombo" CVS of Cayenne pepper (*Capsicum frutescens* L.) was sourced from vegetable farmers around Gidan Kwano, Minna environment. Healthy fruits were selected for seed extraction. The seeds were extracted by cutting the fruits open with a knife and teasing the seeds out by hitting it gently. The extracted seeds were rinsed under running tap water. The clean seeds were spread thinly on paper for 72 hours on the laboratory bench to dry.

### Treatment and Experimental Design

The treatment was harvesting one "Sombo" genotype at three fruit maturation colours Viz: Green, greenish yellow and red ripe colour stages.

### Land preparation and field layout

The existing vegetation of the field was cleared with the application of Gramaxone at the rate of 0.072kg a.i/ha delivering through a red nozzle prior to land preparation. The land preparation was done two weeks after the herbicide application manually with a hoe. Mass planting of the pepper at 50 × 75 cm inter and intra row spacing was done.

### Weeding

The field was weeded at 3, 6 and 9 weeks after transplanting manually with a hoe.

### Fertilizer application

Fertilizer was applied at the rate of 120 kg N, 60 kg P2O5 and 60 kg K2O $ha^{-1}$. A basal application of 60 kg N, 60 kg P2O5 and 60 kg K2O $ha^{-1}$ was made using NPK 15:15:15 as source at 3 weeks after transplanting. The balance of 60 kg N was applied at split doses of 30 kg N at 6 and 9 weeks after transplanting (WAT) using Urea 46% N as source.

### Flower Tagging

Flowers were date-tagged as they open and fruits were harvested at three colour stages: Green, greenish yellow and red ripe colour stages. The tagging was done to determine the ages of fruits at the different colour stages of harvest.

**Harvesting of fruits and seed extraction**

Fruits were harvested at green, greenish yellow and red ripe stages. Immediately after each harvest, fruits of each lot were taken to the laboratory for further handling. They were cut open with a knife and the seeds teased out. The extracted seeds of each fruit colour (maturity stage) was rinsed through a running tap-water and air-dried for seven days before packaging (Demir *et al.,* 2002).

**Data Collection**

The following data was collected prior to fruit harvest and seed extraction.
fruit length, fruit girth, fruit weight, number of seeds per fruit, weight of seeds per fruit and 100 seed weight determination

**Seed Storage**

The seeds extracted from the three colour stages of the fruits (fruit maturation stages) were stored in open plastic plates measuring 500 ml, placed in an incubator set at 35° C and 75 % relative humidity for five (5) weeks to accelerate the ageing process of the seeds. This is with the aim to determine the relative longevity of the seeds.

**Viability and longevity parameter**

The following viability and longevity parameters were recorded, Seed Germination Percentage (SGP), Seed Moisture Content (SMC), Germination Rate Index and Germination Index.

**Data analysis**

The data collected on all the parameters were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) and where significant differences among the treatments are obtained, means were separated using the Least Significant Difference (LSD) at 5% probability unless otherwise stated. All data in percentage will be transformed to arcsin values before statistical analysis.

**RESULTS AND DISCUSSION**

**Table 1: Effect of fruit colour at harvest on fruit weight, fruit length, fruit girth, number of seed per fruit and weight of seeds per fruit of hot pepper**

| Treatment | Fruit weight (g) | Fruit length (cm) | Fruit girth (cm) | Number of seed per fruit | Weight of seeds per fruit (g) |
|---|---|---|---|---|---|
| Fruit colour | | | | | |
| Green | 7.19c | 9.28b | 5.84c | 96.00a | 0.71c |
| Greenish-yellow | 8.68b | 10.12a | 6.38b | 104.00a | 0.98b |
| Red-ripe | 11.10a | 10.68a | 6.98a | 116.00a | 1.17a |
| LSD (0.05) | 1.04 | 0.79 | 0.34 | 22.84 | 0.17 |

Any two means within each column not sharing a letter differ significantly from each other at 5 % probability level.

Table 1 examines how the fruit color at harvest affects various traits of hot peppers, such as fruit weight, length, girth, number of seeds, and seed weight per fruit. Fruit Weight, Red-ripe fruits weighed the most (11.1 g), significantly heavier than green (7.19 g) and greenish-yellow (8.68 g) fruits. More also for Fruit Length, Green fruits were shortest (9.28 cm), with red-ripe (10.68 cm) and greenish-yellow (10.12 cm) fruits being statistically similar but longer. Likewise, Fruit Girth increased with color development—green (5.4 cm), greenish-yellow (6.38 cm), and red-ripe (6.98 cm), with red-ripe fruits being significantly wider, while the number of seeds per fruit did not differ significantly across stages, with green (96), greenish-yellow (104), and red-ripe (116) seeds. Lastly, Seed Weight increased with fruit maturity, with red-ripe fruits producing the heaviest seeds (1.17 g), compared to green (0.71 g) and greenish-yellow (0.98 g).

**Table 2: Effect of fruit colour on seed moisture content of hot pepper during storage**

| Treatment | Storage periods (Weeks) | | | | |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 |
| Fruit colour | | | | | |
| Green | 26.11a | 30.76a | 33.92a | 38.06a | 41.13a |
| Greenish-yellow | 18.19b | 22.24b | 26.37b | 29.41b | 33.45b |
| Red-ripe | 13.11c | 18.26c | 22.10c | 25.56c | 28.90c |
| LSD (0.05) | 1.71 | 1.66 | 1.82 | 1.32 | 0.66 |

Any two means within each column not sharing a letter differ significantly from each other at 5 % probability level.

The effect of fruit colours at harvest on seed moisture content is presented in Table 2. Prior to storage, seeds extracted from green fruits contained 26.11 % moisture which is significantly higher than moisture content of seeds from greenish-yellow (18.19 %) and red-ripe (13.11 %) fruits. Following storage between one and four weeks, slight increase in moisture content was recorded in seed extracted from fruits of all the colours. The moisture content of seeds obtained from green fruits was significantly higher than those of other fruit colours both before and during storage. Red-ripe fruits produced seeds which contained the lowest MC significantly throughout the storage.

The effect of fruit colour on seed germination percentage of hot pepper during storage is shown in Table 3. Fruit colour significantly enhanced the germination of seeds of hot pepper. Before storage, germination was not noticeable in seed extracted from green fruits. Harvesting seeds at greenish-yellow fruits enhanced germination up to 50 %. When fruit were delayed to red-ripe stage, seeds produced germinated up to 90.50 %. This value (90.50 %) was significantly higher than those obtained from seeds of other fruit colours. Following storage, seeds extracted from red-ripe fruits germinated optimally (100 %), marginal increase was recorded after one week of storage for seeds of green fruits. Generally, germination decline for the seeds of the two early colours (green and greenish-yellow). The superiority of red-ripe seeds was sustained throughout the storage.

**Table 3: Effect of fruit colour on seed germination percentage of hot pepper during storage**

| | Storage periods (Weeks) | | | | |
|---|---|---|---|---|---|
| **Treatment** | 0 | 1 | 2 | 3 | 4 |
| Green | 0.00c | 17.00c | 14.50c | 12.50b | 4.00c |
| Greenish-yellow | 50.00b | 40.00b | 33.00b | 22.50b | 17.50 |
| Red-ripe | 90.50a | 100.00a | 100.00a | 90.00a | 85.50a |
| LSD (0.05) | 5.52 | 6.13 | 9.28 | 11.95 | 5.39 |

Any two means within each column not sharing a letter differ significantly from each other at 5 % probability level.

**Table 4: Effect of fruit colour on germination index during storage of hot pepper seed**

| | Storage periods (Weeks) | | | | |
|---|---|---|---|---|---|
| **Treatment** | 0 | 1 | 2 | 3 | 4 |
| Green | 0.00c | 3.89c | 3.11c | 4.13b | 0.81b |
| Greenish-yellow | 15.79b | 13.03b | 10.68b | 6.56b | 5.41b |
| Red-ripe | 38.97a | 37.19a | 42.16a | 43.44a | 32.87a |
| LSD (0.05) | 1.69 | 2.00 | 4.84 | 4.21 | 6.14 |

Any two means within each column not sharing a letter differ significantly from each other at 5 % probability level.

Table 4. presents the effect of fruit colour on germination rate index of seeds of hot pepper during storage. Prior to storage, seeds extracted from red-ripe fruts recorded 38.97 GI, this value was significantly higher than the 0.00 GI and 15.79 GI obtained from seeds of green and greenish-yellow fruits. The GI of 3.89 was noticeable when seeds of green fruits were stored for one-week, marginal values of GI were recorded uptill 4 WAS for seed of green fruits. The superiority in the GI performance of seeds extracted from red-ripe fruits was mintained both before and throughout storage. The effect of fruit colours at harvest on the germination rate index (GRI) of seeds of hot pepper during storage is presented in Table 5. Before storage, no GRI value was noticed when seed extracted from green fruits were tested. The GRI of 0.43was recorded with the seeds of red-ripe fruits, this value was significantly higher than the GRI obtained from seeds of greenish-yellow fruits (0.32) though there are marginal differences between the GRI values of seeds of red-ripe and greenish-yellow fruits as storage progressed, these differences were not significant except at 3 WAS, where seeds of red-ripe fruits recorded 0.48, a value significantly higher than 0.29 obtained with seeds of greenish-yellow fruits. Seeds extracted from green fruits recorded the lowest GRI significantly both before and during storage. seed germination rate index (0.24). But that was not the case at 2 and 3 WAS where red fruits significantly produced the highest seed

germination rate index (0.42) which was not statistically different from yellowish-green fruits (0.35) compared with green fruits which had the lowest seed germination rate index (). At 4 WAS, red and yellowish-green fruits significantly produced similar highest seed germination rate index (0.38 and 0.32) than green fruits which recorded the lowest seed germination rate index (0.17) in this study.

**Table 5: Effect of fruit colour on germination rate index during storage of hot pepper seeds**

| | Storage periods (Weeks) | | | | |
|---|---|---|---|---|---|
| **Treatment** | 0 | 1 | 2 | 3 | 4 |
| Green | 0.00c | 0.24b | 0.22b | 0.38ab | 0.17b |
| Greenish-yellow | 0.32b | 0.33a | 0.35ab | 0.29b | 0.32a |
| Red-ripe | 0.43a | 0.37a | 0.42a | 0.48a | 0.38a |
| LSD (0.05) | 0.04 | 0.05 | 0.13 | 0.12 | 0.14 |

Any two means within each column not sharing a letter differ significantly from each other at 5 %
probability level.

**Table 6: Effect of age of plant at harvest and weed management on fruit weight, fruit length, fruit girth, number of seeds per fruit and weight of seed per fruit of hot pepper**

| Treatment | Fruit weight (g) | Fruit length (cm) | Fruit girth (cm) | Number of seeds per fruit | Weight of seeds per fruit (g) |
|---|---|---|---|---|---|
| Age of plant (AP) | | | | | |
| 85 | 6.07b | 7.10bc | 4.85b | 80.45c | 0.63c |
| 92 | 5.63b | 7.24b | 4.69c | 76.30cd | 0.61c |
| 99 | 6.83a | 7.62a | 5.08a | 92.35a | 0.87a |
| 106 | 7.07a | 7.79a | 5.05a | 86.20b | 0.81b |
| 113 | 5.99b | 7.07bc | 4.59cd | 74.25d | 0.62c |
| 120 | 5.70b | 6.99c | 4.52d | 64.45e | 0.55d |
| LSD (0.05) | 0.44 | 0.23 | 0.15 | 5.57 | 0.06 |
| Weed management (WM) | | | | | |
| Pendimethalin + hoeing at 40 DAT | 7.45b | 9.26a | 6.00a | 87.67c | 0.82c |

| | | | | | |
|---|---|---|---|---|---|
| Butachlor + hoeing at 40 DAT | 7.90a | 9.18a | 5.95a | 105.46a | 0.90b |
| Hoeing at 20 + 40 DAT | 7.80ab | 8.84b | 5.98a | 93.79b | 0.73d |
| Hoeing at 20 + 40 + 60 DAT | 7.91a | 9.23a | 6.05a | 108.08a | 0.96a |
| Weedy check | 0.00c | 0.00c | 0.00b | 0.00d | 0.00 |
| LSD (0.05) | 0.40 | 0.21 | 0.14 | 5.08 | 0.05 |
| Interaction | | | | | |
| AF × WM | ** | * | * | ** | ** |

Any two means within each column not sharing a letter differ significantly from each other at 5 % probability level. *= Significant **= Highly significant

Table 6 reveal the impact of mother plant age at harvest and weed management practices on key fruit and seed traits of hot pepper. Fruits harvested at 99 and 106 days after transplanting (DAT) were heavier (6.83 g and 7.07 g, respectively), significantly outperforming fruits from other ages (5.63–6.07 g), Fruits at 99 and 106 DAT were also longer (7.62 cm and 7.79 cm) compared to other plant ages (6.99–7.24 cm), The widest girths (5.08 cm and 5.05 cm) occurred at 99 and 106 DAT, significantly surpassing other ages (4.25–4.59 cm), The highest seed count (92.35 seeds per fruit) was observed at 99 DAT, with a decline at 106 DAT (86.20) and further reductions as plant age increased. And Seeds were heaviest at 99 DAT (0.87 g), with weight declining progressively as the mother plant aged. While Heavier and longer fruits were produced under weed management practices involving Butachlor + hoeing at 40 DAT or hoeing at 20+40+60 DAT, compared to other methods, weed control improved girth significantly, except under "weedy check" or hoeing at 20+40 DAT and Both the number and weight of seeds per fruit were maximized under the same weed management protocols, with hoeing at 20+40+60 DAT producing the heaviest seeds.

## CONCLUSION

Based on the content of this study fruits harvested when their colour was red produced heavier fruits, longer fruits, bigger fruits, higher number of seeds per fruit, heavier number of seeds per fruit, heaviest 100 seeds, lowest seed moisture content, highest seed germination percentage, highest seed germination index, highest seed germination rate index and highest mean germination time of hot pepper. The harvesting at 99 and 106 days of fruit age produced heavier fruits, longer fruits, wider fruits, higher number of seeds per fruit, heaviest seeds per fruit and heaviest 100 seeds. The fruits harvested at 99 and 106 days of age similarly produced the highest seed germination percentage and seed germination index. Harvested fruits at 120 days of age recorded the lowest seed germination percentage and index. The use of hoeing at 20 + 40 + 60 DAT produced highest yield and yield parameters of pepper, heaviest 100 seeds, lowest seed moisture content, lowest electro-conductivity, highest seed germination percentage, germination index, germination rate index and mean germination time of hot pepper across the storage periods in this study. The weedy check treatment recorded the lowest of all the parameters measured except with the application of Butachlor + hoeing at 40 DAT and application of Pendimethalin + hoeing at 40 DAT which recorded the highest seed moisture content and seed electro-conductivity.

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# CHARACTERIZATION OF SHEA BUTTER OBTAINED FROM BIDA REGION NIGER STATE, NIGERIA

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## ABSTRACT

Shea butter (*Vitellaria paradoxa*) is a highly valued natural fat extracted from the seeds of the shea tree, predominantly found in the West African region. It has widespread applications in cosmetics, pharmaceuticals and food products due to its unique chemical composition and therapeutic properties. This paper presents a comprehensive characterization of shea butter sourced from the Bida region in Niger State, Nigeria, focusing on its physical, chemical, and microbiological properties. The aim is to provide insights into the quality, composition, and potential for commercialization of shea butter from this region, contributing to the understanding of its economic and nutritional benefits. The study involves the analysis of lipid content, fatty acid profile, saponification value, unsaponifiable matter, acid value, iodine value, peroxide and microbial contamination using standard methods. From the analysis, 3.2mgKOH/g, 198 mg KOH/g, 19.8% and 3.2 mg KOH/g were obtained for fatty acid profile, saponification value, unsaponifiable matter andacid value respectively while iodine value ranged from 45 to 56 gl/100g and range of 1.2 to 2.0 meq/kg peroxide value was obtained. The predominant unsaturated fatty acid was oleic (36.3%), linoleic (5.4%), and alpha linoleic (1.5%). The most dominant saturated fatty acid found was stearic acid (52.4%). The results demonstrate that shea butter from Bida region exhibits high-quality characteristics that align with African Organisation for Standardisation (ARSO) highlighting its potential for value-added processing and export.

**Keywords:** chemical properties, microbial analysis, quality control, fatty acid, lipid content

## INTRODUCTION

Shea butter is a natural fat derived from the seeds of the Shea tree (Vitellaria paradoxa), which grows predominantly in the dry savannah belt of West Africa. The tree and its products have significant cultural, economic and health importance in countries such as Nigeria, Ghana, Burkina Faso and Mali. Shea butter has long been utilized in traditional medicine, soap industries, as a moisturizer in cosmetic formulations, and as a cooking fat in various African cuisines. Funeral beds of kings were carved in wood of old shea trees, and shea butter has always been a stable of Africa pharmacology (Pobeda and Gango, 2019). The Bida region in Niger State, Nigeria, is one of the key areas where shea butter production plays an essential role in local economies. It was estimated that Nigeria currently produces 350,000 metric tons of shea butter annually of which about 57% is from Niger state (Amissah et al., 2019). However, the scientific characterization of shea butter, particularly from Bida regions, Niger State in Nigeria, remains sparse. This study aims to fill this gap by investigating the physical, chemical, and microbiological properties of shea butter obtained from Bida region of Niger State, Nigeria..

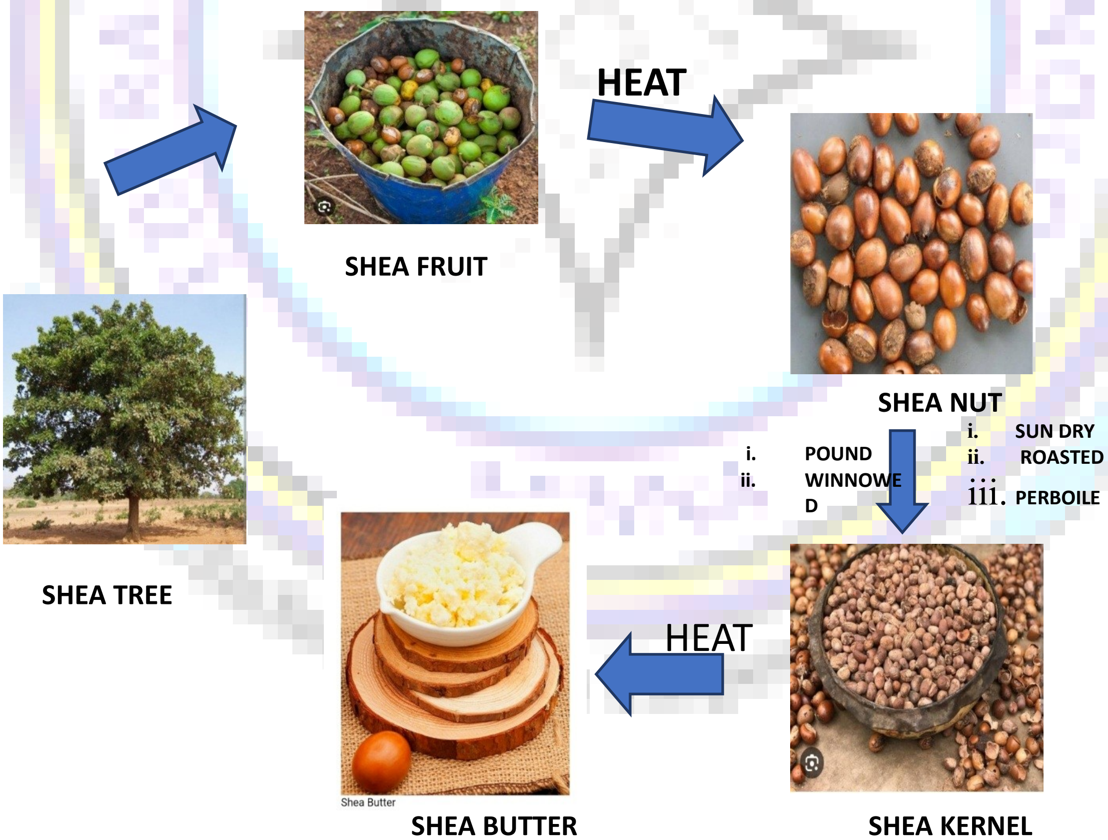
## MATERIALS AND METHODS

### Study Area

The Bida region of Niger State is located in the central part of Nigeria. The climate is characterized by a tropical wet and dry season, which influences the growth and distribution of shea trees. Shea butter produced in this region is largely extracted by local farmers, often using traditional methods involving manual crushing, roasting and cold-pressing.

### Sample Collection

Samples of Shea butter were collected from local producers in Bida during the peak harvest period (May to August). Three distinct batches were collected from different villages (Egubagi, Bida & Doko) to ensure representativeness. The Shea nuts were cracked, roasted, and manually pressed to extract the butter




### Laboratory analyses

Samples of Shea butter was subjected to laboratory analyses at National Cereals Research Institute Badeggi, Niger State. Refractive index of the samples was also obtained using Abbe refractometer (Carl Zeiss121554, Germany). Saponification value, iodine value, unsaponifiable matter, acid value and peroxide value were determined using standard methods of AOAC., 1995.

**Physical and Chemical Characterization**

5. Moisture Content: The moisture content of shea butter was determined using the oven-drying method (AOAC, 1995).
6. Melting Point: The melting point of shea butter was determined using a Differential Scanning Calorimeter (DSC).
7. Fatty Acid Profile: Fatty acid composition was determined through gas chromatography (GC) of methyl esters.
8. Saponification Value: This was determined by titrating the solution of a known fat sample with a standardized KOH solution, as per standard procedures.
9. Iodine Value: Iodine value was determined by the Wijs method, which measures the unsaturation of the fat.
10. Peroxide Value: The peroxide value was determined to assess the degree of rancidity using the iodometric method.

**Microbiological Analysis**

Microbial contamination in the Shea butter was assessed by standard microbiological techniques to determine the presence of bacteria, fungi, and other pathogens. Total viable count (TVC), yeasts, and molds were enumerated using selective media (Mauriceet *et al*. 2022).

**Statistical Analysis**

Data were analyzed using SPSS software (version 25). The mean values of physical and chemical parameters were calculated and differences between samples were evaluated.

**RESULTS AND DISCUSSION**

**Physical Properties of Shea Butter**

The Shea butter samples from Bida were pale yellow in color with a smooth texture, indicating good quality. The melting point ranged from 27°C to 33°C, which is typical for high-quality Shea butter. This characteristic is important for its use in cosmetic formulations, as it remains solid at room temperature but melts when applied to the skin (Adejumo*et al*., 2022).

**Chemical Properties of Shea Butter**

The fatty acid composition of Shea butter is a critical parameter for determining its nutritional and functional properties (Goumbri*et al*., 2021). The predominant fatty acids found in the samples were oleic acid (40-50%), stearic acid (30-40%), and linoleic acid (5-10%). The high content of oleic and stearic acids contributes to the stability and moisturizing properties of Shea butter. From Table 1,

**Saponification Value**: The Saponification values of the samples ranged from 180 to 200 mg KOH/g, indicating a high level of ester bonds in the butter, which is typical for vegetable fats.

**Iodine Value**: The iodine values ranged from 45 to 56, suggesting that the shea butter is moderately unsaturated, which is beneficial for its emulsifying properties in cosmetics.

**Peroxide Value:** The peroxide values were generally low (1.2 to 2.0 meq/kg), indicating that the shea butter samples were fresh and had not undergone significant oxidation.

**Microbial Contamination**

Microbial analysis revealed that all Shea butter samples from Bida had low levels of contamination, with total viable fungi counts ranging from 10^2 to 10^3 CFU/g. Yeast and mold counts were also low, indicating good hygiene practices in the local production process. However, minor bacterial contamination was observed in a few samples, which could be attributed to handling during processing.

**Table 1**: Physiochemical properties of crude shea butter from Bida

| Area | Ref 1ndex | Specific value | Iodine Value | Perioxide Value | FFA | Acid Value | SAP Value | PH |
|---|---|---|---|---|---|---|---|---|
| Bida | 1.472 | 0.908 | 42.73 | 8.20 | 3.16 | 6.32 | 183.67 | 5.38 |
| Doko | 1.471 | 0.907 | 42.72 | 8.20 | 3.16 | 6.33 | 183.67 | 5.38 |
| Egub agi | 1.472 | 0.906 | 42.72 | 8.21 | 3.17 | 6.33 | 183.67 | 5.38 |

**Table 2**: Specific quality criteria for unrefined shea butter quality parameters

| Quality parameters | Type A | | Type B | | Type C | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| Moisture content %(m/m) | - | 0.05 | >0.05 | - 0.2 | >0.2 | - 2.0 |
| Free Fatty Acid FFA (%) m/m | - | 1.0 | > 1.0 | - 3.0 | >3.0 | - 8.0 |

| | | | | |
|---|---|---|---|---|
| Perioxide Value (mfg/kg) | - | 10.0 | >10.0 - 15.0 | >15.0 - 50.0 |
| Insoluble impurities (%) m/m | 1.09 | | >1.09 - 0.2 | >0.2 - 2.0 |

Note: Type A is the highest and the best quality, type B is the moderate quality, type C is the lowest quality.

**Table 3**: African Organization for Standardization (ARSO) for unrefined shea butter

| | |
|---|---|
| Relative density g/ml (40c) | 0.89 - 0.93 |
| Sponification Value mg KOH/g | 160 - 190 |
| Iodine Value (wijs) | 30 - 75 |
| Unsaponifiable(%) | 1 - 19 |
| Refractive index at 44c | 1.4620 – 1.4640 |
| Melting point (0c) | 32 – 40 |
| Volatile matter at 105c (%)m/m | < 0.2 |
| Soap Content % (m/m) | < 0.005 |

Source: ARSO

From Tables 2 and 3 it can be seen that values obtained for selected quality parameters from characterization of the shea butter from Bida were all within the recommended range specified by ARSO. These values were in tandem with what was reported by Abdul-Hammed et al., (2020); Honfo et al., (2014); and Isaac et al., (2021).

## CONCLUSION

The Shea butter samples from the Bida region of Niger State exhibit favorable physical and chemical properties that align with international standards for high-quality shea butter. The predominant fatty acids—oleic, stearic, and linoleic acids contribute to the butter's stability, moisturizing ability, and suitability for various applications in cosmetics, pharmaceuticals, and food industries. The relatively low levels of microbial contamination further suggest that the production processes in this region are adequate, though improvements in hygiene could enhance product quality. These findings highlight the potential of shea butter from the Bida region for both local consumption and export. Further studies focusing on large-scale production, value-added processing, and market access are recommended to improve the economic benefits for local farmers and producers.

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# GERMINATION AND SEEDLING GROWTH OF OKRA: A COMPARATIVE STUDY WITH COMPETITIVE WEEDS UNDER SALINITY STRESS

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## ABSTRACT

This study explores the effects of salinity stress on the germination and seedling growth of okra (*Abelmoschus esculentus*) and its competitive weeds. The experiment was conducted under controlled conditions with a factorial combination of four salinity levels (0, 5, 10, and 15 mM NaCl) and three plant species (okra, *Portulaca oleracea,* and *Cynodon dactylon*) arranged in a completely randomized design, having four replications each. Data were collected on germination percentage (GP), germination energy (GE), germination rate index (GRI), mean germination time (MGT), and seedling vigor index (SVI). The results demonstrated that increasing salinity levels significantly negatively affected the plant species germination and seedling growth, as the higher the concentration the stronger the effect. Increasing salinity levels from 5 to15 mM concentration caused a reduction in GP from 25 % - 98.1%, GE from 33.3 % - 93.6 %, GRI from 39.2 % - 98.6 %, and SVI from 41.1 % - 99.9 % compared to the control. In contrast, *P. oleraceae* showed higher resilience to salinity stress, maintaining superior GP, GRI and SVI compared to okra and *C. dactylon*. The *C. dactylon* exhibited moderate tolerance to salinity between okra and *P. oleraceae*. The findings have shown the competitive disadvantage of growing okra in saline environments and suggest that *P. oleraceae* could exacerbate weed competition under such conditions. This study highlights the need for targeted weed management strategies and the development of salt-tolerant okra varieties to improve its production in salt-affected regions.
**Keywords**: Competitive weeds, okra, salinity, seedling growth

## INTRODUCTION

Crop plants are usually affected by different abiotic stresses which limit their vegetative and reproductive growth and development. Among these stresses, salinity is the most severe one (Gao *et al*., 2013). Salinity is a major environmental constraint to crop productivity in different regions, especially in arid and semi-arid regions of the world (Carpici *et al*., 2009). About 800 million hectares of land in the world are affected by salinity and sodicity (Khodarahmpour *et al*., 2012) such that 20 % of the agricultural lands, and 50 % of the cropland in the world is seriously affected by salinity problems (Arvind, 2017). In Nigeria, there are approximately 2.23 million hectares of coastal land of which about one million ha are salt-stressed (SRDI, 2010; Howlader and Haque, 2018; Ahmed and Nawaz, 2017). Salinity has a drastic effect on almost all development stages during the plant life cycle, including seed germination, seedling establishment and development, vegetative and reproductive growth, and crop survival and yield (Shu and Wang, 2017).

The major adverse effects of salt stress on plant growth and development have been imposed to osmotic inhibition of water availability as well as the toxic effect of salt ions responsible for salinization (Sardoei and Mohammadi, 2014). Such ions are responsible for nutritional imbalance which leads to a reduction in photosynthetic efficiency and physiological disorders of crop plants (Hakim and Aslam, 2010). Due to the salinity problem, approximately 30-50 % of net cropped areas in the arid region of Nigeria remain fallow in the dry season (Howlader *et al*., 2018). The salinity problem increases in January – February (dry months) and decreases in July- August (wet months) (Mahmud and Ali, 2016). Salinity is another major constraint to okra production, as it can reduce germination, seedling growth, and yield. Also, okra's production is often threatened by weeds, which compete with the crop for water, nutrients, and light.

Understanding the germination and seedling growth of okra with competitive weeds under salinity is crucial for developing effective weed management strategies and improving okra productivity. Competitive weeds can significantly impact the early stages of okra growth, affecting both germination rates and subsequent seedling development (Ben Hassine and Ghorbel, 2016). This impact can manifest through various mechanisms including competition for resources, allelopathy, and physical interference. The present study was, therefore, carried out to compare the germination and seedling growth of okra with some competitive weeds under salinity; and to identify the most competitive weed species with okra under salinity.

## MATERIALS AND METHODS

### Experimental Site

The experiment was carried out at the laboratory of the Department of Crop Production, Federal University of Technology, Minna, Niger State, Nigeria. Minna is located in Southern Guinea Savanna agro ecological zone of Nigeria.

### Sources of Experimental Materials

The experimental material consisted of seeds of the most commonly grown okra cultivar in Nigeria 'NHAe 47-4 (obtained from an Agrochemical Store based in Minna, Niger State), The weed seeds were collected from the previous year from matured weed plants and were kept in envelopes under room temperature, until when used. The seeds of the competitive weeds used in this study, *Cynodon dactylon* and *Portulaca oleraceae* were selected based on their prevalence in agricultural fields where okra is commonly grown and their known competitive interactions.

### Treatments and Experimental Design

The treatment consisted of a factorial combination of okra with some competitive weeds (*Cynodon dactylon* and *Portulaca oleraceae*) and four salinity levels (control as 0 mM Nacl, low salinity as 5 mM Nacl, moderate salinity as 10 mM Nacl, and high salinity as 15 mM Nacl) arranged in a completely randomized design (CRD) with four replications.

### Preparation of Saline Condition

To simulate a saline condition, four salinity levels were prepared using sodium chloride (Nacl), as follows: control (0 mM Nacl), low salinity (5 mM Nacl), moderate salinity (10 mM Nacl), and high salinity (15 mM Nacl). The salinity levels were chosen based on preliminary studies to represent a range of conditions that could affect plant germination and growth.

### Seed Preparation and Salinity Treatment

Four replicates containing 50 seeds each of okra, *Cynodon dactylon* and *Portulaca oleraceae* were germinated in three rolled filter papers. The seeds were watered with a solution of 10 ml of the respective test solutions. The filter papers were replaced every two days to prevent the accumulation of salts. To prevent evaporation, each rolled filter paper was put into a sealed plastic bag. The prepared seeds were then incubated and allowed to germinate at 20±1ºC in the dark for 10 days. A seed was considered germinated when the emerging radicle elongated to 2 mm. Daily observations were made, and the number of germinated seeds were recorded from the 24-hour mark of incubation until the conclusion of the experiment.

**Data Collection**

The following data were taken daily (24 hours) for 10 days. Therefore, seedlings were separated into the shoot and root parts, then oven-dried at 70 ℃ to a constant weight and weighed. Data on germination and seedling vigour parameters were calculated based on the following formulae:

i. Germination Percentage (GP): This was calculated using the formulae described by Zohaib *et al.* (2016), as:

$$\% \text{ Germination} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds incubated}} \times 100$$

ii. Mean Germination Time (MGT): This was calculated using the formulae described by, Kaya *et al.* (2009), as;

Mean Germination Time (MGT)=∑(n) / ∑(Dn )

Where:

- Dn = number of days from the start of germination to the day of counting.
- n = number of seeds that germinated on day D.

**Germination Energy (GE):** This was calculated using the formula described by Ruan *et al*. (2002) as;

$$\text{Germination Energy (GE)} = \left(\frac{\text{Number of seeds germinated within a specific time}}{\text{Total number of seeds}}\right) \times 100$$

iii. **Germination Rate Index (GRI):** This was calculated using the formula described by Kader (2005) as;

$$\text{Germination Rate Index (GRI)} = \frac{G1}{1} + \frac{G2}{2} + \frac{G3}{3} + \cdots + \frac{Gn}{n}$$

Where:

- *G1, G2, G3,…,Gn* are the number of seeds germinated on the first, second, third, etc., days of the germination test.
- *n* is the corresponding day of germination.

iv. **Seedling Vigour Index (SVI):** This was calculated using the formula described by Abdul-Baki and Anderson (1973) as;

Seedling Vigour Index (SVI) = Germination Percentage × Mean Seedling Length (cm)

**Data Analysis**

Data collected were subjected to analysis of variance (ANOVA) using a Statistical Analysis System (SAS). Means with significant differences were compared using the Least Significance Difference (LSD) test at a 5 % significance level.

## RESULTS

**Germination percentage**

The results presented in Table 1 demonstrate the significant impact of salinity stress on the germination and seedling growth of the plant species studied. Germination percentage differed significantly among the plant species, with *Portulaca oleracea* exhibiting the highest germination percentage (63.59 %) compared to the other species. Salinity stress also had a marked effect on germination percentage, with the control (0 mM) showing the highest germination percentage (97.00 %) across all treatments. The interaction between plant species and salinity stress on germination percentage was significant (Table 2). Regardless of the plant species, germination percentage decreased as salinity levels increased from 0 to 15 mM. However, under 0 mM salinity, the germination percentage was higher and similar among all the plant species in this study.

### Germination energy

The result of the germination energy was not significantly different among the plant species (Table 1). Salinity stress had a significant impact on germination energy, with the control (0 mM) exhibiting the highest germination energy (13.00) beyond which there was a significant reduction. The interaction between plant species and salinity stress on germination energy was not significant.

### Germination rate index

There were significant differences in the germination rate index among the plant species, with *Portulaca oleracea* showing the highest germination rate index (10.53), outperforming both okra (7.08) and *Cynodon dactylon* (7.02) (Table 1). The effect of salinity on the germination rate index was evident, with the control treatment (0 mM) achieving the highest value (17.21), while increased salinity levels led to a marked decrease in the germination rate.

**Table 1: Germination and seedling characteristics of plant species under salinity stress**

| Plant species | Germination Percentage (%) | Germination Energy (%) | Germination Rate Index (%/day) | Mean Germination Time (days) | Seedling Vigour Index (%) |
|---|---|---|---|---|---|
| **(C)** | | | | | |
| **Okra** | 47.87$^{b}$ | 7.63$^{a}$ | 7.08$^{b}$ | 4.67$^{a}$ | 224.38$^{c}$ |
| **Cynodon** | 45.75$^{c}$ | 6.63$^{a}$ | 7.02$^{b}$ | 4.23$^{a}$ | 240.44$^{b}$ |
| **Portulaca** | 63.50$^{a}$ | 7.50$^{a}$ | 10.53$^{a}$ | 4,24$^{a}$ | 328.41$^{a}$ |
| **LSD (0.05)** | 1.64 | 2.73 | 0.90 | 0.97 | 8.04 |
| **Salinity (S) (mM)** | | | | | |
| **0** | 97.50$^{a}$ | 13.00$^{a}$ | 17.21$^{a}$ | 4.52$^{a}$ | 592.27$^{a}$ |
| **5** | 73.17$^{b}$ | 8.67$^{b}$ | 10.47$^{b}$ | 4.77$^{a}$ | 349.09$^{b}$ |
| **10** | 37.00$^{c}$ | 6.50$^{b}$ | 4.93$^{c}$ | 5.35$^{a}$ | 118.36$^{c}$ |
| **15** | 1.83$^{d}$ | 0.83$^{c}$ | 0.24$^{d}$ | 2.88$^{b}$ | 0.90$^{d}$ |
| **LSD (0.05)** | 1.91 | 3.15 | 1.04 | 1.12 | 9.28 |
| **Interaction** | | | | | |
| **C x S** | ** | NS | ** | NS | ** |

Means with the same letter(s) in a column are not significantly different according to the least significant difference at 5 % level of probability

**Table 2: Interaction between plant species under salinity stress on germination percentage**

| Plant species | Salinity(mM) 0 | 5 | 10 | 15 |
|---|---|---|---|---|
| **Okra** | **97.50$^{a}$** | **65.00$^{c}$** | **27.50$^{e}$** | **1.50$^{g}$** |
| **Cynodon** | **97.50$^{a}$** | 60.50$^{d}$ | 23.00$^{f}$ | 2.00$^{g}$ |
| **Portulaca** | **97.50$^{a}$** | 94.00$^{b}$ | 60.50$^{d}$ | 2.00$^{g}$ |
| **LSD (0.05)** | **2.29** | | | |

Means with the same letter(s) in a column are not significantly different according to the least significant difference at 5 % level of probability

The interaction between salinity and plant species on germination rate index was significant (Table3). As salinity levels rose from 0 to 15 mM, the germination rate index decreased across all plant species.

**Mean germination time**

The result of the mean germination time was not significantly different among the plant species, with okra, *Portulaca oleracea*, and *Cynodon dactylon* showing relatively similar times (4.67, 4.24, and 4.23 days, respectively) (Table 1). However, salinity stress influenced the mean germination

**Table 3: Interaction between plant species under salinity stress on germination rate index (%/day)**

| Plant species | Salinity(mM) 0 | 5 | 10 | 15 |
|---|---|---|---|---|
| **Okra** | **17.00[b]** | **8.57[f]** | **2.59[g]** | **0.16[h]** |
| **Cynodon** | **15.54[c]** | 9.84e | 2.36[g] | 0.33[h] |
| **Portulaca** | **19.06[a]** | 12.99[d] | 9.83[e] | 0.23[h] |
| **LSD (0.05)** | **1.26** | | | |

Means with the same letter(s) in a column are not significantly different according to the least significant difference at 5% level of probability

time, such as there was a similar mean germination time at 0-10 mM, and mean germination time decreased slightly at the highest salinity level (15 mM). The interaction between plant species and salinity stress on this parameter was not significant

**Seedling vigour index**

The result of the seedling vigour index varied significantly among the plant species, with *Portulaca oleracea* displaying the highest vigour (328.41) compared to the other plant species (Table 1). Salinity stress had a pronounced effect on the seedling vigour index, with the control (0 mM) having the highest seedling vigour index (592.27). As salinity levels increased, the seedling vigour index decreased sharply, particularly at the highest salinity level (15 mM), where values dropped to near zero. The interaction between plant species and salinity stress on the seedling vigour index was significant (Table 4). Regardless of the plant species, the seedling vigour index decreased as salinity varied from 0 to 15 mM.

**Table 4: Interaction between plant species under salinity stress on seedling vigour index (%)**

| Plant species | Salinity(mM) 0 | 5 | 10 | 15 |
|---|---|---|---|---|
| **Okra** | **590.00[a]** | **307.3[c]** | **0.00[f]** | **0.00f[h]** |
| **Cynodon** | **589.69[c]** | 296.6[c] | 75.54[e] | 0.00[f] |
| **Portulaca** | **597.00[a]** | 434.40[b] | 279.60[d] | 2.70[f] |
| **LSD (0.05)** | **1.26** | | | |

Means with the same letter(s) in a column are not significantly different according to the least significant difference at 5% level of probability

## DISCUSSION

In general, *Portulaca oleracea* exhibited the highest germination percentage, germination rate index, and seedling vigour index among the plant species tested in this study. These suggest that *Portulaca oleracea* was the most competitive species under the given conditions, particularly in saline environments. Its ability to maintain higher germination rates and seedling vigour even under moderate salinity levels indicates a greater resilience to stress, allowing it to outcompete both okra and *Cynodon dactylon*. This superior performance highlights the competitive disadvantage faced by okra in environments where salinity and weed pressure are high. Similar findings have been reported by Chikoye and Fayinminnu (2010), who also observed that competitive weed species, like *Portulaca oleracea*, can significantly reduce crop establishment under stress conditions. The highest germination percentage, germination rate index, and seedling vigour index observed in the control treatment (0 mM) can be attributed to the absence of salinity stress. In the absence of salt, the plants were able to germinate and grow under optimal conditions, leading to enhanced germination and seedling vigour. Salinity typically reduces water availability and disrupts nutrient uptake, which is critical for seed germination and early growth (Khodarahmpour *et al*., 2012). The absence of these stressors in the control treatment allowed for better overall plant performance compared to the saline treatments, where increased salinity levels hindered these processes, leading to reduced growth and vigour. This is consistent with the findings of Munns and Tester (2008), who highlighted that salinity imposes osmotic and ionic stresses on plants, ultimately reducing their growth potential.

## CONCLUSION

Based on the findings of this study, salinity significantly affects the germination and seedling growth of okra and *Cynodon dactylon*, but also enhances the competitiveness of salt-tolerant weeds like *Portulaca oleracea.* Increasing salinity levels from 5 to 15 mM concentration caused a reduction in GP from 25 % - 98.1%, GE from 33.3 % - 93.6 %, GRI from 39.2 % - 98.6 %, and SVI from 41.1 % - 99.9 %. The *P. oleraceae* exhibited greater resilience to salinity stress, maintaining superior GP, GRI and SVI in this study. The *C. dactylon* exhibited moderate tolerance to salinity between okra and *P. oleraceae* with varying degrees of impact depending on the level of salinity. To enhance okra production in saline soils, breeding salt-tolerant okra varieties and adopting effective weed management practices is hereby recommended to breeders.

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# TOWARDS THE DEVELOPMENT OF AN INTELLIGENT EVAPORATIVE COOLING SYSTEM FOR POST-HARVEST STORAGE OF SELECTED FRUITS

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## ABSTRACT

Poor management of post-harvest storage of fruits and vegetables has led to enormous food wastage and economic loss globally. Refrigerating systems have been adopted over the years to avert these losses; however, installing them is expensive and can cause chilling injury and moisture loss to the fruits and vegetables when they go below 20℃ temperature. An evaporative cooling system has recently been widely used to preserve fruits and vegetables because it's cheap to implement, especially for small-scale farmers. This system reduces the temperature and increases the air humidity in their chamber by removing latent heat from the evaporated water when exposed to sunlight. The existing evaporative system has been efficient in preserving the quality of fruits and vegetables as well as extending their shelf-life; however, they lacked automated operation and control mechanisms, intelligent mechanisms capable of identifying the physical state of the fruits, adaptive control techniques for the storage and remote monitoring, feedback scheme of the system for use by the farmers. The abovementioned limitations have prevented the system from achieving optimal performance in preserving fruits. Hence, this research aims to develop a multi-chamber evaporative cooling preservative system for post-harvest storage of fruits. In the first step, Tomato images were collected and trained with the MobileNetV2 model, achieving accuracy, precision and recall of 88%, 89% and 88% respectively. Overall, the model performs well, however, fine-tuning the model or using more training data could help improve its performance further.

**KEYWORDS**: Intelligent, Evaporative, Cooling system, Tomato, post-harvest, Transfer Learning

## INTRODUCTION

Food waste is a global menace that spans the food supply chain from agricultural production to consumption. More than 40% of fruit production is lost to post-harvest loss globally as shown in the attached Figure 1, while 50% is lost in Nigeria annually, according to the Nigerian Stores Products Research Institute (NSPRI) (Amjad, *et al.,* 2023). These contribute largely to hunger, loss of revenue to the government and farmers. Furthermore, fruit waste is an ecological concern due to its severe environmental effects. This is because the release of greenhouse gas emissions can be tied to the amount of disposed fruits' waste from methane generation during decomposition (Anand & Barua, 2022). Hence, proffering a potent solution to fruit waste through an effective post-harvest management system will enhance food security, reduce hunger, and mitigate global greenhouse gas emissions.

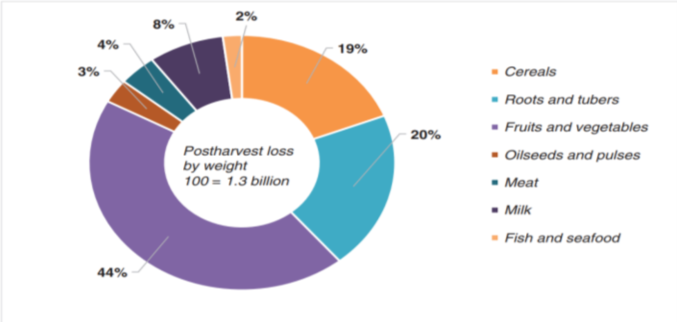


Figure 1: Post-harvest Losses of Commodities in the World (Amjad, *et al.,* 2023).

The post-harvest stage covers the period from which the fruit is harvested until it is consumed or deteriorated. Inherently, the fruits' quality can not improve because the nourishment they receive from the soil has ceased when harvested (Sani, *et al.,* 2023). However, the deterioration process can be decelerated using several existing approaches in the literature. One of these approaches is the refrigerator that can preserve different kinds of fruits; however, it's expensive to install and can lead to moisture loss and chilling injury when it goes below a certain temperature range. This proves the unsuitability of refrigerators because they can not maintain the fruits' optimum storage conditions. Another viable method is using an evaporative cooling system to preserve fruits, which mainly depends on the environmental condition. The effectiveness of this method relies on the ability of the system to maintain the optimum and suitable environmental conditions of the fruits, which is lacking in the existing evaporative cooling systems. This research aims to address this identified problem by developing an intelligent multi-chamber evaporative cooling preservative system for post-harvest storage of fruits capable of preserving the quality of fruits and extending their shelf-life. Consequently, the system will enable farmers to generate more income from their farm products and boost the nation's economy.

**REVIEW OF RELATED WORKS**

The importance of fruits and vegetables in our daily diet regimen can not be over-emphasized. This underscores why fruits and vegetables were produced in large quantities in recent years. According to FAO, 2022, the production of fruits and vegetables reached 1.2 billion metric tonnes, with 59% production growth in 2021, as shown in Figure 2. The most produced fruit in 2021 was Banana, with 125 million tonnes, and orange, was 76 million tonnes. Moreover, the most grown vegetable was tomatoes, with 189 million in 2021 (FAO, 2022).

Tomatoes, bananas and oranges are highly sought-after fruits and vegetables due to their high nutritional value. However, due to their high susceptibility to spoilage, significant post-harvest losses are always incurred quantitatively and qualitatively. Banana and orange fruits incur 35% and 25% post-harvest losses in Nigeria, according to research carried out by the International Institute of Tropical Agriculture (IITA), while tomatoes incur 40 to 60% of the total number of tomatoes produced in Nigeria (Anajekwu, *et al.,* 2023).

Hence, developing a cooling evaporative system for the selected fruits is essential to minimize this monumental economic loss drastically. This also ensures food availability and security, job opportunities, and environmental preservation for the ever-growing population, boosting economic growth and development in Nigeria's agricultural sector.

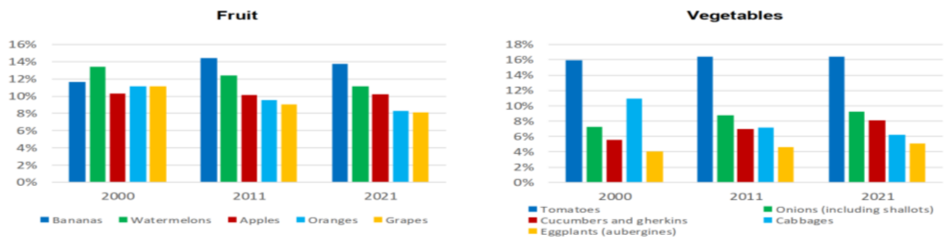


Figure 2: Percentages of Fruits and Vegetables Production in the World (FAO, 2022)

Thus, this research aimed at developing an evaporative cooling system for the optimum preservation of the selected fruits owing to their nutritional and economic value to the human populace. In addition, this section reviews the related works undertaken in this area to bring out the gaps left to be filled.

Defraeye, *et al.* (2022) developed an innovative evaporating cooling system to successfully maintain the quality and freshness of agricultural goods after harvesting. The effort aimed primarily to support marginalised and petite farms in rural and isolated regions. This developed system incorporated an insulation layer as an underlying structure, which can be constructed using charcoal or recyclable substances. This blanket is designed with multiple compartments to facilitate the storage of the charcoals. The trial findings of the produced evaporative cooler showed a significant increase in the longevity of fresh fruits, extending their shelf life to 14 days. The temperature values of both the interior and exterior air were decreased, while the humidity was increased. Several constraints constrained the study's findings. Firstly, the developed system that was constructed lacked full automation. Additionally, the increased shelf-life achieved was quite brief, and the temperature and relative humidity values were not optimised.

Kapilan & Patil (2022) constructed a low-cost evaporative cooling system to store agricultural products. This research addressed the problems related to the high cost of cold storage systems by introducing a solar photovoltaic system to power the evaporative cooling system and coconut coir as the cooling medium. The efficacy of the developed system was measured with the standard metrics, including efficiency, power, discharge and dry bulb temperature, and it was shown to achieve preservation of some agricultural products. However, it fell short in performance when compared with the existing systems due to the nature of the cooling medium adopted. The cooling medium used affected the regulation of temperature and humidity. Yenenh (2023) developed an evaporative cooling system to store horticulture products. This system combined direct and indirect evaporative cooling systems to extend the shelf life of fruits and vegetables, considering varying environmental conditions. The system Temperature was pre-set to 9.6°C and 10.3°C and a humidity value of 85% with a capacity of 260kg. The developed system was tested using tomato fruits and maintained the quality of the tomato. However, the system could not maintain the tomatoes' shelf life for extended periods due to the environmental conditions affecting the internal temperature and humidity.

Zhu *et al.* (2023) developed a novel dew-point evaporative cooler based on fibre membrane automatic wicking. In the study, the authors investigated four different kinds of fibre material. The wicking component of the evaporated cooler was automatically powered; however, artificial intelligence to make the system smart was not employed. In extending injera's shelf-life and preventing Fungi's growth, Birhanu & Belay (2023) developed an evaporative cooler clay chamber to regulate the temperature and humidity of this Ethiopian ethnic food. The system reduced the ambient temperature from 28.89°C to 22.9°C and the ambient relative humidity from 28.78% to 80.94%. However, the system could not maintain the shelf-life of injera for an extended period.

Attempts have been made to introduce an evaporative cooling system to store various kinds of fruits, reduce post-harvest waste, and improve agricultural productivity (Nkolisa, *et al.,* 2018). However, these systems have limitations such as manual operation and lack of control technology, lack of remote monitoring of the fruits' shelf life and a feedback system for the farmers and lack of intelligent technology. Hence, a system capable of classifying, detecting, and post-harvest storage of the selected fruits is needed. Furthermore, based on the literature reviewed, it is evident that there is a need for an improved system to address the research gaps identified. These gaps include the manual operation and lack of control mechanism, lack of an intelligent mechanism capable of identifying the physical state of the selected fruits, absence of an adaptive control technique for the storage system, and lack of remote monitoring and a feedback scheme of the system for use by the farmers.

## MATERIALS AND METHODS

This stage involves collection, processing and storage of the selected fruits (Tomatoes, bananas and orange) in Not Only SQL (NoSQL) database. The selected fruits will be collected from various points (study sites) and the clear images of the fruits will be taken with a high-resolution camera equipped with high memory capacity for further processing.

### DATA COLLECTION

Data from the selected fruits will be collected using a high-resolution digital camera with high-capacity memory card.

### DATABASE DEVELOPMENT

The collected dataset of ripe and unripe images will be stored in NoSQL database. The choice of the database is informed by the fact the NoSQL is efficient, reliable and faster access as compared to other available databases (de Oliveira, *et al.,* 2021; Tsai, *et al.,* 2022).

### DEVELOP AN INTELLIGENT SELECTED FRUIT RECOGNITION AND CLASSIFICATION

Incorporating intelligence into the existing evaporating cooling system is a game changer for the selected fruits' storage as the system will be able to identify the state of the selected fruit and adjust to its suitable parameters' values, including temperature, humidity and carbon dioxide. The steps to achieve this is as shown in Figure 3 .

First, the stored data will be accessed from the image database, as explained earlier. Then, the data will be pre-processed as follows: first, an improved filtering algorithm will be applied to filter the noise on the image. Noise, such as speckle, salt and pepper and other noises, must be filtered as they are obtained during image capture and affect the intelligent system's overall performance if not filtered. After noise filtering, the image will be cropped, followed by erosion and dilation, which will be carried out in this section. Finally, the pre-processed data will be fed into the proposed convolutional neural network (CNN) model. The hyperparameters of the CNN model architecture will be fine-tuned to yield better results.

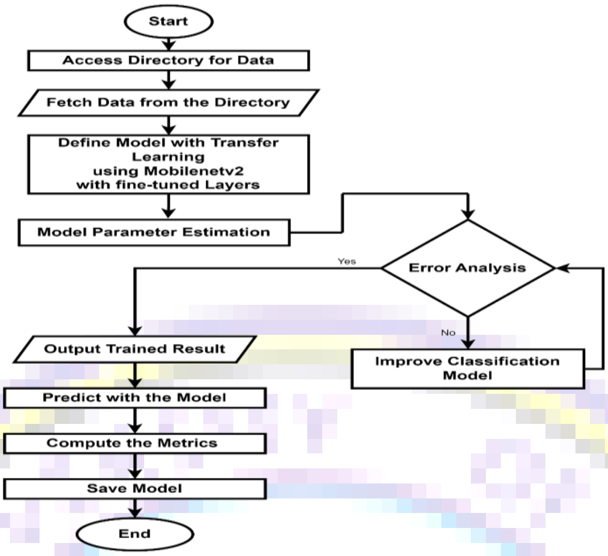


Figure 3: Proposed Deep Learning Model flow chart

Like other deep learning models, the CNN deep learning model is sensitive to hyperparameters (Şen & Özkurt, 2020). Therefore, choosing the optimal parameter leads to better results. The parameters will be fine-tuned using a nature-inspired metaheuristic strategy called Particle swarm optimization (PSO) algorithm (Jain, *et al.,* 2022; Jeelani & Veena, 2018) and the PSO equations are shown in equations 1 and 2.

$$x_i(t+1) = x_i(t) + v_i(t+1)t \quad (1)$$

$$v_i(t+1) = wv_i(t) + c_1r_1(pbest(t) - x_i(t) + c_2r_2(gbest(t) - x_i(t) \quad (2)$$

Where,

$x$ is the particle's position

$v$ is the particle's velocity

$gbest$ is the global best

$c$ and $r$ are constant parameters

The particles are described as a 'flock of birds' exhibiting a collective motion in search of the best solution or global optimum in a solution space (Xu, *et al.,* 2023). It has been tested on some combinatorial optimisation problems and has proven very effective.

After optimising the hyperparameters of the CNN model, such as the one shown in Figure 4, it will be trained with the dataset collected and pre-processed as described earlier. After training, the model error will be estimated and checked for several iterations. The model will be saved and deployed when the error reaches an acceptable limit. So, the trained deep learning model will now have the ability to intelligently and autonomously inform the next stage of the ECS pipeline, the state of the selected fruit.

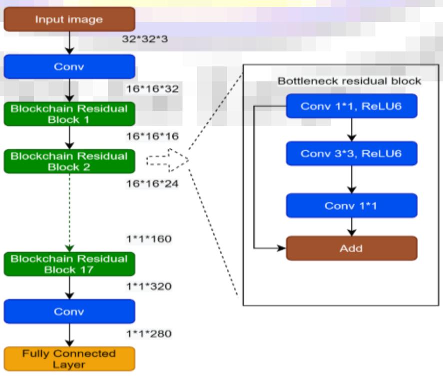


Figure 4: MobileNetv2 Architecture (Akay, *et al.,* 2021)

## RESULTS AND DISCUSSION

This section discusses the preliminary results obtained from the collection of tomato fruits (ripe and semi-ripe).

Figure 5: Collected Ripe Tomatoes

Figure 6: Collected Semi-ripe Tomatoes

A thousand images of ripe and semi-ripe tomatoes were collected, washed and snapped. The image samples are shown in Figues 5 and 6. The images were transferred to a computer system and had their backgrounds removed to obtain a clearer images and reduce computational complexity. The images were divided into 70% training, 15% each for testing and validation. Furthermore, the images were trained with a transfer learning architecture, MobileNetV2.

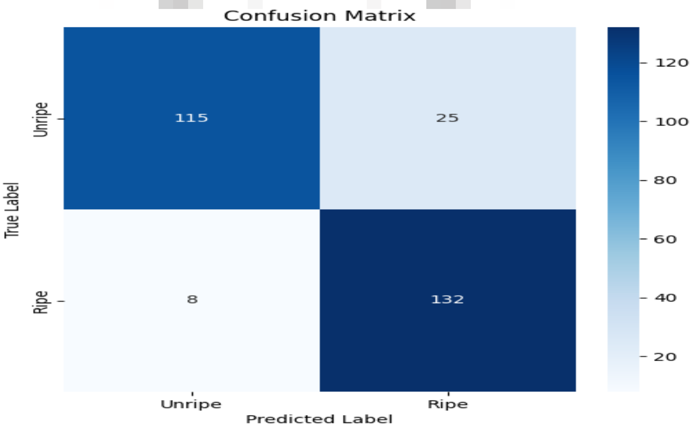


Figure 9: Confusion Matrix of the Trained Model

The confusion matrix shown in Figure 9 is a great way to evaluate the performance of the classification model for distinguishing between ripe and unripe tomatoes. The True Positives (Ripe correctly classified as Ripe): 132; True Negatives (Unripe correctly classified as Unripe): 115; False Positives (Unripe incorrectly classified as Ripe): 25 and the False Negatives (Ripe incorrectly classified as Unripe): 8

The model's accuracy can be calculated as the ratio of correctly classified instances to the total instances. In this case, the accuracy is 88%. This indicates that the model is quite reliable in classifying the tomatoes correctly.

The precision measures the accuracy of the positive predictions. It is calculated as 89%. This means that when the model predicts a tomato is ripe or unripe, it is correct 89% of the time.

The recall measures the ability of the model to identify all relevant instances. It is calculated as 88%. This means that the model correctly identifies 88%% of all ripe and unripe tomatoes.

Furthermore, the model has a high recall for ripe tomatoes, meaning it is very good at identifying ripe tomatoes. The precision for unripe tomatoes is also high, indicating that when the model predicts a tomato is unripe, it is usually correct. In addition, the lower recall for unripe tomatoes suggests that the model sometimes misses unripe tomatoes, classifying them as ripe instead.

Overall, the model performs well, but there is room for improvement, especially in reducing the number of false positives (unripe tomatoes classified as ripe). Fine-tuning the model or using more training data could help improve its performance further.

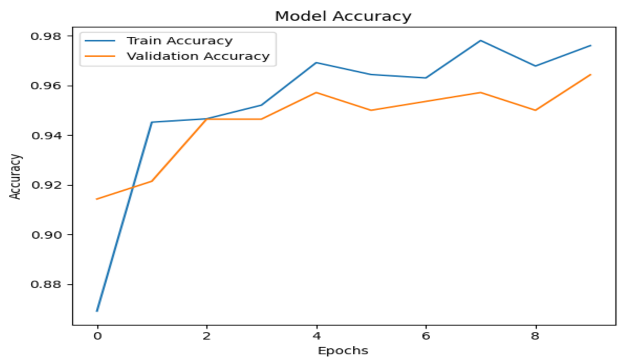


Figure 10: Model Accuracy of the Trained Model

Figure 10 shows the accuracy of a machine learning model trained to classify tomato images into ripe and unripe categories over 10 epochs. The blue line represents the training accuracy, which starts at approximately 0.88 and increases rapidly, reaching around 0.96 by epoch 2. It continues to fluctuate slightly but generally trends upwards, peaking at around 0.98 by epoch 9.

The orange line represents the validation accuracy, which starts at approximately 0.90 and increases steadily, reaching around 0.94 by epoch 2. It then fluctuates slightly but generally trends upwards, reaching around 0.96 by epoch 9. Thus, the increasing trend in both training and validation accuracy indicates that the model is learning effectively. The model's ability to generalize well to unseen data is demonstrated by the close alignment of the training and validation accuracy lines.
Also, The close alignment of the training and validation accuracy lines suggests that the model is not overfitting. Overfitting occurs when a model performs well on training data but poorly on validation data. In this case, the model's performance on both training and validation data is similar, indicating good generalization.
The high accuracy values (around 0.96 to 0.98) suggest that the model is reliable in classifying tomato images into ripe and unripe categories. This high level of accuracy is promising for practical applications, such as automated identification of tomato fruits.

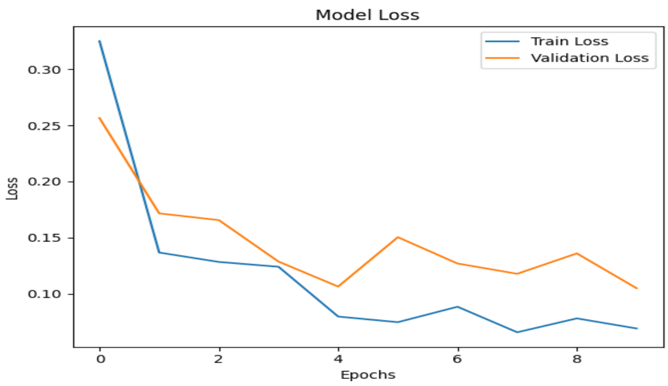


Figure 11: Model Loss of the Trained Model

Figure 11 depicts the model loss over 10 epochs for a machine learning model trained to classify tomato images into ripe and unripe categories. The blue line represents the training loss, which starts at around 0.35 and decreases steadily, showing a significant drop in the first few epochs and then gradually decreasing to around 0.05 by the 9th epoch. Then, the orange line represents the validation loss, which starts at around 0.25 and decreases, but it fluctuates more than the training loss, ending at around 0.10 by the 9th epoch. Thus, the decreasing trend in both training and validation loss indicates that the model is learning effectively. The model's ability to generalize well to unseen data is demonstrated by the decreasing validation loss. The fluctuations in the validation loss suggest that there might be some overfitting or variability in the model's performance on unseen data. Overfitting occurs when a model performs well on training data but poorly on validation data. In this case, the model's performance on both training and validation data is similar, indicating good generalization, but the fluctuations in validation loss suggest that there might be some overfitting. Furthermore, the low loss values (around 0.05 to 0.10) suggest that the model is reliable in classifying tomato images into ripe and unripe categories.

## CONCLUSION

This research proposed an Intelligent Evaporative Cooling System that reduces the post-harvest wastage of the selected fruits including tomatoes, orange and banana while increasing the food security potential. The system is aimed at classifying stored fruits and adapts to temperature and humidity states suitable for storing, preserving quality, and improving the shelf life of the fruits, thus providing enough market time for the farmer to get his fruits to the customers. Tomatoes fruits have been collected and trained to show the efficacy of the pre-trained model. An intelligent storage, Automatic control, and remote monitoring will be achieved after the implementation of this research.


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# EVALUATION OF HERBICIDE MANAGEMENT ON NODULATION OF COWPEA

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## ABSTRACT
The use of herbicides will surely have diverse effects on cowpea performance. A screen house trial was conducted in the School of Agric. and Agricultural Technology, Federal University of Technology, Minna. Four treatments (pre-emergence (PE)+manual weeding (MW), pre+post emergence (PPE), manual weeding (MW), and weedy check (WC)) replicated thrice were laid in Completely Randomized Design (CRD). Two cowpea varieties nodulation, shoot, and root biomass were assessed. Manual weeding recorded the highest shoot dry biomass followed by PE+MW, while WC and PPE had the least shoot biomass in Sampea 14. Also, the highest root dry biomass was recorded for MW, followed by PE+MW, while, PPE and WC applications recorded the least root biomass. Similarly, Sampea 14 had the highest number of nodules under MW, followed by WC, PE+MW recorded the least number of nodules, while, PPE treatment had no nodules. Likewise, MW had the highest nodule effectiveness recorded followed by PE and WC. Sampea 14 treated with MW had the highest nodule weight followed by WC and PE+MW. In conclusion, the overall result of the experiment showed that the application of herbicides has a hazardous effect on cowpea nodulation, and shoot and root growth. Therefore, there is an urgent need to conduct further studies on the impact of different herbicides on cowpea growth.
**Keywords**: Biological nitrogen Fixation, Weedy check, Nodulation, Herbicides

## INTRODUCTION
Cowpea (*Vigna unguiculata* L. Walp) is an important grain and fodder pulse. It's a dual-purpose grain legume crop; it is used as food for humans, fodder for livestock, and income to over 10 million households (Kebede, 2020a). In today's world, man's requirement for protein makes cowpea an acceptable option for food as cowpea provides an affordable source of human dietary protein mostly in developing countries (Xu *et al.,* 2016). It is adapted to dry and low fertility conditions where it still produces leaves even though not to its optimal ability under such conditions (Nagarajan *et al.*, 2019). In Nigeria, cowpeas are one of the important crops that contribute to food security in several ways by constituting part of the daily menu in many households. The seed contains about 25 % protein and 64 % carbohydrates with 27–34 % protein in the leaves (Oloyede *et al.*, 2022). Cowpea is grown all over the world an estimated 14.5 million cultivation of cowpea is mainly to maintain the level of nitrogen in the soil, thereby reducing the expenses of commercial nitrogen fertilizers (Owade *et al.*, 2020). In the agricultural system, it is a control measure for the loss of nitrogen absorbed by cereals, thus, it has a positive effect on the soil properties, due largely to its unique capacity to fix atmospheric nitrogen and performs well even in poor soils. In natural ecosystems, the highest input of nitrogen comes from nitrogen fixed by microorganisms, called *diazotrophs* (Korked *et al.*, 2017). Nitrogen input from cowpeas can be a sustainable source of nitrogen in agricultural systems.

Weeds are a permanent constraint to crop productivity in agriculture they are plants that strive for nutrients, space, and light and they exert lots of harmful effects by reducing the quality as well as quantity of crop yield if the weed population is left uncontrolled (Kavalinus and Bobinas, 2006). Herbicide management in cowpeas has been with a low level of technology this is partly due to being mostly cultivated in less developed countries. The nature of weed interference strongly determines the kinds of weed management practices Adigun *et al.,* (2018). Different methods of weed control in cowpea have been shown to reduce weed competition in cowpea (Singh *et al*., 2006). Weed control methods applicable to crops comprise preventive measures which include all sanitary measures routinely used such as vigilance to note the presence of a strange plant on the field, rouging isolated weeds that have escaped control by other methods, inspection of cowpea seeds at entry points into country to ensure freedom from weed seeds (quarantine) and preventing weed spread to new cowpea fields. Other options are cultural, physical, biological, and chemical weed control methods. According to Abdul Rahman *et al*., (2021), competition of weeds with crops is mainly for available nutrients, moisture, space, and sunlight, thus causing a significant crop yield loss. Weeds may also reduce crop yield by releasing allelopathic compounds into the environment (Marinov-Serafimov 2015) and by providing favorable environments for pests and viruses (Caporaso *et al*., 2020). Hence altering the activities of microorganisms in the soil.

The use of chemical weed control in cowpeas is limited due to the scarcity of studies into the selectivity of herbicides for the crop (Sousa *et al.,* 2017) and there are no registered herbicides for cowpeas. Thus, one of the components of improved production technology is appropriate weed control, but weeds continue to render destruction to the efforts applied towards increasing cowpea yield. Broadleaf weeds also reduce the availability of photosynthetic area radiation (PAR) to the lower layer leaves of the crop canopy (Langyintuo *et al*., 2001), and reduce the longevity and expansion rate of lower leaves due to a decrease in the availability of soil nitrogen and moisture content. Therefore, the Biological Nitrogen Fixation of such plants will be affected because the nodulation and root growth are likely to have been negatively influenced. Resource-poor farmers in Nigeria employ hand-and-hoe weeding for weed control, but this cultural method is time-consuming, energy-depleted, and costly. The common method of weeding such as hand weeding is costly, and labor is not usually available during the growing season due to workload (Abdul Rahman *et al.*, 2021). Whereas the use of herbicides gives rapid results, is more convenient to the farmers, increases the yield of crops, and reduces labor costs. Hence, the use of herbicides in cowpeas to control weeds appears to be useful (Osipitan, 2017). However, it is necessary to investigate the effect of weed management on the shoot, root, and nodulation of cowpea, to ascertain which should be efficient, cost-effective, and environmentally friendly. Therefore, the present study was conducted to examine the effect of weed management on the shoot, root, and nodulation of cowpeas (Sampea 14) in Minna.

## MATERIALS AND METHODS

### Study site

The experiment was conducted in the screen house of the School of Agriculture and Agricultural Technology, FUT, Minna, Niger State. The geographic positioning system (GPS) coordinates of the screen house are latitude 9°31’27’’N and longitude 6°26’ 23’’E, with an elevation of 189.60 m above sea level. Minna is located in the Southern Guinea Savanna of Nigeria. It has a mean annual rainfall of l248 mm and a sub-humid climate. It is also characterized by a dry season of about 5 months occurring from November to March and also has a mean maximum temperature of 33.5 °C from March to June (Abdullahi, 2021).

**Collection and preparation of soil sample**

Soil sample was collected from the horticultural garden using soil auger from the plot systematically from 40 auger points over the entire landscape of the field at a depth of 0-15 cm. The collected samples were bulked and mixed in the field to form a composite sample. Subsamples were collected into a well-labeled sampling bag, which was air–dried and taken to the Soil Science and Land Management laboratory where it was gently crushed with a porcelain mortar and pestle, screened through 2.0 and 0.5 mm sieve in preparation for routine analysis.

**Treatments and Experimental Design**

The treatments used are (i) PE+MW (application of herbicides Butaclor with active ingredient (2-Choro-N-(2,6=diethylphenyl) acetamide), (ii) PPE (application of herbicide Butaclor with active ingredient (2-Choro-N-(2,6=diethylphenyl) acetamide) and Upl iris with active ingredients (Sodium Acifluorfen 16.5 + Clodinafop propargyl 8 % EC), (iii) MW (3 and 6 weeks after sowing) and (iv) WC replicated thrice. 5 kg of soil was used per pot in Completely Randomize Design (CRD).

**Agronomic Practices**

Collected soil was mixed, and weighed and 5 kg of soil was transferred into the labeled polythene pots in the screen house. Water was added at 40 % water holding capacity (WHC) and left to equilibrate. Sowing of two seeds per pot was done. Pre-emergence herbicides application (Butachlor) 5 ml was diluted in 5 liters of water and was sprayed a day after planting. After one week of emergence, 0.33 g of NPK 15:15:15 fertilizer was weighed, basal application of the fertilizer (NPK 15:15:15) was done to all the replicates, and 0.005 g single superphosphate was applied to augment for phosphorus. MW was done at 3 and 6 WAS. Post-emergence herbicides (Upl) were sprayed 5 WAS. Insecticide (Cytalothrin) was sprayed at 6, 8, and 10 WAS.

**Laboratory Analysis of the Soil**

The physical and chemical properties of the sieved soil were analyzed by the standard method described by IITA (1982) as follows: Particle size of the soil was determined using the hydrometer method. Soil pH was measured in 1:2.5 soil/water and 0.01M CaCl2 suspension with a pH meter. Total nitrogen was determined by the micro Kjeldahl method. Total organic carbon was determined by the Walkey - Black wet oxidation method. Available phosphorous was determined colorimetrically after Bray-Pl extraction. The exchangeable bases were extracted with a neutral 1N NH4OAC solution. Exchangeable Cations: Sodium and potassium in the extract were determined by flame photometry while Calcium and Magnesium in the filtrate were determined with an Atomic Adsorption Spectrophotometer (AAS). Exchangeable acidity was extracted with 1.0 N KCl (potassium chloride) solution. The total acidity from exchangeable Hydrogen and Aluminum was determined by titration. Effective Cation Exchange Capacity was obtained by the summation of exchangeable cations and the exchangeable acidity.

**Data collection**: **Measurement of cowpea growth and nodulation parameters**

**Shoot and root Weight (**Fresh and Dry**)**

Shoot and root weight in grams (g) was measured immediately after harvesting (Fresh weight) and was measured after drying in an oven at 75oC for 48 hrs and the weight was measured using an electronic weighing balance.

**Nodule Count**
After 6 weeks of planting, plants were harvested using a sharp scissor to cut the shoot from the plant base. The roots were immediately washed in a 2 mm sieve using water to remove soil and prevent detached nodules from flowing off with the water. The nodules were separated from the roots for counting.

**Nodule Weight (**Fresh and Dry**)**
Fresh nodule weight in grams (g) was measured immediately after harvesting. The nodules were oven-dried at 75oC for 48 hrs and dry weight of the nodule was obtained.

**Nodule Percentage Effectiveness**
Nodules from each treatment were selected randomly and cut open with a blade to determine the effective ones. Nodules with pink to reddish-brown color were considered effective while nodules with green or dark color were considered ineffective (Gwata *et al.,* 2022). The percentage effective numbers were recorded.

**Statistical analysis**: All data collected were subjected to Analysis of Variance (ANOVA) using the GLM procedure of SAS (SAS Institute, 2012). Comparisons between significant treatment means were made by the Duncan's Multiple Range Test (DMRT) at a 5 % level of significance.

**RESULTS AND DISCUSSION**
**Soil physical and chemical properties before sowing**
The result of the particle size analysis showed that the soil contains 809 g kg-1, 56 g kg-1, and 135 g kg-1 of sand, silt, and clay respectively given a textural class of Loamy Sand. The pH in 1:2.5 H20 (6.36) was moderately acidic. The organic carbon (10.8 g kg-1) was moderate and total nitrogen (1.19 g kg-1) was moderately low, available phosphorus (3.36 mg kg-1) was low. The calcium (2 cmol kg-1) was low, potassium (0.33 cmol kg-1), sodium (0.68 cmol kg-1) and magnesium (2.8 cmol kg-1) were all moderate. The Exchangeable acidity value (0.6 cmol kg-1) was very low according to Chude *et al*., (2011).

**Effect of Herbicides on Cowpea Shoot and Root Biomass**
The effect of herbicides on cowpea shoot dry biomass of Sampea 14 as shown in Figure 1 shows that manual weeding recorded the highest biomass followed by PE, while WC and PPE had the least shoot biomass. The MW had 42 % of the shoot dry biomass than WC, 47 % shoot dry biomass than PPE, and 6 % shoot dry biomass than PE, while PE had shoot dry biomass of 39 % than PPE and 35 % shoot dry biomass than WC respectively. The effect of weed control on root dry biomass of Sampea 14 as represented in Figure 2 shows that MW recorded the highest root dry biomass followed by PE, PPE, and WC recorded the least root biomass. The MW had the highest root biomass of 100 % than the WC, 69 % than PE+MW, and 91 % than PPE, while the PE had a higher root biomass of 13 % than PPE and 18 % than WC, while PPE had 5 % root biomass than WC.
The results of this study revealed that the effect of different weed control methods employed significantly affected the performance of cowpea growth. The presence of weeds in the WC control significantly hindered cowpea growth, this could be as a result of competition for nutrients and water. In contrast, the weed-free condition evident on MW, PE+MW, and PPE-treated plots could have resulted in efficient utilization of nutrients and water by cowpea plants due to reduced weed competition. The various shoot and root dry biomass was significantly influenced by different weed control treatments. MW recorded maximum shoot

and root dry biomass, this shows that the reduction in shoot and root dry biomass was apparently due to growth and yield components caused by weed infestation in WC plots.

Herbicides may affect soil microflora, beneficial microflora, and their activities by affecting plant growth or by directly affecting nitrogen-fixing organisms and their efficiency. There are complex processes that are affected by herbicides. The overall effect of herbicides is reflected in dry matter production. Either above-ground plant growth or root growth or both can be affected by the herbicides.

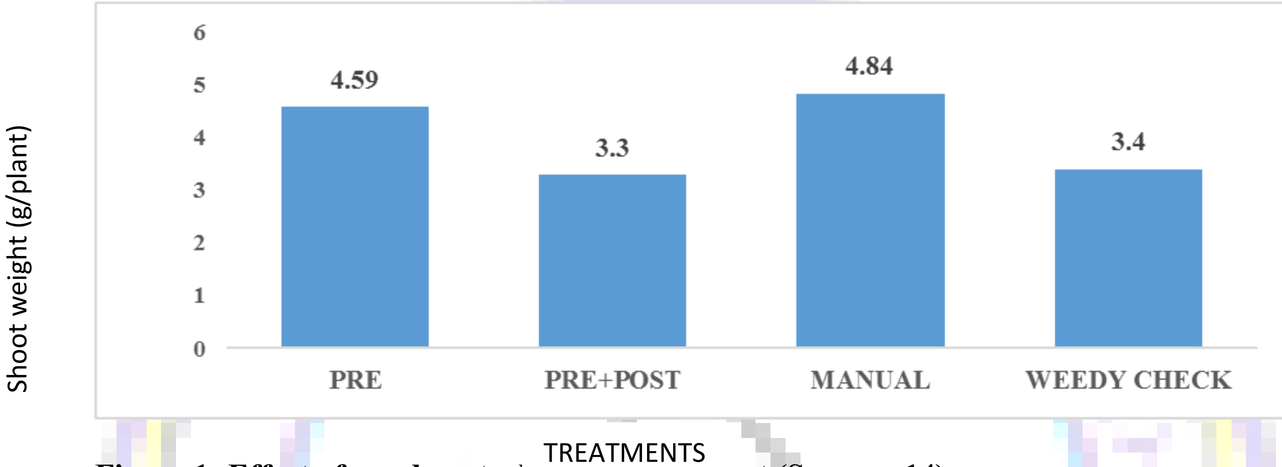


**Figure 1: Effect of weed control on Cowpea shoot (Sampea 14)**

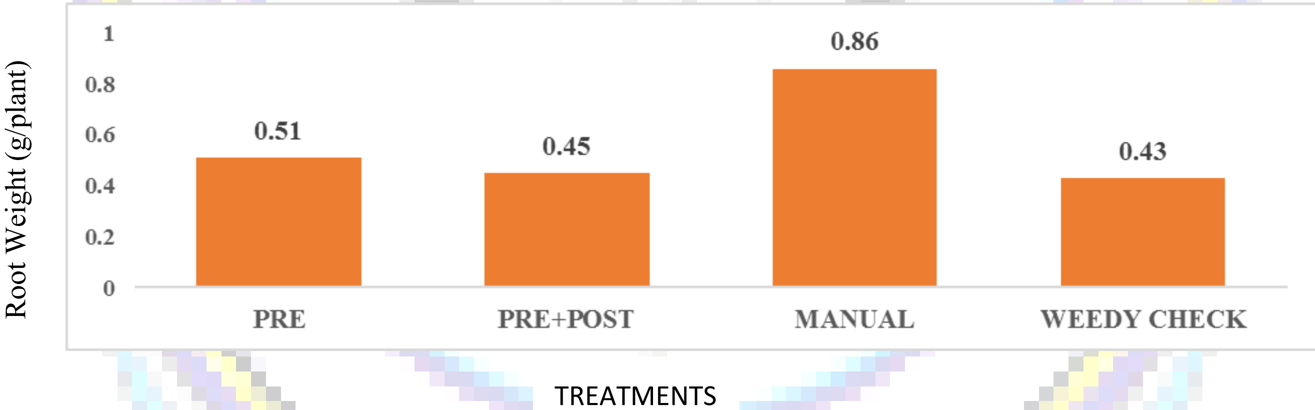


**Figure 2: Effect of weed control on Cowpea root (Sampea 14)**

**The effect of herbicides on the number of nodules and effectiveness**
The effect of herbicides on the number of nodules of Sampea 14 as shown in Figure 4 shows that MW had the highest number of nodules followed by WC, PE+MW recorded the least number of nodules, PPE had no nodule, MW100 % over PE+MW and 60 % than weedy check, while WC had 25 % than PE. The nodule effectiveness of Sampea 14 as represented in Figure 5 shows that MW recorded the highest effectiveness followed by PE and WC. MW had 100 % of the mean differences than the WC and PE+MW because there was no weed competition and the effect of herbicides on nodule effectiveness, MW nodule tends to be

more effective. This result agrees with other researchers that herbicides can influence the success of legume-rhizobium symbiosis either by affecting the plant or rhizobium or both (Aderson *et al*., 2004). Although many researchers have concluded that the effect of herbicide application on symbiotic partnership is due largely to a direct effect of herbicide on plant growth and consequent photosynthate allocation to the nodules (Ayaz *et al.,* 2001). High concentrations of the herbicides significantly reduce the number of nodules. The results of this study agree with earlier observations that the application of some selected herbicides to soil inhibited nodulation and nitrification in leguminous crops (Singh and Wright,1999). Scientists have reported a decrease in microbial activity when a double quantity of glyphosate was applied to two Romanian soils (Sumalan *et al*., 2010). A low rate of herbicides has been recommended for weed control, to ensure effective nodulation and nitrogen fixation (Osipitan, 2017). The reduced number of nodules recorded with high herbicide concentrations could be attributed to the inhibitory effects of these pesticides on the leguminous crop under symbiotic *Rhizobium*-legume interactions in the soil. Gupta *et al.* (2002) by their experimentation, led to conclude that, the herbicide application can result in substantial loss of nodules from the roots, likely due to the herbicide-induced stress on the plant *Rhizobium* symbiosis.

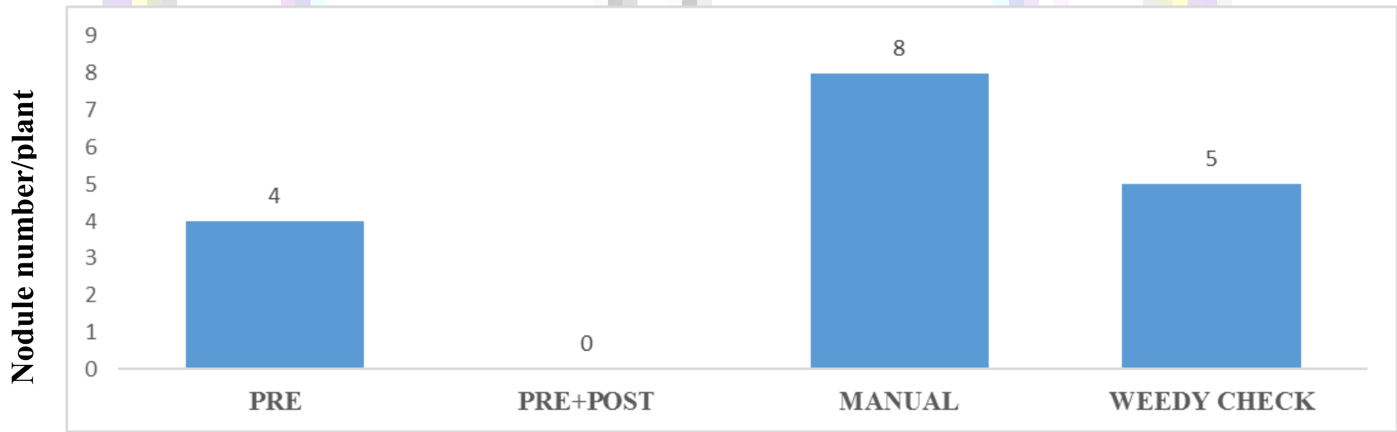


**Figure 3:** **Effect of weed management ... pea 14)**

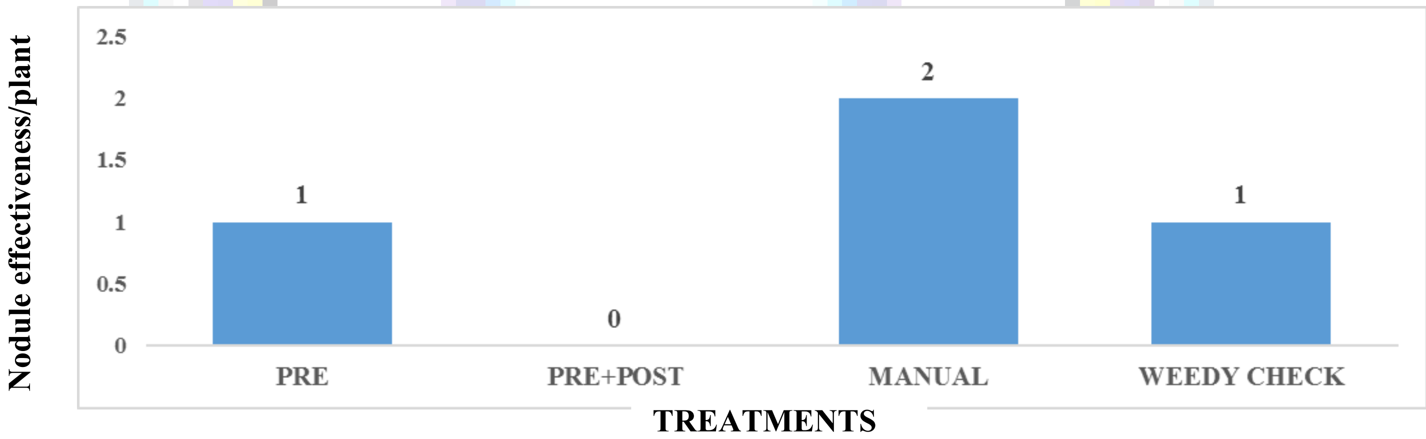


**Figure 4:** **Effect of herbicides on Nodule effectivenss (Sampea 14)**

**The effect of herbicides on nodule dry weight**

The effect of herbicides on nodule dry weight of Sampea 14 as represented in Figure 7 shows that MW recorded the highest nodule weight followed by WC, PE+WC, PPE treatment had no record on dry weight, MW recorded 100 % than PE+MW, and WC. The beneficial effects of rhizobia on nodulation are that it enhances nitrogen fixation which by symbiotic N2–fixing bacteria on the morphology and physiology of the root system which promotes vegetative growth. These results were in agreement with those obtained by Bin Ishaq (2002) and El–Waraky et *al.* (2013) on peas which showed a significant increase in the nodule dry weight and seed yield compared with the WC.

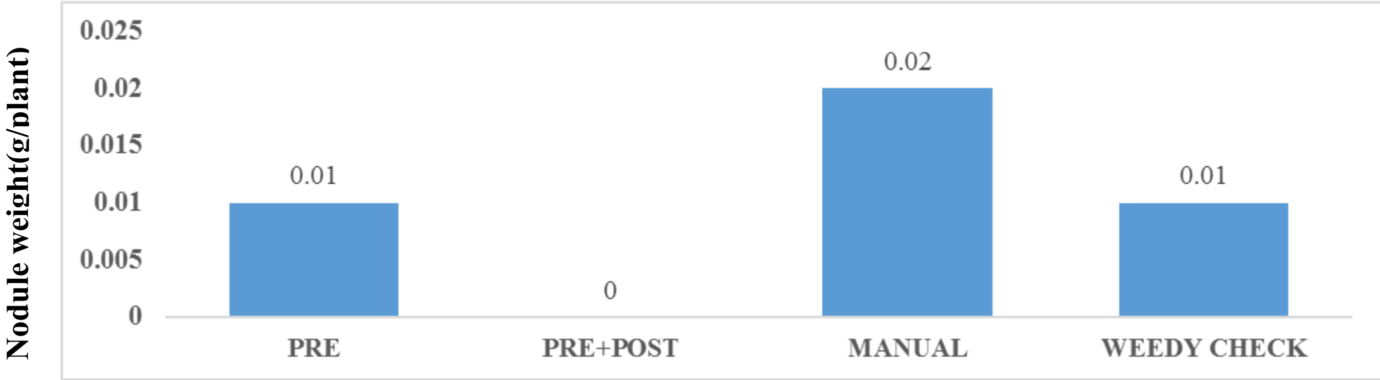


**Figure 5: Weed management on Nodule Dry Weight (Sampea 14)**

Although this research contradicts many studies that herbicides affect nitrogen fixation largely via indirect effects on plant growth and consequent availability of photosynthate to the root nodules (Fran *et al*., 2006), there is evidence that some herbicides might impair the ability of the rhizobia to recognize appropriate host plants. However, according to Fran *et al*., (2006), not all herbicides had a negative impact on nodulation and the degree to which nodulation was inhibited was dependent on herbicide concentrations. These contrasting results suggest that the impact of various herbicides on specific nodulation events may be highly dependent on specific environmental conditions, including different soil characteristics (i.e., pH, organic matter, moisture, etc.) and weather conditions.

In conclusion, the overall result of the experiment showed that the application of herbicides had a hazardous effect on the nodulation characteristics of cowpeas. The treatment with manual weeding produced an overall outstanding effect on the nodulation and yield characteristics. The herbicide application resulted in great loss of nodules from the roots, likely due to the herbicide causing stress to the plant-rhizobium symbiosis. The ability of the plant to support a healthy relationship with the rhizobia housed in root nodules. Thus, when assessing the potential for any chemical treatment to have an impact on nitrogen fixation, chemicals that have less negative effect on the plant should be applied, because nodules depend on the host plant for energy supply (in the form of plant photosynthates), striving to maintain healthy, actively growing plants is the first step in achieving optimal levels of nitrogen fixation. Thus, although the research demonstrates the possibility for herbicides to affect nodulation via root hair deformations, it is not known if this phenomenon occurs under field conditions. Therefore, there is an urgent need to conduct further studies on the effect of different herbicides on nodulation and yield characteristics of cowpeas *in situ.*

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# THE ROLE OF SPICES IN THE PREVENTION OF MICROBIAL FOOD SPOILAGE: A REVIEW

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## ABSTRACT
This review is to provide in-depth insight into the use of spices as natural preservatives against spoilage microorganisms of food origin. The safety of spices is primarily based on their antimicrobial properties. Spices and herbs are gaining prominence in the food industry as natural alternatives to synthetic preservatives, driven by their antimicrobial properties and alignment with clean-label consumer preferences. Spices rich in essential oils and bioactive compounds such as phenolics and terpenoids, include clove, thyme, oregano, rosemary and sage which exhibit significant efficacy against spoilage and pathogenic microorganisms, such as Salmonella, Escherichia coli and Listeria monocytogenes. These properties enhance food safety, extend shelf life, and improve overall product quality. Furthermore, the integration of essential oils into edible coatings and packaging materials offers innovative preservation solutions, reducing reliance on synthetic additives. However, the microbiological safety of spices themselves is critical, as contamination during production and processing can pose food safety risks. Implementing stringent quality controls and processing standards is essential to maximize their benefits. As consumer demand for natural food preservation grows, further research into the mechanisms and applications of spice-derived antimicrobials is crucial to optimize their use in modern food systems.
**Keywords:** Food spoilage, spices, antimicrobial activities, microorganisms, preservation

## INTRODUCTION
Food spoilage caused by microorganisms is a major concern in food production and storage, resulting in quality degradation and potential health hazards. Traditional preservation methods include refrigeration, drying, and chemical additives. However, increasing consumer preference for natural and minimally processed foods has spurred interest in alternative preservation strategies. Spices, cherished for their flavour and therapeutic properties, have emerged as promising natural preservatives due to their antimicrobial effects. This review assesses the role of spices in preventing microbial food spoilage, focusing on their efficacy and application in food systems. Spices and herbs are increasingly valued in the food industry as natural alternatives to synthetic preservatives due to their rich content of essential oils and bioactive compounds such as allicin found in garlic, eugenol in clove, piperine in black pepper, curcumin in turmeric, gingerol in ginger and carvacrol in oregano. These active compounds possess potent antimicrobial properties that can effectively inhibit the growth of spoilage and pathogenic microorganisms, such as *Salmonella, Escherichia coli,* and *Listeria monocytogenes,* thereby enhancing food safety and extending shelf life (Arshad and Batool, 2017, Rao *et al*., 2019 and Gottardi *et al*., 2016). Given the increased global demand for more natural and organic foods and the growing interest in spicy food, an attempt has been made to review the role of spices as a potential preservative.

## SPICES AND FOOD SPOILAGE
The antimicrobial activity of spices arises from their complex chemical composition, including phenolics, terpenoids, and other phytochemicals. These substances not only combat microbial growth but also improve the overall quality of food products (Gottardi *et al*., 2016

and Juneja *et al*., 2012). For instance, essential oils from rosemary and sage demonstrate strong antimicrobial effects and are increasingly incorporated into food coatings and packaging materials to further suppress microbial contamination (Aloui and Khwaldia, 2016 and Royo *et al*., 2010). This natural approach aligns with the growing consumer demand for clean-label products that exclude synthetic additives (Saeed *et al*., 2019, Aziz and Karboune, 2016). Nevertheless, the microbiological quality of spices themselves can present risks, as contamination during production and processing may lead to the presence of harmful microorganisms. High contamination levels in retail spices highlight the importance of stringent safety protocols to ensure spices do not contribute to foodborne illnesses (Koohy-Kamaly-Dehkordy *et al*., 2013; Székacs *et al*., 2018). Thus, while spices offer promising antimicrobial benefits, maintaining their safety and quality is essential to maximize their effectiveness in food preservation (Paramithiotis and Drosinos, 2010; Hashem and Alamri, 2010). Beyond their direct antimicrobial effects, spices play a significant role in advancing innovative preservation strategies. For example, incorporating essential oils into edible coatings and packaging enhances their antimicrobial properties, extending the shelf life of various food items (Hintz *et al*., 2015; Zubair *et al*., 2022). This dual functionality not only improves food quality but also reduces dependence on synthetic preservatives, addressing health concerns (Saeed *et al*., 2019; Aziz and Karboune, 2016).

## CONCLUSION

In, conclusion spices are a natural and effective tool against microbial spoilage in food. Their antimicrobial properties and ability to improve food safety and quality position make them a viable alternative to synthetic preservatives. Continued exploration of their mechanisms and applications will be key to optimizing their use in sustainable food preservation solutions. Spices hold significant potential as natural preservatives in combating microbial food spoilage. While challenges exist in terms of sensory impacts and variability in efficacy, spices offer a viable alternative to synthetic preservatives, aligning with consumer demand for natural food products.

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# EFFECTS OF CRUSHED GROUNDNUT SHELL AND OTHER SOURCES OF NUTRIENT ON YIELD AND GROWTH OF OKRA (*Abelmoshus esculentus* L.)

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## ABSTRACT

The research was conducted at the Nursery field of Department of Horticulture, School of Agriculture and Agricultural Technology, Federal University of Technology Minna, Gidan kwano campus. The research aimed to assess the effect of crushed groundnut shell solely and in conjunction with poultry dropping on growth and yield of Okra. The experiment comprised 5 treatments (crushed groundnut shell, poultry dropping, poultry dropping and groundnut shell, NPK (15:15:15) and Control each replicated 3 times which was laid out in a Randomized Complete Block Design. The application rates included crushed groundnut shell at the rate of 1.38Kg/plot (0.115 kg per plant), Poultry droppings at the rate of 0.44 Kg/plot [0.036 kg per plant), and a combined rate of crushed groundnut shell (0.095 kg/plant) and (0.009 kg/plant) for poultry droppings, while NPK (15:15:15) at the rate of (0.559kg/plant). Data on various growth and yield parameters such as Plant height, number of leaves, stem girth, days to first flower appearance, days to 50% flowering, days to first fruit appearance, number of fruits and weight of fruit were collected over a period of 12weeks post- sowing. Data collected were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) and Means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability. The result of the study indicated that crushed groundnut shell exhibited a positive impact on the growth and yield of okra akin to the effects observed with chemical fertilizer (NPK 15:15:15). Hence, it is concluded that the application of 1.38kg/plot (0.115 kg/plant) of crushed groundnut shell can serve as a viable alternate to use of chemical fertilizer (NPK 15:15:15) in field experiments in the southern guinea savannah ecological zone of Nigeria.

**Keywords**: Okra, groundnut shell, poultry manure, organic-fertilizer, inorganic-fertilizer

## INTRODUCTION

Okra (*Abelmoschus esculentus*) which is also known as lady's finger is a plant that belongs to Malvaceae family. Almost every parts of this crop plant are useful and also edible, the leaves, seeds, fruits, and pods. Okra is eaten in cooked or processed form and fruits may be eaten raw, the pods are commonly used in numerous spicy vegetable dishes and are also cooked with beef, lamb, chicken and mutton (Willis, 2014; Siemonsma and Kouame, 2004).). Okra like all other crops requires some essential plant nutrients (macro and micro) such as nitrogen, phosphorus, potassium, calcium, magnesium, zinc etc. Groundnuts, being a leguminous crop, are rich in nitrogen, while their shell contains small amount of fat and protein, calcium, phosphorus, potassium and over 10 other essential trace elements (Nirmala *and Vasavi*., 2018). Poultry manure plays a crucial role in organic farming by significantly benefiting crop production. It enhances uniform rainwater infiltration, minimizes direct soil surface water evaporation, conserves soil moisture, promotes soil aeration and effectively manages weed interference. poultry manure is preferred over other animal wastes due to its rich concentration of essential micronutrients such as nitrogen, calcium, phosphorus (Adesina and wiro, 2020; Shuvan *et al*. 2017).

In the tropics, inorganic fertilizers were recommended to enhance the poor natural fertility of soils in crop production, despite their efficacy, issues like insufficient supply, fertilizer unavailability when needed, adulteration, and high expenses have been associated with their adoption and usage (Eze *et al.,*2022). Crushed groundnut shells refer to groundnut shells that have been processed into smaller, granular particles or pieces. Due to their nutritional content, it has sparked interest as a useful organic fertilizer, crushed groundnut shell has the potential to improve the soil structure, and soil nutrient content. Crushing groundnut shells can help release nutrients more easily and quickly, can also accelerate the decomposition of the shells. Organic fertilizers are environmentally safe since they are derived from natural sources, and they are gaining popularity globally due to the fact that they are ecologically friendly, safe, and beneficial to human health (Breman, 2020). Breman (2020) reported that organic fertilizers, like crushed groundnut shell supply nutrient required for plants, increase the productivity and quality of agricultural crop yields, and include substances that promote growth such as indole acetic acid (IAA), gibberellic acid (GA), as well as beneficial microbes. Apart from pollution, the cost of inorganic fertilizer can indeed be relatively high, and this can be a barrier to adoption for farmers especially those in regions with limited resources (Smith *et al,* 2019). Poultry droppings (cured) are traditionally readily accessible and cost free, has become increasingly scarce and costly due to its high demand in recent time. Groundnut shells are known for their affordability and accessibility making them a practical resource for farmers to utilize. The aim of this study therefore is to determine whether poultry droppings alone or in combination with granulated groundnut shell have any impact on okra plant growth and yield.

## MATERIALS AND METHODS

**Description of The Study location:** The study was carried out at the Nursery of Department of Horticulture, School of Agriculture and Agricultural Technology, Federal university of Technology (FUT), Minna, Niger State with average rainfall of 1,100mm. The rainfall is distributed between April and early October of each year. The temperature ranges from $35^0$ C and $37^0$ C while relative humidity is between 40% and 80%.

### Pre-planting Soil collection and Analysis

In order to assess the nutrient status of the experimental site, the soil sample was collected after the land preparation using hand trowel and polythene bags, randomly from each plot at the experimental site and it was taken to the Department of Soil and Land Management laboratory for analysis. The sample was analyzed for textural class, pH, organic carbon, exchangeable bases and acidity.

### Crushed groundnut shell analysis

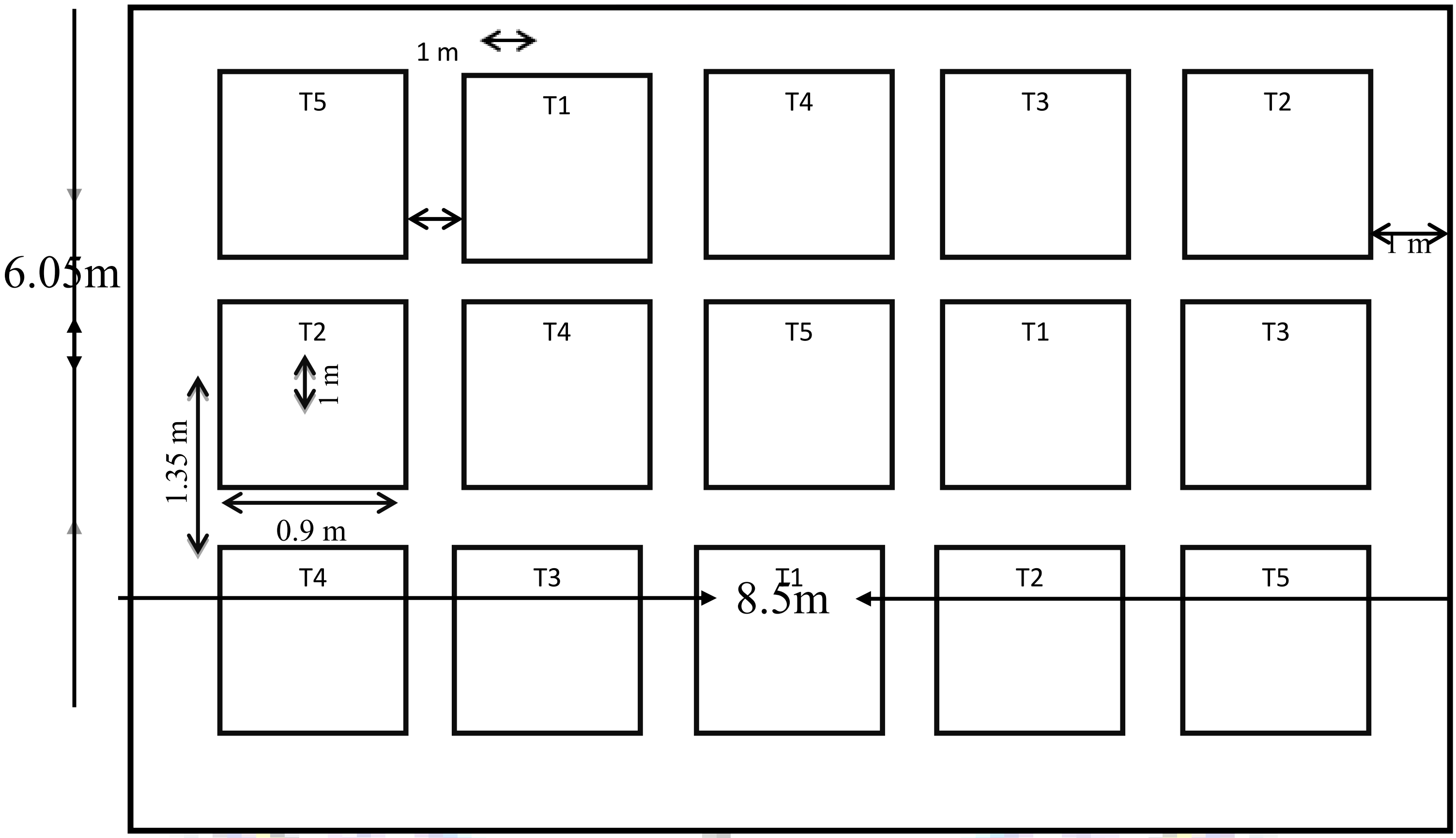
The Crushed groundnut shell obtained was taken for analysis at the laboratory of the Department of Soil science and Land Management, Federal university of Technology (FUT), Minna, Niger state. The sample was analyzed for its Nitrogen, Phosphorus, Potassium content.

### Poultry droppings analysis

The poultry dropping analysis obtained was taken for analysis at the laboratory of the Department of Soil science and Land Management, Federal university of Technology (FUT), Minna, Niger state. The sample was analyzed for its Nitrogen, Phosphorus, Potassium content.

**Experimental design and treatment**

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments and 3 replicates.




**Data Collection:** The following vegetative, reproductive and yield data was collected during the pre-harvest and post-harvest stages of the experiment:

**Statistical data analysis**: Data collected was subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) to test significance of nutrient effect and means will be separated using Duncan Multiple Range Test (DMRT).

**RESULTS**

**Plant height of okra as affected by crushed groundnut shell and other sources of nutrients at 2,4,6 and 8 WAS**

The effect of crushed groundnut shell and other sources of nutrient on plant height at 2,4,6 and 8 WAS are shown in table 1 At 2WAS, there was no significant ($P>0.05$) difference amongst the treatments, although groundnut shell (11.00cm) produced the tallest plants while PD(8.17cm) produced the shortest. At 4WAS, no significant ($P>0.05$) difference was observed amongst the treatments but groundnut shell (15.67cm) produced the tallest while

PD (7.67cm) yielded the shortest plants. At 6WAS, significant (P<0.05) differences were observed amongst the treatments (Table 4.3). Groundnut shell (18.00cm) had the tallest plant height followed by NPK (16.00cm) and control (13.00cm) while the mixture of poultry droppings and groundnut shell and poultry droppings produced similar value as the shortest plants (11.00cm). At 8WAS, all treatments effects were not significantly different (Table 4.3). However, Groundnut shell (26.00cm) produced the tallest while control plants were the shortest (16.33cm).

Table 1 **Effect of crushed groundnut shell and other sources of nutrient on plant height of okra at 2,4,6 and 8(Week after planting) WAS**

| | Plants height(cm) | | | |
|---|---|---|---|---|
| Treatment | 2WAS | 4WAS | 6WAS | 8WAS |
| C | 9.87$^{a}$ | 11.83$^{a}$ | 13.00$^{ab}$ | 16.33$^{a}$ |
| GNS | 11.00$^{a}$ | 15.67$^{a}$ | 18.00$^{a}$ | 26.00$^{a}$ |
| NPK | 10.47$^{a}$ | 13.50$^{a}$ | 16.00$^{ab}$ | 22.17$^{a}$ |
| PD+GNS | 9.33$^{a}$ | 10.17$^{a}$ | 11.00$^{b}$ | 19.33$^{a}$ |
| PD | 8.17$^{a}$ | 7.67$^{a}$ | 11.00$^{b}$ | 18.33$^{a}$ |
| SE± | 0.97 | 2.37 | 1.75 | 3.14 |

Means with the same letter (s) in a column are not significantly different at 5%level of probability. SE± = Standard Error

Keys: C=Control, GNS: Groundnut shell, NPK=(NPK 15:15:15), PD+GNS=50% Poultry dropping+50% Groundnut shell, PD=Poultry droppings

**Number of leaves of okra as affected by crushed groundnut shell and other sources of nutrients at 2,4,6 and 8 WAS**

The effect of crushed groundnut shell and other sources of nutrient on number of leaves at 2,4,6 and 8 WAS are shown in table 2. At 2 WAS, all treatments recorded statistically similar number of leaves, although control and groundnut shell had the highest number of leaves (9.33 leaves) while poultry droppings produced the lowest number of leaves. At 4 WAS, no significant at (P>0.05) difference was observed amongst the treatments (Table 2) The highest number of leaves were recorded in control plants (7.67 leaves) while poultry droppings produced the lowest number of leaves. At 6 WAS, number of leaves varies significantly (p<0.05) amongst the treatment. However, the mixture of poultry dropping and groundnut shell (12.33 leaves) produced the most number of leaves followed by control plants and NPK which recorded same number of leaves (9.67 leaves) while the smallest number of leaves were observed in groundnut shell (8.00 leaves). At 8 WAS, there was no significant (p>0.05) difference amongst all treatments. Although, the mixture of poultry droppings and groundnut shell produced the highest number of leaves (17.67 leaves) while groundnut shell (12.33 leaves) had the smallest number of leaves.

**Table 2: Effect of crushed groundnut shell and other sources of nutrient on number of leaves of okra at 2,4,6 and 8(Week after planting) WAS**

| | Number of leaves | | | |
|---|---|---|---|---|
| Treatment | 2WAS | 4WAS | 6WAS | 8WAS |
| C | 9.33$^{a}$ | 7.67$^{a}$ | 9.67$^{ab}$ | 12.67$^{a}$ |
| GNS | 9.33$^{a}$ | 6.67$^{a}$ | 8.00$^{b}$ | 12.33$^{a}$ |
| NPK | 7.00$^{a}$ | 8.33$^{a}$ | 9.67$^{ab}$ | 14.67$^{a}$ |
| PD+GNS | 6.33$^{a}$ | 7.33$^{a}$ | 12.33$^{a}$ | 17.67$^{a}$ |
| PD | 6.00$^{a}$ | 5.33$^{a}$ | 8.33$^{a}$ | 17.67$^{a}$ |
| SE± | 1.40 | 1.21 | 1.10 | 2.22 |

Means with the same letter (s) in a column are not significantly different at 5%level of probability. SE± = Standard ErrorKeys: C=Control, GNS: Groundnut shell, NPK=(NPK 15:15:15), PD+GNS=50% Poultry dropping+50% Groundnut shell, PD=Poultry dropping

**Number of fruits and fruit weight of okra as affected by crushed groundnut shell and other sources of nutrients at 2,4,6 and 8 WAS**

The effect of crushed groundnut shell and other sources of nutrient on number of fruits and fruits' weight of okra are shown in Table3. There was no significant ($p>0.05$) difference in number of fruits amongst the treatments, although groundnut shell (11.33) produced the most number of fruits while the least number of fruits was recorded in control plants (3.00). Fruit weight varied significantly ($p<0.05$) amongst all the treatments. The heaviest fruit weight was recorded in groundnut shell (102.20g), followed by poultry droppings(74.81g) and mixture of poultry droppings and groundnut shell (72.07g) while control plants had the heaviest weight(22.56g).

**Moisture content crude protein, crude fiber, ash, fat and carbohydrate as affected by crushed groundnut shell and other sources of nutrients**

The effect of crushed groundnut shell and other sources of nutrient on moisture content, crude protein, crude fiber, ash, fat and carbohydrate of okra as shown in Table 4. In moisture content there was no significant ($p>0.05$) difference amongst the treatments, NPK had the highest moisture content (30.17%) while the mixture of poultry droppings and groundnut shell (28.50%) had the highest percentage of crude protein, while control, groundnut shell and NPK and poultry droppings recorded similar statistical values. All treatments recorded the same valve for crude fiber (0.50%). Ash content did not vary significantly ($p>0.05$) amongst the treatments. Although control and groundnut shell had the highest percentage (0.50%) while NPK, and mixture of poultry droppings and groundnut shell had similar lower percentage (0.33%). All treatments recorded the same valve for fat content (0.06%). There was no significant ($p>0.05$) differences in carbohydrate content amongst the treatments.

**Table 3: Effect of crushed groundnut shell and other sources on number of fruits and fruits' weight of Okra**

| Treatment | Number of fruits | Total fruit weight |
|---|---|---|
| C | 3[a] | 22.56[b] |
| GNS | 11[a] | 102.20[a] |
| NPK | 4[a] | 34.18[ab] |
| PD+GNS | 9[a] | 72.07[ab] |
| PD | 8[a] | 74.81[ab] |
| SE± | 2 | 21.60 |

Means with the same letter (s) in a column are not significantly different at 5%level of probability. SE± = Standard Error **Keys**: C=Control, GNS: Groundnut shell, NPK= (NPK 15:15:15), PD+GNS=50% Poultry dropping+50% Groundnut shell, PD=Poultry droppings

However, the mixture of poultry droppings and groundnut shell (3.75%) had the highest percentage while NPK (2.23%) recorded the lowest value.

**DISCUSSION**

The use of crushed groundnut shell resulted in the tallest plants and highest yield, consistent with Nimala and Vasavi, (2018) findings, indicating that employing crushed groundnut shell as a substitute for inorganic fertilizers enhanced vegetable plant growth and acted as an effective organic fertilizer. From the results gotten from this study, the application of NPK (15:15:15) yielded the tallest and widest stem girth aligning with the findings of (Eze et al., 2022) who reported similar outcomes associated with NPK application.

**Table 4: Effect of crushed groundnut shell and other sources of nutrient on moisture content, crude protein, crude fiber, ash, fat and carbohydrate of Okra**

| Treatment | MOISTURE | CRUDE PROTEIN | CRUDE FIBER | ASH | FAT | CHO |
|---|---|---|---|---|---|---|
| C | 29.00[a] | 0.07[b] | 0.50[a] | 0.50[a] | 0.06[a] | 3.21[a] |
| GNS | 29.17[a] | 0.03[b] | 0.50[a] | 0.50[a] | 0.06[a] | 3.08[a] |
| NPK | 30.17[a] | 0.05[b] | 0.50[a] | 0.33[a] | 0.06[a] | 2.23[a] |
| PD/GNS | 28.50[a] | 0.17[a] | 0.50[a] | 0.33[a] | 0.06[a] | 3.75[a] |
| PD | 28.83[a] | 0.03[b] | 0.50[a] | 0.33[a] | 0.06[a] | 3.58[a] |
| SE± | 0.70 | 0.02 | 0.08 | 0.12 | 0.01 | 0.46 |

Means with the same letter (s) in a column are not significantly different at 5%level of probability. SE± = Standard Error
Keys: C=Control, GNS: Groundnut shell, NPK= (NPK 15:15:15), PD+GNS=50% Poultry dropping+50% Groundnut shell, PD=Poultry dropping, CHO= Carbohydrate

## CONCLUSION

Crushed groundnut shell produced the higher number of fruits followed by the mixture of poultry droppings and crushed groundnut shell and control produced the lowest number of fruits. It is therefore recommended that the application of crushed groundnut shell as an effective alternate source to chemical fertilizer to enhance the yield of okra without affecting the fertility of the soil and environment.

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# EVALUATION OF DURUM WHEAT (*Triticum turgidum* L.) PERFORMANCE IN JEGA, SUDAN SAVANNA, OF NIGERIA.

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**ABSTRACT**

Production of wheat in the Sudan savanna agro ecological zone of Nigeria is restricted to period of low temparature that prevailed from early November to late February. The general approach for wheat in this region is to relate the varietal differences and performance, the experiment was conducted at University Teaching and Research Farm during 2019/2020 dry season to determine the varietal performance in the study area. Days to 50% heading, days to physiological maturity, plant height and tiller per plant of F1 Durum wheat varieties are presented in Table 1. Durum wheat F1 variety entries showed no significant difference on days to 50% heading. However, in terms of days to physiological maturity, F1G matured significantly earlier than the other varieties. Result of plant height and tiller per plant showed significant difference among varieties as presented in Table 2. Entries F1A, F1B, F1C, F1D, F1E, F1I and F1J recorded statistically similar and taller plants than entries F1F, F1G and F1H. Tiller per plant was significantly influenced by durum wheat where all the entries produced significantly more tillers than entry F1A. Result of plant height and tiller per plant showed significant difference among varieties as presented in Table 2. Entries F1A, F1B, F1C, F1D, F1E, F1I and F1J recorded statistically similar and taller plants than entries F1F, F1G and F1H. Tiller per plant was significantly influenced by durum wheat where all the entries produced significantly more tillers than entry F1.

**Keywords**: Durum wheat, Evaluation, Performance, Sudan savanna,

## INTRODUCTION

Durum wheat (*Triticum turgidumL. var. durum*) is one of the most important food crops in semi-arid tropics (Nachit and Ouassou,1998). It is the most widely cultivated cereal in the world (Kemthorne,2014). It is a temperate crop mainly produced in Europe, America, Asia, and northern and southern Africa (Olabanji, 2014). It's an annual plant growing between 0.5 to 1.5m in height, with along stalk that terminates in a tightly form cluster of plump kernels enclosed by abeard of bristly (Smith, 2010). Wheat is the most widely cultivated cereal in the world (kemthorne, 2014). It is essentially a temperate crop whose production is mainly in Europe, America, Asia, and northern and southern Africa (Olabanji, 2014). The cultivation of the crop date back to sixteenth century and is successfully cultivated under small quantity irrigation in west and central Africa on high altitude (Raemaekers, 2001). Durum wheat, also called pasta wheat or macaroni wheat (*Triticum durum or Triticum turgidum subsp. durum),* is a tetraploid species of wheat. It is the second most cultivated species of wheat after common wheat, although it represents only 5% to 8% of global wheat production. It was developed by artificial selection of the domesticated emmer wheat strains formerly grown in Central Europe and the Near East around 7000 BC, which developed a naked, free-threshing form. Like emmer, durum wheat is awned (with bristles). It is the predominant wheat that grows in the Middle East.

## MATERIALS AND METHODS

**Experimental site**

The experiment was conducted at Kebbi State of University of Science and Technology Teaching and Research Farm during 2019/2020 dry season. The area is located in Kebbi State in Sudan Savannah agro-ecological zone of Nigeria. The climate of the area is characterized by annual rainfall range from 550-700mm and temperature average between 27- 30°C during dry season and 27°C and 41°C during the raining season and the relative humidity range from 21 to 47 percentages in the dry season and 51 to 79 percentages during rainy season. The area characterized by long dry season with a cool air during hammatan (November to February), followed by short rainy season may/June to September/October (Anonymous, 2011).

**Treatment and Experimental Design**

The experiment consisted of thirty treatments and was laid out in a Randomized Complete Block Design (RCBD).

**Data Analysis**

The data generated was subjected to Analysis of Variance (ANOVA), using SPSS software version 2003.The treatment mean was separated using the Least Significance Difference (LSD) at 0.05% level of probability.

## RESULTS AND DISCUSSION

Days to 50% heading, days to physiological maturity, of F1 Durum wheat varieties are presented in Table 1. Durum wheat F1 variety entries showed no significant difference on days to 50% heading. However, in terms of days to physiological maturity, F1G matured significantly earlier than the other varieties except F1D, F1H and F1J only.

**Table 1: Variation on days to 50% heading and physiological maturity of F1 Durum wheat entries during the dry season of 2019/2020 at Jega, Sudan Savanna of Nigeria**

| Treatments | Days to 50% heading | Days to physiological maturity |
|---|---|---|
| F1A | 48.67 | 90.66bc |
| F1B | 48.00 | 99.66a |
| F1C | 48.00 | 98.66a |
| F1D | 47.33 | 99.33a |
| F1E | 52.00 | 96.00ab |
| F1D | 50.33 | 90.66bc |
| F1G | 49.00 | 90.00c |
| F1H | 51.66 | 92.00bc |
| F1I | 46.66 | 95.33ab |
| F1J | 51.66 | 94.67abc |
| **LSD (0.05)** | 6.25 | 5.80 |

Means followed by the same letter (s) within a treatment group are not significantly different at 5% using LSD. NS = not significant at 5%. WAS= Weeks after Sowing.

Result of plant height and tiller per plant showed significant difference among varieties as presented in Table 2. Entries F1A, F1B, F1C, F1D, F1E, F1I and F1J recorded statistically similar and taller plants than entries F1F, F1G and F1H. Tiller per plant was significantly different among the durum wheat entries where all the entries produced significantly more tillers than entry F1A only.

**Table 2: Variation in plant height at 8WAS and tiller per plant of F1 Durum wheat entries during dry season of 2019/2020 at Jega, Sudan Savanna, Nigeria**

| Treatments | Plant height (cm) | Tiller per plant |
|---|---|---|
| F1A | 49.70ab | 5.66b |
| F1B | 45.46ab | 6.60ab |
| F1C | 46.03ab | 7.00a |
| F1D | 43.20ab | 6.00ab |
| F1E | 43.20ab | 6.33ab |
| F1D | 39.16b | 6.00ab |
| F1G | 38.53b | 6.66ab |
| F1H | 37.86b | 6.33ab |
| F1I | 44.73ab | 6.66ab |
| F1J | 37.98cd | 6.33ab |
| **LSD (0.05)** | **9.96** | **1.31** |

Means followed by the same letter (s) within a treatment group are not significantly different at 5% using LSD. NS = not significant at 5%. WAS= Weeks after Sowing.

## CONCLUSION

Base on the result of this study, Durum wheat give an average yield in Sudan savanna region, Kebbi state inclusive.

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# ASSESING THE EFFECTS OF DIFFERENT NUTRIENT SOURCES ON THE GROWTH, YIELD AND PHYSIOLOGICAL PROPERTIES OF FLUTED PUMPKIN (Telfairia occidentalis HOOK F.)

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**ABSTRACT**

The study location was at the Department of crop production farm, horticultural unit, School of Agriculture and Agricultural Technology, Federal University of Technology Minna, Gidan Kwano campus. The study was to Assess the effects of different nutrient source on the growth, yield and physiological properties of Fluted pumpkin (Telfairia ocidentalis). The experiment involved four (4) treatments (Groundnut shell, poultry manure, NPK (15:15:15) and mixture of NPK (15:15:15) and Groundnut shell replicated 3 times. The field experiment was laid out in a Randomized Complete Block Design (RCBD). Therefore, groundnut shell at the rate of 200g per plot was applied. Poultry manure at the rate of 200g per plot was applied. NPK (15:15:15) at the rate of 66.7g per plot was applied. Mixture of NPK (15:15:15) and Groundnut shell at rate 133.4g per plot was applied. Data were collected on growth, yield ABSTRACT The study location was at the Department of Crop Production farm, horticultural unit, School of Agriculture and Agricultural Technology, Federal University of Technology Minna, Gidan Kwano campus. The study was to Assess the effects of different nutrient source on the growth, yield and physiological properties of Fluted pumpkin (Telfairia ocidentalis). The experiment involved four (4) treatments (Groundnut shell, poultry manure, NPK (15:15:15) and mixture of NPK (15:15:15) and Groundnut shell replicated 3 times. The field experiment was laid out in a Randomized Complete Block Design (RCBD). Therefore, groundnut shell at the rate of 200g per plot was applied. Poultry manure at the rate of 200g per plot was applied. NPK (15:15:15) at the rate of 66.7g per plot was applied. Mixture of NPK (15:15:15) and Groundnut shell at rate 133.4g per plot was applied. and physiological parameters viz: vine length, number of leaves, stem girth, leaf area, leaf weight, selected Vitamins (A and C) and selected Minerals (mg, P, Ca, and K). Data collected were subjected to analysis of variance (ANOVA). Means were separated using least significant difference (LSD) and statistical means were tested at 5% level of probability. The result of the study showed that N:P: K 15:15:15 fertilizer has the highest growth and yield parameters compared to poultry manure and groundnut shell. However, poultry manure and the combination of NPK and groundnut shells also demonstrated significant potential, producing relatively good yields while offering additional benefits such as higher rate of mineral properties and vitamins. It was recommended that, for optimal growth and yield of fluted pumpkin, N:P:K 15:15:15 fertilizer should be considered. However, considering the environmental benefits and cost-effectiveness, poultry manure and combinations of NPK and groundnut shells is a suitable alternative for farmers, particularly those interested in organic farming practices.

**Keywords**: Teliferia, Ugwu, groundnut shell, yield, vitamins, minerals, nutrition

## INTRODUCTION

Fluted pumpkin (*Telfeiria occidentalis*) is a member of the Cucurbitaceae family and is characterized as a perennial vine cultivated primarily for its highly nutritious leaves and seeds (Schippers, 2017). Originating from southeastern Nigeria, it has been historically grown by the Igbo people, who have cultivated this crop for centuries (Adebisi-Adelani *et al*., 2019). It is also possible that the wild ancestors of fluted pumpkin were once more widespread, but the wild forms may have been over-harvested and replaced by cultivated varieties. Today, fluted pumpkin is one of the most significant and widely grown crops in Africa, valued for both its nutritional benefits and economic contributions. (Adebisi-Adelani *et al,* 2019). Agricultural production in Nigeria is primarily driven by small-scale farmers who are responsible for producing most of the country's food supply. Among the key crops they grow is fluted pumpkin, a vital component of Nigerian agriculture and an important ingredient in the national cuisine (Nwangwa *et al.*, 2017). Agriculture stands as the largest sector in Nigeria's economy, employing 70% of the workforce, contributing over 40% to the gross domestic product, and providing more than three-quarters of the non-oil foreign exchange earnings (Ajekigbe, 2017). Fluted pumpkin (*Telfairia occidentalis* Hook F.) is a highly valued vegetable in West Africa. This leafy plant produces fruits and is classified within the Cucurbitaceae family (Enabulele and Uavbarhe, 2001). Leafy vegetables, as defined by Tindall (1989), are herbaceous plants used in cooking to enhance the nutritional value of dishes. The mature fruit of the fluted pumpkin weighs about 10 kg and features 10 distinct longitudinal ribs. The vegetable is popular in West Africa for its large red seeds, leaves, and young shoots, which are used in traditional soups. The protein-rich seeds can be roasted or ground into porridge, while the fruit's flesh contains valuable oil that can be used for cooking. Fluted pumpkin is crucial among vegetables due to its role in providing an affordable source of essential minerals and vitamins, complementing diets that are predominantly carbohydrate-based. It is one of the most significant and widely cultivated crops in Africa, contributing to both food security and income generation (Adebisi-Adelani *et al.*, 2011). The consumption of fluted pumpkin has increased over time and remains a staple in the diets of many Nigerians (Okoli and Mgbeogu, 2003). Its hypolipidemic properties help lower blood cholesterol, which can reduce the risk of various health issues such as heart disease, hypertension, and diabetes (Margret, 2011).

The use of chemical fertilizer has been the dominant practice in fluted pumpkin cultivation, but environmental and health concerns have highlight the need for alternative nutrients as the residual effect of synthetic fertilizer has contributed to the highly increasing rate of greenhouse gas emission (GEG) which has increased by 20% in the recent time (Agromondis, 2023).Organic and integrated fertilizer options have shown promises but their effect on growth, yield and physiological properties are not well understood. Low soil fertility has been recognized as one of the major production constrains affecting agriculture in the sub Saharan Africa (Aderi *et al,* 2018) Production of fluted pumpkin are majorly done by poor resource base farmers (Spore, 2015) wrote about pumpkin production specifically while the shortage and high cost of inorganic fertilizer has limited their use for crop production by peasant farmers in Nigeria and also post a threat on the average user as the residual effect of some of this synthetic fertilizer remain harmful to human health (Taminu *et al,* 2017). Hence this research aimed at determining the effect of poultry manure and groundnut shells on the growth and yield, nutrient uptake and to suggest rate(s) or treatment that will suit its production. Also, it is to study the field comparative effect of poultry manure applications as well as groundnut shells and NPK fertilizers on the growth, plant nutrient composition and fluted pumpkin yield. The aim of this study was to examine the effects of organic (Poultry manure and groundnuts shell) and inorganic fertilizers (NPK 15:15:15) as sole application and in combination (N;P;K 15;15;15 and groundnut shell) on the growth, yield, and physiological properties of fluted pumpkin (*Telfairia occidentalis*)

## MATERIALS AND METHODS

**Study Location:** The study was conducted at crop production department farm behind horticultural unit of Federal university of technology Gidan Kwano campus, Minna, Niger state during the raining season of 2024.

**Sources of planting Materials**: Local variety of fluted pumpkin (*Telfaina occidentallis*) was purchased from a source in Kure local market in Minna Niger State. while other materials such as the polyethylene pots, NPK 15,15,15 fertilizer, meter rule were also gotten from the local market within Niger state.

**Land Preparation:** Land clearing was done manually with the aid of local tools such as Cutlass, Hoe and rake. A total of 35 $m^2$ size of land was used (7 by 5-meter plot size). 12 raise bed were made in accordance with the research treatment requirement with the land spacing of 1 m by 1 m. Poultry manure and ground shell were applied to the required treatments

**Treatments and Experimental Design**

There are four treatments that were replicated three times,

T1 Crushed Groundnut Shells (which was applied at the rate of 2 tons per hectare)

T2 Poultry manure (which was applied at the rate of 2 tons per hectare)

T3 NPK 15:15:15 (applied at the rate of 100kg per hectare)

T4 NPK 15:15:15 and groundnut shells (were evenly applied at the rate of 50kg and 1 ton per hectare respectively).

The experiments were laid out on the field in a randomized complete block design (RCBD)

**Data Collection**

Data were collected based on the following parameters,

Number of leaves: the number of leaves was taken by manual counting of the leaves of the plants

Length of vine (Base to up) ($cm^3$) the length of vine was measure and recorded using a meter rule and a twine by following the pumpkin vine length with a twine and the measure the twine length.

Stem girth (cm) was determined by using a twine and meter rules.

Leaf areas of plant (cm) was determined by measuring the length and breadth of the leaf using meter rule.

Micromineral contents (Calcium, phosphorus, magnesium, potassium) and selected vitamins (Vitamins A and C): was carried out in Food science laboratory Futminna using the Atomic Absorption Spectrophotometer (AAS) to determie various mineral properties, and also using a Microbiological method to evaluate the vitamins contents.

**Data Analysis**

The data collected was subjected to Analysis of Variance (ANOVA) using Genstat 12.1 version and the treatment means was separated using the Least Significant Difference (LSD) at a 5% level of probability.

## RESULTS

**Table 1: Pre-planting analysis of the sample of experimental soil**

| Properties | Values |
|---|---|
| **Physical** | |
| Sand ($g\ kg^{-1}$) | 830 |
| Silt ($g\ kg^{-1}$) | 100 |
| Clay ($g\ kg^{-1}$) | 70 |
| **Textural class** | Loamy sandy |
| **Cacl$_2$** | 5.91 |
| **PH ($H_2O$)** | 6.34 |
| **Organic carbon ($g\ kg^{-1}$)** | 3.00 |
| **Total nitrogen ($g\ kg^{-1}$)** | 1.26 |
| **Available phosphorus ($mg\ kg^{-1}$)** | 10.00 |
| **Exchangeable bases ($cmol\ kg^{-1}$)** | |
| $Na^+$ | 0.13 |
| $K^+$ | 0.11 |
| $Mg^+$ | 3.00 |
| $Ca^+$ | 4.20 |
| **Exchangeable acid ($mg\ kg^{-1}$)** | 0.11 |

The result indicates that textural class is loamy sandy. It is a good soil for the research experiment especially that nutrient level is low which will allow for the treatment effects to be seen.

**Table 2: Pre-planting analysis of the sample of experimental groundnut shell and poultry manure**

| Properties | Values |
|---|---|
| **Groundnut shell** | |
| **Total nitrogen ($g\ kg^{-1}$)** | 6.40 |
| **Available phosphorus ($mg\ kg^{-1}$)** | 6.70 |
| **$K^+$** | 2.33 |
| **Poultry manure** | |
| **Total nitrogen ($g\ kg^{-1}$)** | 20.8 |
| **Available phosphorus ($mg\ kg^{-1}$)** | 8.80 |
| **$K^+$** | 6.67 |

The result shows the nutrient value present in the groundnut shell and poultry manure sample used in the experimental research

**Number of leaves of fluted pumpkin as affected by different nutrients sources at 2, 3, 4, 5, 6 and 7 weeks after transplanting.**

The effect of granulated groundnut shells and other nutrient sources on number of leaves of fluted pumpkin are shown in table 4.3. There was no significant difference between Poultry manure, NPK 15,15,15 and the combination of NPK and groundnut shells at week 2, 3, 4, 5, with NPK heaving the highest numbers of leaves and groundnut shells with lowest. There was significant difference among the treatments and groundnut shells has the lowest mean.

**TABLE 3:** Effect of nutrients source on number of leaves of fluted pumpkin

| | Weeks after planting | | | | | |
|---|---|---|---|---|---|---|
| Treatments | 2 | 3 | 4 | 5 | 6 | 7 |
| G.nut shell | 18.33b | 32.33b | 43.61b | 53.00b | 64.33c | 72.67c |
| PM | 20.67ab | 40.67a | 51.00a | 58.67a | 81.67a | 93.33ab |
| NPK | 24.00a | 44.33a | 52.67a | 62.33a | 83.00a | 95.00a |
| G.nut+NPK | 23.33a | 45.00a | 51.67a | 59.67a | 70.67b | 88.67b |
| LSD0.05 | 4.89 | 4.10 | 5.73 | 5.49 | 5.73 | 6.01 |

Mean carrying similar alphabets are not significantly different.

**Vine length of fluted pumpkin as affected by different nutrient sources.**

The effect of granulated groundnut shells and other nutrient sources on vine length are shown in table 4. There was significant difference among the treatments with groundnut shell having the lowest mean. There was no significant difference between NPK and combinations of NPK and groundnut shells at week 3,4,5,6 and 7, with NPK having the highest mean throughout the weeks.

**Table 4.** Effect of nutrient source on vine length(cm) of fluted pumpkin.

| | Weeks after transplanting | | | | | |
|---|---|---|---|---|---|---|
| Treatments | 2 | 3 | 4 | 5 | 6 | 7 |
| G.nut shell | 441.33b | 45.63b | 62.80c | 77.67c | 95.53b | 159.00c |
| PM | 43.86ab | 51.65b | 76.33b | 90.23b | 102.70b | 18177b |
| NPK | 46.57a | 71.16a | 89.03a | 101.47a | 127.83a | 204.67a |
| G.nut+NPK | 43.10b | 71.00a | 88.10a | 101.23a | 127.40a | 197.73a |
| LSD0.05 | 8.88 | 14.19 | 6.62 | 10.19 | 8.06 | 12.92 |

Mean carrying similar alphabets are not significantly different.

**Stem girth of fluted pumpkin as affected by different nutrient sources.**

The effect of granulated groundnut shells and other nutrient sources on the stem girth of fluted pumpkin are shown on table 5. There were no significant differences among the treatments at week 2, 3, and 4 with groundnut shells having the lowest mean. There are significant differences among the treatments at week 6 and 7 with NPK having the highest stem girth.

**Table5** Effect of nutrient sources on stem girth(cm) of fluted pumpkin.

| | Weeks after transplant | | | | | |
|---|---|---|---|---|---|---|
| Treatments | 2 | 3 | 4 | 5 | 6 | 7 |
| G.nut shell | 1.00b | 1.23b | 2.40b | 2.67c | 2.93c | 2.93c |
| PM | 1.23ab | 1.83a | 2.93a | 3.53b | 4.50ab | 4.50ab |
| NPK | 1.40a | 2.10a | 3.10a | 4.23a | 4.80a | 4.80a |
| G.nut+NPK | 1.30a | 180a | 2.83ab | 3.80ab | 4.13b | 4.13b |
| LSD0.05 | 0.25 | 0.38 | 0.52 | 0.69 | 0.44 | 0.44 |

Mean carrying simar alphabets are not significantly different.

**Leaf weight of fluted pumpkin as affected by different nutrient sources.**

The effect of granulated groundnut shells and other nutrient sources on Leave weight of fluted pumpkin as shown in table 6. There was significant difference among the treatments with NPK having the highest weight of and poultry manure with the lowest mean weight.

**Table 6:** Effect of nutrient source on leave weight(kg) of fluted pumpkin

| Treatments | Leave weight (kg) |
|---|---|
| G.nut shell | 1.00bc |
| PM | 0.38c |
| NPK | 1.83a |
| Groundnut shell+NPK | 1.62ab |
| LSD0.05 | 0.83 |

Mean carrying simar alphabets are not significantly different.

**Laboratory analysis of fluted pumpkin for some selected minerals and vitamins as influenced by different nutrient sources**

Table 7 shows the level of different minerals and vitamins as affected by different nutrient sources. All treatments exhibit similar potassium levels, ranging from 328.00 to 328.32 mg/100 kg. This consistency suggests that potassium availability was not significantly altered by the different nutrient sources. The phosphorus content varies slightly across treatments, with Poultry Manure showing the highest level at 57.47 mg/100.Calcium levels are relatively consistent, with Poultry Manure having the highest at 69.62 mg/100 kg. The increase in vitamin A in the combination treatment indicates that integrating organic and inorganic fertilizers may enhance the nutritional quality of fluted pumpkin.

**TABLE 7** Selected minerals and vitamins as influenced by different nutrient sources.

| Treatments | K(mg/100kg) | P(mg/100kg) | Ca(mg/100kg) | Mg(mg/100kg) | Vit.A | Vit.C |
|---|---|---|---|---|---|---|
| Groundnut Shells | 328.18 | 57.16 | 68.75 | 62.06 | 0.52 | 52.18 |
| Poultry manure | 328.14 | 57.47 | 69.62 | 66.14 | 0.68 | 53.45 |
| NPK | 328.32 | 58.72 | 65.72 | 63.65 | 0.64 | 53.08 |
| NPK + Groundnuts shells | 328.00 | 58.96 | 69.51 | 68.13 | 0.69 | 54.10 |

K= Potassium, P=Phosphorus, Ca= Calcium, Mg=Magnesium.
Vit.A= vitamin A, Vit.B= Vitamin B

## DISCUSSION

The soil analysis indicated a loamy sandy texture, characterized by high sand content, the low fertility allows for the effectiveness of the treatments applied in the experiment. The analysis of groundnut shells and poultry manure revealed significant nutrient content. This highlights the higher nutrient profile of poultry manure, making it a potent option for enhancing soil fertility.

**Number of Leaves**: The treatments significantly influenced the number of leaves per plant. NPK consistently resulted in the highest leaf count across all weeks, while groundnut shells yielded the lowest. By week 7, NPK produced an average of 95 leaves, indicating its superior effectiveness in promoting vegetative growth.

**Vine Length**: Similar trends were observed in vine length, where NPK treatment again outperformed other treatments, achieving the longest vines.
Stem Girth: Groundnut shells exhibited the lowest stem girth measurements throughout the experiment, with significant differences noted at weeks 6 and 7. NPK had the highest stem girth, reinforcing its role in supporting robust plant structure.

**Leaf Area**: Leaf area results paralleled previous growth measurements, with NPK exhibiting the largest leaf area at weeks 6 and 7. Groundnut shells continued to show the smallest leaf area, emphasizing their inadequate nutrient contribution.

**Leaf Weight**: The leaf weight data demonstrated significant differences among treatments, with NPK yielding the highest weight. This indicates that NPK not only supports leaf growth but also contributes to overall biomass accumulation mineral and vitamin Analysis
Laboratory analysis of fluted pumpkin revealed that potassium levels remained consistent across treatments, suggesting effective nutrient retention. Poultry manure provided the highest levels of phosphorus and calcium, while the combination treatment of NPK and groundnut shells showed the highest vitamin A content, highlighting the potential benefits of combining organic and inorganic fertilizers for enhanced nutritional quality.

## CONCLUSION

The results of this study demonstrate that different nutrient sources significantly affect the growth and nutritional properties of fluted pumpkin. NPK fertilizer consistently outperformed other treatments in terms of growth parameters, while poultry manure provided substantial nutrient benefits. Groundnut shells, while beneficial for soil structure, did not support robust growth as effectively as the other treatments. However, the combination of NPK 15,15,15 also shows great potentials in the growths and yields, so supplementing groundnut shells for NPK 15,15,15 could cut down the cost and still obtain a maximum yield. The findings suggest that integrating high-quality nutrient sources, especially NPK and poultry manure, can optimize fluted pumpkin production and enhance its nutritional value.

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# EFFECT OF POULTRY MANURE RATES ON GROWTH AND YIELDS OF ONION (*Allium cepa L.*) IN SUDAN SAVANNAH OF MAIDUGURI, BORNO STATE NIGERIA

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## ABSTRACT

The study examined the effect of different rates of poultry manure on the growth and yield of onion (Allium cepa L.). The research was carried out at the Teaching and Research Farm, Faculty of Agriculture, University of Maiduguri located at Latitude 11.4$^0$ and longitude 11.4$^0$ during 2017/2018 dry season under dry season. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments replicated three times which comprises of $T_1$ (2.5t/ha), $T_2$ (4.5t/ha), $T_3$ (6.5t/ha), $T_4$ (0t/ha) rates of poultry manue. The parameters assessed were plant height, leaf number, bulb diameter, bulb weight, and yield per hectare. Plant height and leaf number were assessed at 3WAT, 6WAT, 9WAT while bulb diameter, bulb weight and yield per hectare were assessed at harvest. Data collected were analyzed using LSD at 5% level of probability. Results showed that the highest plant height (43cm), highest leaf number (14.6) occurred in $T_3$ (6.5t/ha) poultry manure application while the lowest plant height (29.9cm), lowest leaf number (9.5) was observed in $T_4$ (0t/ha). The highest bulb diameter (14.1cm), highest bulb weight (9.6kg), yield per hectare (14.7t/ha) was recorded in $T_3$ (6.5t/ha) application while the lowest bulb diameter (11.5cm), lowest bulb weight (5kg), lowest yield per hectare (6.6t/ha) was recorded in $T_4$ (0t/ha) application. It is therefore recommended that farmers apply 6.5t/ha of poultry manure for maximum growth and yield in onion production.

**Keywords**: Onion; Allium cepa L.; poultry manure; growth; yield

## INTRODUCTION

Onion (*Allium cepa* L.) is a vegetable crop which belongs to the family *Alliacee*. It is a biennial plant that is usually grown as annual. Onion production under good management practices can yields up to 5kg per meters-square. (Kaka., *et al* 2022). Onion (*Allium cepa* L.) is an important vegetable most valuable crop for its pungent or mild flavour and for being the essential ingredient of the cuisine of many regions (muhammad., et al 2011). Nigeria with 621,000 tons' annual production ranked 24th in the world and 4th in Africa behind Egypt, Algeria and Morocco. In Nigeria, the most producing onion states are Kano, Kaduna, Jigawa, Sokoto, Plateau, Bauchi and Kebbi States (magaji., *et al* 2021). World production of onion is estimated at over 61.6 million metric tons of bulb, and yield per hectare averaged 18.45tons with Nigeria's average yield put at 14.8 tons. Based on the level of consumption, onion is the major spice in the diet, ranking 5th most important vegetable in Nigeria (Muhammad., *et al* 2011). Despite the ranking of onions as second most important vegetable in Nigeria, the present production cannot satisfy the demand of the teeming populace (Gambo *et al*. 2008). Several factors are responsible for this discrepancy, which among are irrigation intervals, fertilizer application and rate spacing among others. Fertilizer rate/dosage and when and how to apply it for optimum onion production is one of the great challenged that hindering onion production in Nigeria (Magaji *et al,* 2004). The use of organic manure and inorganic manure to meet the nutrient requirement in crops production will be an inevitable practice for sustainable agriculture. Organic manure, improves soil's physical, chemical and biological properties along with conserving moisture-holding capacity of the soil, which improves crop productivity. While the use of inorganic manures also increases soil nutrient but it has been observed it cause the destruction of soil texture and structure which often leads to soil erosion, acidity as a result of leaching effects of mineral nutrients if it used continuously and excessively. All these are resulting decreases of crop productivity (Ojeniyi 2000).

## MATERIALS AND METHODS

### Experimental site and Design

The experiment was carried out at the Demonstration farm of the Faculty of Agriculture, University of Maiduguri. The farm is located between latitude 11º 50'N and 13º40'N and longitude 10º14'E and altitude of 352mm above sea level of the north-eastern Nigeria. The experiment was carried out during dry season. The experiment consisted of 4 treatments in a Randomize Complete Block Design (RCBD) which are T1 (0t/ha), T2 (2.5t/ha), T3 (4.5t/ha), and T4 (6.5t/ha), replicated 3 times. The total experimental area used was 15.5m × 4.5m. The plots were sunken bed measuring 2m × 2m with 0.5m intra-rows and 1m inter-rows. The variety of onion (*Monguno white*) used was it obtained from the College of Agriculture Maiduguri. It is an early maturity local variety. The seedlings were transplanted one per stand at spacing of 20cm x 30cm each bed consisted of 7 rows and 8 stand to give a total of 56 stands.

### Cultural Practices

The agronomic practices were Manure application; poultry manure was applied to each plot two weeks before transplanting in order to enable proper decomposition of nutrients that would be released for the growth and development processes. Irrigation was done manually on daily basis at the first two weeks after transplanting and later scheduled for 2 - 3 times per week after seedling establishment. At two weeks after transplanting weaker and dead seedlings were replaced by more vigorous and healthy seedlings were supplied. Regular weeding was carried out manually at every 2 weeks on the field in order to prevent the infestation by weeds. The onions were harvested after most of the tops have fallen and the leaves turned yellow. The harvest was done at the same time and the bulbs were left on plot for 2 days before removing the leaves. This was done to ensure proper curing of the onion bulbs.

### Data Collection

The parameters measured were plant height, number of leaves per plant, bulb diameter, and bulbs weight. Four plants were randomly tagged per plot at net plot for data collection. The plant high were took from the tagged plants were measured using a meter rule, measured from the base to the tips of the leaves and count the leaves which were taken at 3, 6, and 9 weeks after transplanting and the mean were determined and recorded. The diameters of bulbs were taken at random after harvest from each treatment, measured with the help of vernier caliper and the average bulb diameter was expressed in centimeter (cm). The weights of the sampled bulb for each treatment after harvest were weighed using weighing balance calibrated in kilogram. Fresh weight of bulbs was expressed in tons per hectare**.** The total yield was taken from the net plot at harvest in kg /plot and later converted to tons/ha. The whole data collected were subjected to statistical analysis using analysis of variance

(ANOVA) after which the means were separated using fisher's least significant difference (LSD) at 5% level of probability.

## RESULTS AND DISCUSSION

### Effect of Poultry Manure Rates on Plant Height

Table 1 shows the effect of poultry manure rates on plant height of onion. The result indicated that there was a significant effect among the various treatments, at 3 and 6 WAT. Treatment T4 (6.5t/ha) and T3 (4.5t/ha) produced the tallest plants followed by 2.5t/ha and the least was obtained from the 0t/ha. At 9WAT, treatment T4 (6.5t/ha) also produced the tallest plant followed by T3 (4.5t/ha) and the least plant height was obtained from T1 (0t/ha). This could to be attributed to high nutrient content of poultry manure released to crop. This finding is in line with the findings of Adekiye *et al.,* (2009) who stated that plant height, number of leaves and fibrous root length increase with increase in rate of poultry manure. Similar findings were reported by Emuh (2010) that application of poultry manure significantly increased growth parameter and yield parameter in onion.

### Effect of poultry manure rates on number of leave per plant of onion

Table 2 reveals the effect of poultry manure rates on number of leaves per plant at 3, 6 and 9 WAT. The result showed that there was a significant effect among the treatments. Application of 6.5t/ha (T4) produce the highest number of leaves per plant followed by T3 (4.5t/ha), and T2 (2.5t/ha) the least number of leaves per plant was observed from T1 (0t/ha). This result tallies with the work of Sampath kumar (1988) who reported an increase in number of leaves per plant and increase in leaf area in onion as a rate of poultry manure increase from 5 to 20t/ha.

### Effect of Poultry Manure Rate on Bulb Diameter and Bulb Weight

The effect of poultry manure on bulb diameter of showed that there is no significant difference among the treatments. However, treatment effect on bulb weight showed significant difference. Treatment T4 (6.5t/ha) and T3 (4.5t/ha) recorded the highest bulb weight as compared to other treatment. More so, there was no significant difference between T3 (4.5t/ha) and T2 (2.5t/ha). The Lowest bulb weight was recorded at T1 (0t/ha). These findings coincide with the findings of Ayeni *et al.,* (2010) who reported that poultry manure significantly enhanced growth, yield and macro nutrient content with application at 20 and 30 t/ha which increase nutrient status and yield of onion. He further reported that poultry manure significantly increased number of leaves per plant, leaf area, plant height, bulb weight and bulb diameter per plant at 30t/ha.

### Effect of Poultry Manure Rates on Yield

Table 4 shows the effect of different rates of poultry manure on yield of onion. There is significant difference among the treatments obtained from onion yield at harvest. Poultry manure at rate of 6.5t/ha (T4) gave the highest yield (14.78t/ha) as compared to other treatments, the least yield was obtained from (T1) 0t/ha (6.66t/ha.).

## CONCLUSION

There are significant differences in rates/dosage of poultry manure used on both growth and yield parameters. The highest rate of poultry manure T4 (6.5t/ha) applied was gave high result in the study.

## RECOMMENDATION

Based on the findings from this study, the result recommended that onion farmers should apply 6.5 t/ha of poultry manure for maximum production.

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**Table 1. Effect of poultry manure rates on plant height**

| **Poultry Manure Rate** | **Plant height (cm)** 3 WAT | **6WAT** | **9WAT** |
|---|---|---|---|
| 0t/ha | 11.83 | 25.63 | 29.53 |
| 2.5t/ha | 16.51 | 25.60 | 42.37 |
| 4.5t/ha | 19.23 | 36.60 | 36.13 |
| 6.5t/ha | 19.50 | 37.37 | 43.00 |
| Mean | 16.77 | 31.30 | 37.75 |
| $LSD_{(0.05)}$ | 0.89 | 1.178 | 2.573 |

NB. Mean values in the same column were separated using LSD at ($P \leq 0.05\%$).

WAT week after transplanting

**Table 2. Effect of poultry manure rates on number of leave per plant**

| **Poultry Manure Rate** | **Number of leaves** 3 WAT | **6WAT** | **9WAT** |
|---|---|---|---|
| 0t/ha | 3.50 | 6.87 | 9.53 |
| 2.5t/ha | 3.80 | 7.70 | 10.47 |
| 4.5t/ha | 4.36 | 8.00 | 11.73 |
| 6.5t/ha | 5.43 | 9.80 | 14.60 |
| Mean | 4.27 | 8.09 | 11.58 |
| $LSD_{(0.05)}$ | 0.71 | 0.20 | 0.37 |

NB. Mean values in the same column were separated using LSD at ($P \leq 0.05\%$).

WAT week after transplanting

**Table 3. The effect of poultry manure on bulb diameter and bulb weight**

| Poultry Manure Rate | Bulb diameter(cm) | Bulb weight(t/ha) |
|---|---|---|
| 0t/ha | 11.53 | 5.00 |
| 2.5t/ha | 12.90 | 7.75 |
| 4.5t/ha | 13.07 | 8.58 |
| 6.5t/ha | 14.17 | 9.68 |
| Mean | 13.91 | 7.75 |
| $LSD_{(0.05)}$ | Ns | 0.50 |

NB. Mean values in the same column were separated using LSD at (P≤0.05%).

WAT week after transplanting Ns No significant different

**Table 4 Effect of Poultry Manure Rates on Yield**

| Poultry Manure Rate | Yield (t/ha) |
|---|---|
| 0t/ha | 6.66 |
| 2.5t/ha | 8.54 |
| 4.5t/ha | 10.83 |
| 6.5t/ha | 14.78 |
| **Mean** | **10.20** |
| **LSD** | **1.15** |

NB. Mean values in the same column were separated using LSD at (P≤0.05%).

**Definition of term:**

WAT: Weeks after transplanting

RCBD: Randomize complete block design

# EFFECT OF LAND USE TYPES ON SELECTED SOIL PROPERTIES IN COLLEGE OF AGRICULTURE MOKWA NIGER STATE

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## ABSTRACT
The study investigated the effect of land use types on selected soil properties in Niger State College of Agriculture Mokwa. The five treatments were the land use types namely, Secondary Forest, Citrus orchard, Recreational area, Arable land and the Built-up area. The sub treatment was soil depths (0 – 15, 15 – 30 and 30 – 45cm). The experiment was a 5 x 3 x 3 factorial laid out in a Randomized Complete Block design (RCBD). Soil samples were collected at the three depths (0 – 15, 15 – 30, 30 – 45cm) in the various land use types and replicated thrice for bulk density measurements and for saturated hydraulic conductivity. Auger samples were collected for routine analysis. The saturated hydraulic conductivity (K sat) was determined using the constant head method. The results obtained showed that the soils in the study area were predominately sand and loamy sand in texture. The pH of the soils of the study area was slightly acidic. Secondary forest had the highest organic carbon, total N, pH, Ca, Mg, K and available P while the buildup area recorded the lowest values for most of the soil nutrients above. The nutrients were however not deficient when compared to establish critical levels in all the land use types. Bulk density values obtained were lowest at the forest (1.42gcm) and highest at the buildups areas (1.57gcm$^3$). The highest (46.29%), and the lowest (40.88%) values for total porosity were obtained in the secondary and buildup areas respectively. while the highest (0.408cm/min) and lowest (0.109) cm/min) K sat were obtained at the citrus orchard and built-up area respectively. Thus, the soil properties of the study area were significantly different ($P<0.05$) between the secondary forest and the other land use types.

Key words: Secondary forest, recreational area, orchard, built-up area.

## INTRODUCTION
Land use type can be said to be the arrangements, activities and inputs undertaken by people in given land cover type with a view of producing, changing and managing it (FAO/UNEP, 1999). This is done usually to satisfy human multiple objectives or purposes. Soil quality is influenced by the management practices the land is subjected to such as settlements, arable land, recreational, pasture, roads and managed woodlands. Change in land use types leads to global warming and climate change. Studies had revealed the obvious influence of land use change on various soil properties such as the soil bulk density, hydraulic conductivity, total porosity, infiltration, aggregate stability and the overall health of the soil (Castro *et al.,* 2002). According to Yihenew and Gebeywa, (2013), Gebayaw, (2007), Mohammed (2017), land use affects both the chemical, physical and biological properties of soils that tend to affect their quality attributes and fertility status. Land use types affect surface runoff and change in

resilience of soil to environmental impacts (Hacisalihoglu, 2007). The extent of these changes vary with land use type, management practice and vegetation cover (Celik, 2005).

The land use types have the tendency to cause soil compaction and erosion resulting to alteration of the soil physical and chemical properties (Wang *et al.,* 2006; Misir *et al*., 2007). The degradation which varies in terms of types, severity and socio-economic impact differ from place to place (Aruleba, 2004; Senjobi, 2007). Just within 50 years, about 20% of the worlds agricultural land has been irreversibly damaged, thus, if this degradation process continues in this pace, agriculture will lose about 15 to 30% productivity (FAO, 1984). Uchenna *et al.,* (2017), reported that soil properties vary with land use system over time and that the knowledge of this changes is vital for sustainable food production. At college of Agriculture Mokwa, there are clear evidences of soil degradation leading to very conspicuous erosion. This has apparently arisen from bad land use and indiscriminate allocation of land without consideration of the effect of the proposed use of the land due to lack of adequate soil information to support appropriate land use decision making. There is a strong feeling that if research of this nature was done earlier, perhaps, this problem would not have occurred. Studies like this have been successfully approached by (Khalid *et al.,* 2010, Senjobi and Ogunkunle, 2011, Ovie *et al.,* 2013) in which they determined Bulk density, total porosity, Saturated hydraulic conductivity and infiltration etc. As good predictors of the effect of land use types on soil properties. The main objective of this study was to determine the effects of land use types on selected soil properties in the College of Agriculture Mokwa.

## MATERIALS AND METHODS

### The study location

This study was carried out at the college of agriculture mokwa, Niger State. The area lies between Latitude 6.3904' 154" N to 6.4006' 68" N and Longitude 5.6030' 229" E to 5.6031' 106" E. College of Agriculture Mokwa lies between 97-109m above sea level. The soil type in this area has been classified as Ultisols, according to Ogeh and Ogwurike (2006). The site falls within the Southern Guinea Savannah vegetation belt of Nigeria with an annual average temperature of about 27°C and an annual rainfall of about 1,500mm. The study area experiences two major seasons namely the raining season which last between April to October and the dry season from November to March.

### Field Work

The field work was carried out in five land use types namely, Arable land, secondary forest, Citrus Orchard, Recreational and Built-up area to examine the effect of such land use types on the soil properties. The Arable land is the Experimental farm of the Teaching and Research Farm of College of Agriculture Mokwa, it has been subjected to various types of tillage operations, use of chemicals (like fertilizer, herbicides, and pesticides) and other cultural practices. An area of about 500m$^2$ of the arable land was mapped out for this study. The secondary forest located beside the school gate. It is made up of different species of trees and shrubs, among them are *khaya granufolia, Triplochiton scleronxylon, Tectona grandis, Cedrella odorante, Nucalea diderrichii, Milicie excelsa, Gmelina arborea, Bombas spp, Tarminalia aborensis, Monsonia altissimp and entandrophagma anglelensis* among others. The secondary forest which has an area of about 20 m$^2$ is restricted to only permitted persons. The recreational area was located directly opposite school workshop. It is regularly used by students for various soccer competitions. Grasses grown has been there for over 25 years and mowed regularly over the years.

The citrus orchard is located behind the pest management laboratory. The orchard has been planted about 17 years ago and has some under growth grasses on it. One of the dominant citrus species in orchard is sweet lemon. The built-up area has been affected by construction works and other human activities. The study area has similar parent material, topography and climate.

**Soil Sample Collection**

Soil samples were collected from all the five land use types using auger, for the soil samples were collected from three different depths (0-15,15-30 and 30-45cm) within each land use type three core samples were collected from the three depths and replicated three times. Using core samplers of 6cm height and 5cm of diameter, undisturbed soil samples were collected for hydraulic conductivity and bulk density measurements. Double ring infiltrometer was used for field determination of infiltration rate.

**Laboratory Analysis**

Soil particle size distribution was determined by the hydrometer method (Bouyoucos, 1962). Soil bulk density was determined by the undisturbed core sampling method after the soil was oven dried at 104ºC to constant weights. Saturated hydraulic conductivity (Ksat) was determined by the constant head method (Young, 2001). The soil pH was measured by standardized glass electrode pH meter in a 1;1 soil -water suspension (Udo *et al*.,2009). The total nitrogen content was determined using the Micro-Kjeidal method as described by Bremner and Mulvaney (1982), while organic carbon content was determined by the wet oxidation method. The organic matter content was derived from the value of the organic carbon content by multiplying the organic carbon content with 1.72. Potassium and sodium were extracted with neutral 1N ammonium acetate (pH 7.0) solution and determined using flame photometer. Calcium Ethelynediaminetetra-acetic acid (EDTA) 0.01M method while the available phosphorus was determined by colorimetric method after extracting with Bray-1 solution (Murphy and Riley 1962).

**Data Analysis**

The statistical analysis was performed Using GenStat statistical package for the analysis of variance (ANOVA). Treatment means were compared using the Fisher's least Significant Difference (F- 150) at 5% probability.

**RESULTS AND DISCUSSION**

The results of the chemical properties of the land use types are presented. The soils in the studied area were significantly different ($p<0.05$) among the land use types. From the result, soil from the secondary forest had the highest values for total Nitrogen (N), Organic Carbon, Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium Na), Aluminium and available Phosphorus. In all the land use types, the soils were slightly acidic and increased with soils depths. The pH was highest in top soils of the Built-up area (5.79) and lowest at the secondary forest (5.18). the interaction between land use types and depth in Table 2 showed that the soils were significantly affected ($p< 0.05$) by land use types and decreased with soil depth.

The total Nitrogen (N) content decreased significantly ($p<0.05$) with soil depths in all the land use types. The highest total nitrogen value (1.25gkg) and lowest value (1.07gkg) were obtained at the secondary forest and Built-up Area respectively. In all the land use types, the top soil (0 – 15cm depth) had higher values of N when compared with lower depths. The highest value of organic carbon content was obtained at the secondary forest (19.20g/kg) while the lowest value was obtained at the Built-up area (13.37gkg). organic carbon was observed to be in the following order. Secondary forest> Citrus Orchard>recreational>Arable land >Built-up area. Thus, it was observed that the higher the vegetation cover, the higher the organic carbon contents of the soils. The higher organic carbon contents in the Forest was an indication of the high carbon sequestration ability of the forest trees compared to the low values obtained in the Built-up area. Thus, high nutrient recycling occurs in the secondary forest due to the high litter falls.

Similarly, available P decreased significantly ($p<0.05$) with soil depths, although 0 – 15 cm depth of all the land use types had the highest P contents. Available P was not deficient at the first Two depths (0-15 and 15 -30cm) in all the land use types. However, apart from the built-up area, all other land use types studied were not deficient in available P at the 30 – 45 cm depths, this is in line with the studies carried out by Adeoye and Agboola (2015). The secondary forest had the highest value for available P (13.17 cmol/kg) and lowest at the built-up area (7.46 cmol/kg).

The Potassium (K) content of all the land use types were not significantly different ($p<0.05$) among the land use types although K decreased with soil depths in all the land use types studied, however the highest and lowest K values were obtained at the secondary fores (0.25 cmol/kg) and Built-up area (0.22 cmol/kg) respectively. K values in all land use types fall within the critical value of 0.16 – 0. 25 cmol/kg as reported by (Akinrinde and Obigbesan 2016). Thus, K, was not deficient in all the land use types. Magnesium (Mg) content was significantly different ($p<0.05$) among the land use types studied. The highest value was obtained in secondary forest (0.39 cmol/kg) while the lowest was at the Built-up area (of 0.25 cmol/kg). when compared with the critical value of 0.2 – 0.4 cmol/kg as reported by Akinrinde and Obigbesan (2016), Mg content was not deficient in any of the five land use types. Calcium (Ca) content was significantly different ($p<0.05$) among land use types, and the highest and lowest contents 1.10 cmol/kg and 0.66 cmol/kg were obtained at the secondary forest and built-up area respectively. Although the top soil had the highest values in all the land use types.

Sodium (Na) content was significantly different ($p<0.05$) among land use types. The highest (0.18 cmol/kg) and lowest (0.13 cmol/kg) were obtained at the secondary forest and Built-up area respectively. Aluminium (Al) content was not significantly different ($p<0.05$) among the land use types. Although the highest Al content (0.213 cmol/kg was obtained at the Arable land (0.188 cmol/kg). Generally, the study area had sand fraction ranging from 84.4 to 86.2%, Silt fraction ranging from 3.2 – 5.2% and Clay fraction ranging from 8.5 – 10.7%. Thus, the soils investigated were predominantly sand and loamy sand and was significantly ($p<0.05$) affected by land use. The sand and silt fraction of the soil decreased with soil depths while the clay fraction increased with soil depth in all the land use types studied.

The result of the analysis of the effect of land use types on bulk density (Db) and the total porosity are presented in Table 3. The soil bulk density (Db) was significantly affected ($p<0.05$) by land use types and soil depths. From the lowest bulk density of 1.42 g/cm followed by Citrus orchard (1.46), Recreational (1.51), Arable land (1.49) and Built-up area (1.57). This could be attributed to compaction from the continuous trampling by the individuals using the built-up area, unlike the secondary forest with little or no soil disturbances and high litter fall. However, it was observed in all the land use types that the topsoil (0 – 15cm) obtained had the lowest Db which its increased with soil depth could be attributed to the increase in the clay fraction of the soils with depth. This is in agreement with

Brady and Weil (2002), who reported that fine textured soils generally have lower Db values than coarse texture soils. The bulk density of the study area was within the recommended bulk density range for agriculturally suitable soils as reported by Lal and Shukla (2004). Therefore, the bulk density of the land use types was in the following order:

**Table 3 Effect of land use types on bulk density (Db) total porosity (*f*) and hydraulic conductivity**

| land use types | Db g/cm$^3$ | *f* % | *K*sat (cm/min) | Ksat (cm/hr) |
|---|---|---|---|---|
| Arboretum | 1.42b | 46.29a | 0.0408ba | |
| Citrus Orchard | 1.46b | 44.78a | 0.0697a | 4.18a |
| Football field | 1.51ba | 43.21ba | 0.0133b | 1.06b |
| Arable land | 1.49ba | 43.90ba | 0.0133b | 0.80b |
| Built-up area | 1.57a | 40.88b | 0.0109b | 0.65b |

Means with similar in the same column were not significantly different.

**Table 4: Effect of land use types and depth interaction on soil Bulk density (Db) total porosity (f) and Saturated hydraulic conductivity ksat.**

| Land use types | Depth (cm) | Db g/cm$^3$ | F % | Ksat (cm/min) | Ksat (cm/hr) |
|---|---|---|---|---|---|
| Arboretum | 0-15 | 1.23 | 53.58 | 0.0858 | 5.14 |
| | 15-30 | 1.42 | 46.42 | 0.0287 | 1.72 |
| | 30-45 | 1.62 | 38.87 | 0.078 | 0.47 |
| Citrus orchard | 0-15 | 1.26 | 52.45 | 0.155 | 9.33 |
| | 15-30 | 1.53 | 42.26 | 0.0405 | 2.43 |
| | 30-45 | 1.60 | 39.62 | 0.013 | 0.78 |
| Football field | 0-15 | 1.28 | 51.89 | 0.0082 | 0.49 |
| | 15-30 | 1.57 | 40.75 | 0.0154 | 0.93 |
| | 30-45 | 1.67 | 36.98 | 0.009 | 0.54 |
| Arable land | 0-15 | 1.38 | 47.92 | 0.227 | 1.37 |
| | 15-30 | 1.42 | 46.42 | 0.0132 | 0.79 |
| | 30-45 | 1.66 | 37.36 | 0.0042 | 0.25 |
| Built-up area | 0-15 | 1.39 | 47.55 | 0.262 | 1.57 |
| | 15-30 | 1.63 | 38.49 | 0.0201 | 1.21 |
| | 30-45 | 1.68 | 36.6 | 0.1166 | 0.40 |
| s.e.m | | 0.055 | 2.084 | 0.01812 | 0.018 |
| C.V% | | 6.4 | 8.2 | 99.1 | 99.1 |

Secondary forest < Citrus orchard < Recreational<Arable Land <Built-up area.

Percentage total porosity ranged between 40.88-46.29%. owing to the bulk density values the highest f value was obtained in the forest (46.29%) while the lowest value was obtained in the built-up (40.88%) the high porosity observed in the secondary forest is an indication of the low Db value obtained in the secondary forest, thus it was observed that the higher the Db the % total porosity (f). the f was also observed to increase with soil depths. The effect of different land use types on soil saturated hydraulic conductivity (Ksat) is presented in (table 3). From the result ksat was significantly different ($p<0.05$) among land use types studied. The highest ksat value (0.697cm\min or 2.45cm\hr) was obtained at citrus orchard while the lowest values (0.109cm/min or 0.65 cm./hr) was obtained at the up area. The interaction of land use type and depth in table 4 showed that the ksat decreased with depth; with the top soil obtaining the highest ksat in all land use types. Thus; ksat was observed to be in the following decreasing order: citrus orchard>secondary forest>Recreational>Arable land> Built-up Area. However, due to the significantly high Ksat in the citrus orchard and secondary forest, most of the water that falls on the soil as a result of rainfall has the tendency to enter the soil, resulting in little or no runoff at saturated condition. In contrast the built-up area may be more prone to runoff as a result of the low hydraulic conductivity of the soil when compared to other land use types.

**CONCLUSION AND RECOMMENDATION**

The study of the effect of land use types on selected soil properties was carried out in College of Agriculture Mokwa to determine the effect of land use types on selected soil properties. The study showed that the total N, organic carbon, organic matter, available P, potassium (K), Calcium (Ca) and sodium (Na) were all significantly different ($p<0.05$) among land use types and decreased with soil depths while the soil was slightly acidic. Secondary forest obtained the highest values for organic carbon, total N, Ca. Mg, K, available P while the built-up area recorded the lowest values for most of the soil nutrients stated above.

The secondary forest had the lowest bulk density, highest percentage total porosity and the saturated hydraulic conductivity. These effects could be as a result of the high litter fall which has increasing organic matter content and also due to little or no soil disturbance in the built-up area where the soil has been subjected to frequent disturbance in form of tillage practices, fertilizer, herbicide, pesticide applications and other human interferences also Ksat was found low when compared with other land use types. The significant difference between the secondary forest and other land use types signals a great need to encourage the conservation of our forest lands.

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# EFFECTS OF TILLAGE AND NITROGEN FERTILIZATION ON NITROGEN USE EFFICIENCY OF MAIZE IN THE SOUTHERN GUINEA SAVANNA OF NIGERIA

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## ABSTRACT

The study was to evaluate the effects of tillage and split nitrogen fertilization on Nitrogen Use Efficiency (NUE) of maize in the rainy season of 2022 at Anyigba, southern Guinea savanna agro ecological zone of Nigeria. Agronomic efficiency of nitrogen (AEN) and partial factor productivity of nitrogen ($PFP_N$) were used to evaluate the NUE. The treatments were a factorial combination of two tillage practices [manual ridging (MR) and minimum tillage (MT)] and split nitrogen application rates [0, 30 + 60, 45 + 45, 60 + 30 kg N $ha^{-1}$ applied at 2 weeks after planting (WAP) / at tasseling growth stage, and 90 kg N $ha^{-1}$ applied at 2 WAP] arranged in a Randomized Complete Block Design and replicated three times. The results showed that, tillage had significant effect on AEN and $PFP_N$. Manual ridging recorded significantly higher AEN, $PFP_N$ and maize yield with mean values of 15.7 kg $kg^{-1}$, 22.2 kg $kg^{-1}$ and 1.3 Mg $ha^{-1}$ respectively. There was no significant response of NUE to N fertilization. The split application of N (60 + 30 kg N $ha^{-1}$) produced the highest grain yield of 2.2 Mg $ha^{-1}$ which was significantly higher than that of the split (30 + 60 kg N $ha^{-1}$) and the 0 N treatment. Interaction of Tillage and Nitrogen on NUE and grain yield were not significant. Manual ridging and split application of recommended rate of N is the most appropriate for maize production in the area.

**Key words:** Maize, Nitrogen, Tillage, Southern Guinea savanna

## INTRODUCTION

Conservation agriculture (CA) is a system of farming that involves minimum soil disturbance, (zero and minimum tillage), crop residue retention and crop rotations, this is considered as a soil and crop management system that could potentially increase soil quality and crop yield [Food and Agriculture Organization of the United Nations, (FAO) 2008]. It offers an opportunity to reverse land degradation that prevails in many parts of sub-Saharan Africa (Fowler and Rockstrom, 2001), due to its positive effects on enhancement of physical, biological and chemical properties of soil when compared to conventional tillage practices (Madari *et al.,* 2005; Wander and Yang, 2000). Conservation agriculture is an approach that aims to sustainably improve farm productivity, profits and food security characterized by three principles: minimum soil disturbance, crop residue retention and diversified crop rotations. The three principles increase soil organic carbon, minimize erosion risk, conserve soil water, decrease fluctuations in soil temperature, enhance soil quality and soil's environmental regulatory capacity. Ultimately, CA optimizes crop yields and reduces input costs. (Hobbs *et al*., 2008; Wall, 2008). Soil tillage is the mechanical manipulation of the soil for the purpose of crop production. It negatively affects water conservation, soil temperature, infiltration and evapotranspiration processes. Derspsch *et al.* (2006) reported that continuous cultivation under tillage agriculture leaves soil bare and unprotected, thereby promoting accelerated soil erosion, soil nutrient depletion and soil structural deterioration consequent upon the decline in soil organic matter. This decline is due mainly to accelerated microbial decomposition of organic residues due to improved soil aeration from tillage operations and destruction of aggregates that exposes the high surface area coupled with the release of aggregated-protected organic matter for mineralization. (Govaerts *et al.*, 2009). Conservation agriculture has been reported to mitigate these problems arising from continuous soil tillage (Grahmann *et al.,* 2013).

Blanket fertilizer recommendations both in terms of type and amount can be assessed using indicators such as agronomic nutrient use efficiency (AEN) and partial factor productivity (PFP) (Ichami *et al*., 2019). The AEN is a measure of the increase in crop yield for a given amount of nutrient added and can be used to evaluate the efficiency of a specific nutrient applied. It indicates how much productivity increase was gained by the application of the nutrient and used as a short-term indicator of the impact of applied nutrients in productivity (Dooberman, 2007; Ichami *et al*., 2019). The PFP is determined by dividing the grain yield with the amount of nutrient applied; therefore, it is an indication of production per unit of nutrient applied. The PFP addresses how productive the cropping system is compared to its nutrient input. It is considered the most important index for on-farm studies, among the different indices of nutrient use efficiency, as it integrates the use efficiency of both indigenous and applied nutrients (Dooberman, 2007; Mandal *et al*., 2015).

Maize production has increased over the years in both humid rainforest and moist savannas of Nigeria. It is an enormously important crop grown for human consumption and used as animal feed and agro-industrial raw material. However, maize is a heavy feeder that is easily affected by soil degradation [(Badu-Apraku and Fakorede, 2017) The International Institute of Tropical Agriculture (IITA), 2017]. The total annual production has increased from 1.06 M tons in 1976, to 12.75 M tons in 2021 (FAO, 2022). Maize productivity is largely depending on nutrient availability particularly nitrogen, phosphorus and potassium and management practices (Rasheed *et al.,* 2004). Therefore, this has necessitated the need to evaluate the effects of tillage and nitrogen fertilization on selected organic carbon and maize performance in Guinea Savanna of Nigeria.

One of the major constraints to adoption of CA is poor availability and quality of crop residues that are essential for mulching to achieve one of the three basic principles of CA and/hence prevention of soil erosion. The poor quality of the mulching materials in the form of grass or cereal stover available with high C:N ratio results in short-term immobilization of N. This negative effects can be offset by application of large amounts of N fertilizer in the early years of CA. This is because net mineralization from grass or cereal stover residues may only be achieved in the long-term (Kafesu, *et al*., 2018). In Nigeria, there is dearth of knowledge documented on the effect of N management in the early years of CA on the soil organic carbon and performance of maize. Therefore, the objective of this study was to assess the effect of tillage and N fertilization application rate on nitrogen use efficiency in the early years of CA at Anyigba, Kogi State in the southern Guinea savanna of Nigeria.

## MATERIALS AND METHODS

### Site and Characteristics

The study site was the Teaching and Research Farm of Prince Abubakar Audu University, Anyigba, Kogi State, in the Southern Guinea Savanna agro-ecological zone of Nigeria on latitude 7º 10′ 30″ N and longitude 7º 28′ 50″ E, at an altitude of 289 m above sea level. The climate of Anyigba is sub-humid with average annual rainfall and temperature of 1360 mm and 27 °C respectively. The rainfall, minimum and maximum temperature data of the site during the period of study were presented in Table 1. The area lies in the derived savanna vegetation zone of Nigeria. Derived savanna is evolved from the rain forest by human activities such as regular fire, deforestation and farming (Adekiya *et al.,* 2018). The physical features of the site are flat to gently undulating lowlands filled with Cretaceous and Tertiary rocks over which the rivers have been cut. The soils are Eutric Gleysols and Eutric Fluvisols mainly developed from a wide range of alluvial materials (Ojanuga, 2006). Prior to the research, the field has been cultivated to sorghum and maize with little fertilizer application over a long period of time.

**Table 1: Monthly Climatic Data Observed in Anyigba during Experiment**

| Month | Rain (mm) | Temperature | |
|---|---|---|---|
| | | Min. | Max. |
| June | 400.00 | 24.70 | 34.10 |
| July | 400.20 | 25.00 | 35.10 |
| August | 598.50 | 24.80 | 33.20 |
| September | 500.60 | 23.90 | 35.00 |
| Total | 1898.70 | | |

**Source: National Agency for Space and Research Development Authority (NASRDA).**

### *Treatments and Experimental Design*

The treatments consists of a factorial combination of two tillage practices (minimum and manual) and five levels of nitrogen fertilizer application (0 kg N ha$^{-1}$, 90 kg N ha$^{-1}$ applied in split form of 30 kg N ha $^{-1}$ at 2 WAP and 60 kg N ha$^{-1}$ applied at tasseling growth stage (recommended practice), 45 kg N ha$^{-1}$ applied at 2 WAP and 45 kg N ha$^{-1}$ applied at tasseling growth stage, 60 kg N ha$^{-1}$ applied at 2 WAP and 30 kg N ha$^{-1}$ applied at tasseling growth stage and 90 kg N ha$^{-1}$ applied at once at 2 WAP emerged in a randomized complete block design (RBCD) with three replications to give a total of 30 experimental plots and 10 treatment combinations. The gross plot size was 5 m x 5 m (25 m$^2$) which consist of six ridges and five furrows, while the net plot size was 3 m x 3 m (9 m$^2$) with four inner ridges and three furrows.

### *Soil Sampling and Analysis*

In order to characterize the whole field prior to the commencement of the study in 2022, surface soil (0-20 cm) samples were collected using auger from three diagonal transects at 5 m regular intervals and each bulked together to give 3 composite samples for the routine analysis. Samples were also collected along three diagonal transect from each plots and bulked together to give one sample for the determination of soil organic carbon at various growth stages.

The samples were air-dried, gently crushed using a porcelain mortar and pestle and then sieved with a 2 mm mesh. The routine physical and chemical analysis was determined according to the procedure described by Okalebo *et al.,* (2002). Briefly, Particle size analysis was determined by Bouyoucos hydrometer method. Soil reaction determined potentiometrically in 1:2.5: Soil to water suspension using the glass electrode pH meter. Organic carbon determined by the Walkley and Black wet oxidation method, total nitrogen was determined by Kjeldahl digestion method. Available phosphorus was extracted by Bray P-1 and the P concentration in the extract was determined colorimetrically using spectrophotometer. Exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$) was extracted using 1 $NH_4OAC$ buffered at pH 7.0. $Ca^{2+}$ and $Mg^{2+}$ was determined using atomic absorption spectrophotometer while $K^+$ and $Na^+$ determined using flame photometer. Exchangeable acidity was determined by titration method using 1N KCl extract. Effective cation exchange capacity (ECEC) was estimated by calculation by summing the exchangeable bases and exchangeable acidity.

***Agronomic Practices***

The field was cleared and ridged at 75 cm apart manually with the litters and weeds incorporated into the soil making the surface bare. The minimum tillage plots had the land prepared by the use of hoe to make small heaps at 75 cm apart along the planting lines. The minimum tillage plots were then sprayed with Atrazine at the rate of 0.25 kg $ha^{-1}$ as pre-emergence three days after planting using 16 L knapsack sprayer with flat fan nozzle. The resulting debris and other surface soil litter were left on the soil as mulch; the test crop was yellow maize variety, SAMMAZ 52 (PVA SYN 13) medium maturing between 110 and 120 days, tolerant to maize streak virus, rust, leaf blight and auricularia leaf spot. Three seeds were planted per hole at 25 cm intra-row spacing and thinned to one seed at 2 WAP to give a total plant population of about 53,333 plants $ha^{-1}$. All the plots had basal fertilizer application of 60 kg $P_2O_5$ $ha^{-1}$ using single superphosphate and 60 kg $K_2O$ $ha^{-1}$ using muriate of potash fertilizer both applied at 2 WAP. Urea fertilizer was used to supply N for plots requiring N fertilizer and for plots requiring split application. The first dose was applied at 2 WAP while the second dose was applied at tasseling growth stage of maize. All fertilizer applications were by split placement about 5 cm away and 5 cm deep at the base of each plant stand and covered with soil. Weeding was done manually with hoe where necessary at 2 WAP and 4 – 5 WAP before fertilizer application where necessary. All residues from weeding were left on the surface of the soil.

***Growth Parameters***

***Yield and Yield Component***

At harvest, maize ears and stalk in the net plot were collected, maize cobs were manually separated from stover and hand threshed. After threshing, total fresh weight of maize was separately taken in the field. Thereafter, 5 plants were taken after removal of grains, cut into small pieces and weighed to form a sub-sample whose fresh weight was weighed. The sub-samples were oven dried at 75 ℃ for 48 h to a constant weight before weighing. The grains were further dried in the sun until a moisture content of 12 % was reached using a Dickey-john grain moisture tester.

***Calculation and Statistical analysis***

The nitrogen use efficiency (NUE) of the maize plant was determined using agronomic efficiency of nitrogen ($AE_N$) and partial factor of productivity of nitrogen ($PFP_N$). They were calculated using the formula below

AEN = $Y_1 - Y_0/N$ (Ichemi *et al.,* 2019) Eq. 1

where

$AE_N$ = Agronomic efficiency of N, $Y_1$ = Yield in mega gram of fertilized crop, $Y_0$ = Yield in mega gram of control crop

N = Nitrogen applied in kilogram, $PFP_N = Y_1/N$ (Doberman, 2007) Eq 2

where, $PFP_N$ = Partial factor of productivity of nitrogen, $Y_1$ = Yield in kilogram of fertilized crop
N = Nitrogen applied in kilogram
Data collected were subjected to analysis of variance (ANOVA) and mean separation where significant was carried out using Duncan's New Multiple Range Test (DNMRT) at 5 % level of probability, using GenStat analytical tool (19th edition)

## RESULTS AND DISCUSSION

### *Initial Soil Properties*

The initial properties of the soil at the commencement of the experiment are shown in Table 2. Sand was the dominant fine earth fraction in the soil with a value of 831 g $kg^{-1}$. The textural class of the soil was loamy sand. The coarse nature of the soil indicates low water holding capacity and availability. The sandy nature of the soil allows for tillage of the soil, even at high moisture content with less damage of the structure of the soil. The pH of the soil was 6.1. This falls within slightly acidic range of pH which is optimum for most crops. The pH range of 6.0 – 7.0 is the most suitable for the release of many plant nutrients for uptake and optimum growth and development of most plants (Tan, 2000).

The soil chemical properties were rated based on Chude *et al.* (2011). The soil organic carbon content was 6.8 g $kg^{-1}$ and the total N content was 0.70 g $kg^{-1}$, which is within moderate and low range classes respectively. Available phosphorus of the soil falls within low class and was 6.0 mg $kg^{-1}$. The moderate organic carbon with consequent low N and P are characteristics of savanna soils, due partly to rapid decomposition in tropical climates which makes it difficult to build-up soil fertility (Androen e*t al.,* 2007). The result from the determination of exchangeable cations showed that Ca concentration was 4.02 cmol $kg^{-1}$ (low), Mg was 2.26 cmol $kg^{-1}$ (moderate), K was 2.02 cmol kg-$^{1}$ (very high) and Na was 0.33 cmol $kg^{-1}$ (moderate). The low content of Ca and Mg is a reflection of the low clay and moderate organic matter contents of the soil. In tropical soils, organic matter is the main source of negative charges that these nutrients are adsorbed to, which prevents them from being leached down the soil profile beyond the root zone (Brady and Weil, 2010). The exchangeable acidity ($Al^{3+}$+ $H^{+}$) was low (1.02 $cmol^{-1}$). The soil is thus low in potential acidity and will not contribute to the active acidity, thus may not cause adverse effects on crop growth including root development (Adeboye *et al*, 2020). High amount of aluminum is toxic to roots and cause swelling of the roots impending their ability to absorb water and nutrients from the soil (Brady and Weil, 2010). Effective cation exchangeable capacity (ECEC) was moderate (9.65 cmol $kg^{-1}$), which is a reflection of the moderate organic carbon content.

### *Grain Yield*

The effects of tillage and N fertilization on grain yield of maize are presented in Table 3. Tillage had a significant effect on grain yield. Manual ridging produced significantly higher grain yield (1.3 Mg $ha^{-1}$), compared to MT. The lowest yield observed in the minimum tillage may be attributed to soil surface crusting resulting in surface runoff, nutrient loss and reduced infiltration, and hence greater plant-water stress compared to manual ridging. Similar results have been reported by (Khattack *et al.,* 2005). Significant effect of N fertilization was observed on both grain yield confirming N as the most limiting nutrient to maize production in the southern Guinea savanna of Nigeria (Adeboye *et al*., 2020). The split N fertilization (60 + 30 kg N $ha^{-1}$), recorded significantly higher grain yield which were significantly higher than that of the control treatment having the lowest grain yield of 0.6 Mg $ha^{-1}$. Similarly, Singh and Sharma (2001) also observed that grain yield increased significantly with increasing nitrogen levels up to 150 kg N $ha^{-1}$.

**Table 2: Initial Properties of the Soil Prior to Land Preparation**

| Soil properties | Values |
|---|---|
| Sand (g $kg^{-1}$) | 831 |
| Silt (g $kg^{-1}$) | 66 |
| Clay (g $kg^{-1}$) | 103 |
| Textural Class | Loamy Sand |
| pH (H2O) 1:2.5 | 6.1 |
| Organic Carbon | 6.8 |
| Total Nitrogen (g $kg^{-1}$) | 0.70 |
| Available Phosphorus (mg $kg^{-1}$) | 6.0 |
| **Exchangeable Cations (cmol $kg^{-1}$)** | |
| Ca | 4.02 |
| Mg | 2.26 |
| K | 2.02 |
| Na | 0.33 |
| Exchangeable Acidity | 1.02 |
| ECEC (cmol $kg^{-1}$) | 9.65 |

**Table 3: Effects of Tillage and Nitrogen Fertilization Application on Maize Yields**

| Treatment | Grain Yield (Mg $ha^{-1}$) |
|---|---|
| **Tillage (T)** | |
| Manual Ridging | 1.3a |
| Minimum Tillage | 1.2b |
| SE± | 0.01 |
| N rate (kg N $ha^{-1}$) | |
| 0 | 0.6c |
| 30 + 60 | 1.6b |
| 45 + 45 | 1.8ab |
| 60 + 30 | 2.2a |
| 90 | 1.8ab |
| SE± | 0.22 |
| Interaction | |
| T * N | NS |

All means within a column (for each factor) followed by same letter (s) are not significantly different at 5 % level of significance, SE = Standard error, NS = Not significant

**Table 4: Effects of Tillage and Nitrogen Fertilization Application on Agronomic Efficiency of Nitrogen and Partial Factor Productivity of Nitrogen on Maize**

| Treatment | AEN | $PFP_N$ |
|---|---|---|
| **Tillage (T)** | **(kg grain kg $N^{-1}$)** | |
| Manual Ridging | 15.7a | 22.2a |
| Minimum Tillage | 11.4b | 18.7b |
| SE± | 1.87 | 1.91 |
| **N rate (kg N $ha^{-1}$)** | | |
| 30 + 60 | 11.0b | 18.0b |
| 45 + 45 | 13.1a | 20.1a |
| 60 + 30 | 17.6a | 24.5a |
| 90 | 13.5a | 20.5a |
| SE± | 2.69 | 2.68 |
| **Interaction** | | |
| T * N | NS | NS |

All means within a column (for each factor) followed by same letter (s) are not significantly different at 5 % level of significance, AEN = Agronomic efficiency of nitrogen, PFPN = Partial factor productivity of nitrogen, SE = Standard error, NS = Not significant

The effects of tillage and nitrogen application rate on agronomic efficiency and partial factor productivity of nitrogen are shown in Table 4. Both agronomic efficiency of nitrogen use (AEN) and partial factor productivity of nitrogen ($PFP_N$) were significantly affected by tillage practice and nitrogen fertilizer application rate. The AEN and $PFP_N$ were significantly higher when maize was grown under MR compared to MT. This result was in agreement with those obtained by Huggins *et al.* (1993) and Lopez-Bellido *et al.* (2001) who attributed the higher AEN and $PFP_N$ under MR to an increase in yield or as a result of N fertilizer immobilization through crop residue in MT plots. The values of AEN and $PFP_N$ recorded in this study were lower than 18 kg $kg^{-1}$ reported in small holder maize farm in SSA (Lehami *et al.,* 2019). The low values of AEN and $PFP_N$ recorded are a reflection of the low grain yield obtained in the control plots (Table 3). Also, some soils may be naturally fragile and P-fixing, leading to challenges for increased nutrient use efficiency (Chikowo *et al.,* 2010). The NUE is a function of maize grain yield in the control plots (Lehami *et al.,* 2019). Significantly lower AEN and $PFP_N$ recorded under 30 + 60 kg N $ha^{-1}$ may be attributed to the fact that, the N requirement at that stage of maize growth seems to be higher than 30 kg N $ha^{-1}$ supplied, which resulted into lower grain yield and subsequent reduction in AEN and $PFP_N$ values. The highest values of AEN and $PFP_N$ (17.6 and 24.5 kg $kg^{-1}$ respectively) were recorded in the treatment having application rate of 60 + 30 kg N $ha^{-1}$ suggesting that, split application rates enhanced nitrogen use efficiency of maize.

## CONCLUSION

This study evaluated the effects of tillage and nitrogen fertilization rates on nitrogen use efficiency of maize as part of a broad study to promote conservation agriculture in the southern Guinea savanna of Nigeria. The findings of the study indicated manual ridging enhanced nitrogen use efficiency of maize and produced the highest NUE. Thus, it may seem to be the most appropriate for maize cultivation in the agro ecological zone. The results showed that the highest AEN and $PFP_N$ were recorded under split nitrogen fertilizer application of 60 + 30 kg N $ha^{-1}$ which suggest that N fertilizer application is best applied in split form in the zone.

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# RESPONSE OF MAIZE (*Zea mays* L.) TO WEED CONTROL TREATMENTS USING NICOSULFURON IN SUDAN SAVANNA AGRO-ECOLOGICAL ZONE OF NIGERIA

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## ABSTRACT

Field trial was conducted during the dry season of 2019/2020 at the Teaching and Research Farm of the Kebbi State University of Science and Technology Jega, (lat 12° 11N, long 040 16E; 262m above sea level) located in the Sudan Savannah Agro-ecological zone of Nigeria. The research was aimed at determining the appropriate Nicosulfuron rate for maize production. The experiment consisted of three rates of Nicosulfuron at (0.5, 0.75 and 0.85 kg a.i. $ha^{-1}$, hoe weeding at 3 and 6 WAS, and a weedy check as control). The treatments were laid out in Randomized Completely Block Design (RCBD) and replicated three times. The gross and net plot size were $12m^2$ and $6m^2$ respectively. Weed cover score and weed dry weight were significantly decreased by the weed control treatment compared with weedy check plots. The treatments with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$ and hoe weeding at 3 and 6 WAS had significantly higher values for plant height, number of leaves per plant, and days to 50% tasseling and silking. Yield parameters such as cob weight per plant, cob weight, cob length, 100-grain weight and grain yield per hectare were also significantly increased in plots treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$ and those weeded twice at 3 and 6 WAS Based on the result obtained from this trial, it can be concluded that Nicosulfuron at 0.85 kg a.i. $ha^{-1}$and two hoe weeding at 3 and 6 WAS resulted in effective weed control and the highest grain yield of maize.

**Keywords:** Nicosulfuron, Maize, Weed, Length, Plan, cob

## INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop cultivated worldwide. It is also one of the most important cultivated crops in Nigeria. Maize forms a major component in the diet of the majority of the people and is also a source of raw material for agro-based industries like animal feed production (Iken and Amusa, 2004; Abdulraham and Kolawole, 2006). Maize cultivation in Nigeria cuts across different agro ecologies including; the forest ecology, derived savannah and the guinea savannah (Olaniyan, 2015). Maize is raw material used in the production of alcohol, starch, up abrasive, oil in the pharmaceutics and recently for fuel production (Ellis *et al.,* 1998; Acharya and Young, 2008; Ranum *et al.,* 2014). Worldwide yield losses in maize due to weeds are estimated to be more than 40-60% (Oerke and Dehne, 2004). In Nigeria, yield losses due to weed interference vary between 40 and 100% depending among other things on type of crop, type of weed and weed density (Ekeleme, 2001). For instance, competition from spear grass can cause crop yield losses of over 50% in maize and soybean and over 90% in cassava (Udensi *et al.,* 1999; Avav, 2000; Chikoye *et al.*, 2001). Porwal (2002) observed that severe infestation of weeds particularly in early stage of crop establishment ultimately accounts for a yield reduction of 40% and that farmers' practice of manual hoe weeding is costly, time consuming and back breaking, particularly on heavy soils.

## MATERIAL AND METHODS

### Experimental Site

Field trial was conducted at the University Teaching and Research Farm during 2019/2020 dry season. The University Orchard at Aliero (lat 12° 18.64′ N, long. 04° 29.85′, 262 m above sea level) located in the Sudan Savannah Agro-ecological zone of Nigeria.

### Treatments and Experimental Design

The treatment consisted of three rates of Nicosulfuron at (0.5, 0.7 and 0.85 kg a.i. $ha^{-1}$, hoe weeding at 3 and 6 WAS, and a weedy check as control). The treatments were laid out in complete randomize block design with three replications. The gross plot size consisted of 4 ridges each measured 4m x 3m i.e12$m^2$. While the two inner ridges 4m x 1.5m (6$m^2$) constituted the net plot.

### Cultural Practices

The experimental area was harrowed to a fine tilt and ridged 75 cm apart. The land was then marked into plots and replications. Border spaces of 0.5m between the plots and two ridges between replicates was also be marked Maize seeds were dressed prior to sowing, with dress force 42(indicloprid 20% + metalaxyl N 20% + Tebuconizole 2% WS) Seed dressing chemical at the rate of 10 g of the chemical per 4 kg of the seed. This was done in order to protect the seed from soil borne diseases and pests. The seeds were sown manually at the rate of two seeds per hole at a depth to about 3 cm and a spacing of 75 cm x 25 cm. The emerged seedlings were later thinned down to one plant per stand at two weeks after sowing. The post-emergence herbicide (Nicosulfuron) was applied at 3 weeks after sowing (WAS) on treatment basis. The equipment used is CP3 knapsack sprayer fitted with a green deflector nozzle and set at a pressure of 2.1 kg $m^{-2}$ to deliver 250 L $ha^{-1}$ of the spray solution. The spraying was done in the morning when the weather is calm to avoid wind drift. Hoe weeding was carried out at 3 and 6 WAS only for the hoe weeded treatment. Strong force (methomyl 90 + % SP) was used to control pest that were observed in the field, it was applied at 6 and 9 weeks after sowing respectively, Army killer (Rodenticide) was also used to control against rodent. Harvesting was done by removing the ear manually when the plants have attained physiological maturity as the cobs turn yellowish-brown and grains have hardened. The cobs were sundried, weighed and later threshed and winnowed to obtain clean grain. Data on weed cover score, weed dry weight, plant height, number of leaves were recorded at 6, 9 and 12 WAS. Days to 50% tasselling and silking, number of cobs per plant, number of rows per plant, cob length, cob weight, 100seed weight and grain yield were also recorded. Data collected were subjected to analysis of variance using SAS software package 2003. Means that are significant were separated using least significance difference.

## RESULTS AND DISCUSSION

The influence of weed control treatments on plant height of maize during 2019/2020 dry season at Jega is shown on Table 1. Weed control treatments had significant effect on plant height at all the sampling periods except at 4 WAS when weed control treatments had no significant effect on plant height. At other sampling periods hoe weeding and nicosulfuron 0.85 kg a.i $ha^{-1}$ resulted in the tallest maize plants which was followed by 0.70, 0.5 and the weedy check had the shortest plants. Number of leaves per plant was also significant at all the sampling period. Hoe weeded plots recorded significantly higher number of leaf that was at par with plots that were treated with 0.85 kg a.i. $ha^{-1}$ of Nicosulfuron, and Nicosulfuron 0.70 and 0.5 kg a.i. $ha^{-1}$ only at 4, 8 and 12 WAS. The weedy check consistently produced the least number of leaves per plant. The positive role of weed control treatments observed could have been the reason for improved performance of maize with regards to plant height, number of leaves per plant, compared with weedy check. This is because weed infestation throughout the lifecycle of crop in unweeded plots resulted to competition for environmental factors such as sunlight, nutrients, moisture etc. between weeds and the crop which significantly depressed these growth parameters. (Griehar *et al.*, 2004) observed that good weed control reduces competition for environmental resources which enable the plant to develop more and produce longer leaves resulting to efficient light interception for increase in dry matter accumulation.

The effect of weed control treatments on days to 50% tasselling and silking, number of seeds per row, cob weight, 100seed weight and grain yield is presented in table 3. There was significant effect of weed control treatments on days to 50% tasselling and silking where hoe weeded plots consistently took longer days to attained 50% tasselling and silking while the unchecked plots recorded the theleast number days. The yield components taken were also significant in which plot that received nicosulfuron at higher rate consistently recorded the highest mean values which differed significantly with all other treatments and the least values was recorded in the unchecked plots. This could be due to efficient weed control by the herbicides which causes increase in growth and yield of maize. This result agrees with the findings of Ahmed *et al.* (2017) who reported increase in maize yield when Nicosulfuron applied at higher rate.

**Table 1:** Shows the influence of weed control treatments on plant height (cm) and number of leaves of maize during 2019/2020 dry season at Jega.

| **Weed Control** | | **Plant Height** | | | **Number of Leaves** | |
|---|---|---|---|---|---|---|
| **Nicosulfuron (kg a.i ha$^{-1}$)** | **4WAS** | **8WAS** | **12WAS** | **4WAS** | **8WAS** | **12WAS** |
| 0.5 | 25.66 | 53.42$^{b}$ | 95.64$^{b}$ | 5.40$^{a}$ | 7.07$^{b}$ | 11.87$^{a}$ |
| 0.70 | 26.25 | 58.75$^{b}$ | 98.92$^{b}$ | 5.45$^{a}$ | 7.00$^{b}$ | 12.07$^{a}$ |
| 0.85 | 22.01 | 78.05$^{a}$ | 116.36$^{a}$ | 6.82$^{a}$ | 10.13$^{a}$ | 11.75$^{a}$ |
| Hoe weeding @ 3&6WAS | 25.50 | 69.29$^{a}$ | 109.61$^{a}$ | 6.57$^{a}$ | 9.45$^{a}$ | 9.98$^{a}$ |
| Weedy check | 21.13 | 16.90$^{c}$ | 15.98$^{c}$ | 3.00$^{b}$ | 3.75$^{c}$ | 5.25$^{b}$ |
| **LSD** | **6.81** | **7.01** | **9.52** | **1.22** | **2.13** | **2.28** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**). **WAS**= week after sowing, **t ha$^{-1}$**= tone per hectare. **Kg**= kilogram, **a.i**=active ingredient.

**Table 2:** Shows the influence of weed control treatments on weed dry weight and weed cover score of maize during 2019/2020 dry season at Jega.

| **Weed Control** | | **Weed Dry Weight(gm$^{2}$)** | | | **Weed Cover** | |
|---|---|---|---|---|---|---|
| **Nicosulfuron ( kg a.i ha$^{-1}$)** | **4WAS** | **8WAS** | **12WAS** | **4WAS** | **8WAS** | **12WAS** |
| 0.5 | 79.45$^{a}$ | 80.10$^{b}$ | 98.00$^{b}$ | 3.12$^{a}$ | 4.47$^{b}$ | 5.90$^{b}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.70 | 67.55$^{a}$ | 76.83$^{b}$ | 83.28$^{c}$ | 2.67$^{b}$ | 4.20$^{b}$ | 5.05$^{b}$ |
| 0.85 | 67.58$^{a}$ | 71.70$^{b}$ | 58.93$^{e}$ | 2.12$^{b}$ | 3.07$^{c}$ | 3.80$^{c}$ |
| Hoe weeding @ 3&6WAS | 66.70$^{a}$ | 72.80$^{b}$ | 61.35$^{d}$ | 4.25$^{a}$ | 3.62$^{b}$ | 3.47$^{c}$ |
| Weedy check | 136.25$^{b}$ | 562.68$^{a}$ | 661.83$^{a}$ | 4.77$^{a}$ | 7.27$^{a}$ | 8.05$^{a}$ |
| **LSD** | **6.42** | **7.92** | **13.18** | **1.69** | **1.49** | **1.53** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**).
**WAS**= week after sowing, **t ha$^{-1}$**= tone per hectare. **Kg**=kilogram, **a.i**=active ingredient.

**Table 3:** Shows the influence of weed control treatments on days to 50% tasseling and silking, number of seed per row cob weight, 100 grain weight and grain yield of maize during 2019/2020 dry season at Jega.

| WEED CONTROL | Days to 50% Tasseling | Days to 50%Silking | Seed per row | Weight of cob | 100 grain weight | Yield (t ha$^{-1}$) |
|---|---|---|---|---|---|---|
| **Nicosulfuron( kg a.i ha$^{-1}$)** | | | | | | |
| 0.5 | 53.50$^{b}$ | 66.50$^{a}$ | 26.20$^{c}$ | 60.37$^{b}$ | 19.25$^{b}$ | 1.67$^{d}$ |
| 0.70 | 54.00$^{b}$ | 67.25$^{a}$ | 31.75$^{b}$ | 64.77$^{b}$ | 20.22$^{b}$ | 2.22$^{c}$ |
| 0.85 | 55.50$^{b}$ | 67.25$^{a}$ | 37.95$^{a}$ | 79.21$^{a}$ | 25.00$^{a}$ | 2.78a |
| Hoe weeding @3&6WAS | 59.75$^{a}$ | 72.75$^{a}$ | 33.75$^{b}$ | 69.53$^{a}$ | 22.82$^{a}$ | 2.59$^{a}$ |
| Weedy check | 42.00$^{c}$ | 43.00$^{b}$ | 11.55$^{d}$ | 23.38$^{c}$ | 10.77$^{c}$ | 0.19$^{e}$ |
| **LSD** | **3.44** | **5.30** | **4.08** | **9.63** | **3.15** | **0.33** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**). **WAS**= week after sowing, **t ha$^{-1}$**= tone per hectare. **Kg**=kilogram, **a.i**=active ingredient.

## CONCLUSION

However, based on the result obtained from this trial, it can be concluded that Nicosulfuron at 0.85 kg a.i. ha$^{-1}$ and two hoe weeding at 3 and 6 WAS resulted in effective weed control and produced the highest grain yield of maize.

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# MACHINE LEARNING FOR ENHANCED AGRICULTURAL PRODUCTIVITY AND FOOD SECURITY: A REVIEW

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## ABSTRACT

Machine learning (ML) is rapidly transforming agriculture, offering promising solutions for enhancing productivity and contributing to global food security. This review examines the diverse applications of ML across key agricultural domains. We analyze studies demonstrating the efficacy of ML algorithms in crop yield prediction, utilizing historical data and environmental factors to improve decision-making and reduce costs. Furthermore, we explore the role of ML in precision agriculture, optimizing resource management through techniques like soil classification, weather forecasting, and targeted irrigation. The review also highlights the potential of ML for early disease detection and management, enabling timely interventions and minimizing crop losses. While acknowledging the transformative potential of ML, we address existing challenges, including data acquisition and the complexity of agricultural systems. Finally, we briefly discuss the policy implications surrounding ML integration in agriculture, emphasizing the need for supportive frameworks to promote wider adoption and maximize its contribution to sustainable food production.
**Keywords:** Machine learning, agriculture, food security, precision agriculture

## INTRODUCTION

The escalating global population and the concomitant demand for food production present a significant challenge to global food security. Traditional agricultural practices often struggle to keep pace with this growing demand, necessitating the exploration of innovative approaches to enhance productivity and sustainability. Machine learning (ML), a subfield of artificial intelligence, offers a powerful toolkit for revolutionizing agricultural practices and addressing the complexities of modern food production. By leveraging algorithms capable of learning from data, ML can optimize various aspects of agriculture, from predicting crop yields and managing resources to detecting diseases and mitigating environmental impacts.

The integration of ML into agricultural systems holds immense potential to transform the sector and contribute significantly to food security. ML algorithms can analyze vast amounts of data, identify patterns, and make predictions with remarkable accuracy, surpassing human capabilities in many instances. This data-driven approach enables farmers and policymakers to make more informed decisions, leading to increased efficiency, reduced waste, and improved resource allocation. One of the key areas where ML is making a substantial impact is crop yield prediction. By analyzing historical data on weather patterns, soil conditions, and crop characteristics, ML models can accurately forecast future yields, allowing farmers to optimize planting strategies, resource allocation, and harvesting schedules (Bhardwaj & Tiwari, 2022; Mistry *et al*., 2023; Sharma, 2023). This predictive capability is crucial for minimizing risks and maximizing profits in an increasingly volatile agricultural landscape.

Furthermore, ML plays a vital role in precision agriculture, enabling farmers to tailor their practices to the specific needs of individual fields or even individual plants. By integrating data from sensors, drones, and satellites, ML algorithms can provide insights into soil variability, nutrient deficiencies, and pest infestations (Baburao *et al*., 2023; Condran *et al*., 2022). This granular level of information allows for targeted interventions, optimizing the use of fertilizers, pesticides, and water, thereby reducing costs and minimizing environmental impact. Another critical application of ML in agriculture is disease detection and management. Early and accurate identification of crop diseases is essential for preventing widespread outbreaks and minimizing yield losses. ML algorithms can analyze images of plants, detect subtle signs of disease, and even predict the likelihood of future infections (Ajmera *et al*., 2022). This proactive approach to disease management empowers farmers to take timely action, preventing significant economic losses and ensuring the health and productivity of their crops.

While the potential of ML in agriculture is vast, several challenges remain. These include the need for large, high-quality datasets, the complexity of agricultural systems, and the accessibility of ML technologies to farmers in diverse settings. Overcoming these challenges requires collaborative efforts from researchers, policymakers, and the agricultural community. This review will delve into the various applications of ML in agriculture, examining its potential benefits, addressing the existing challenges, and exploring the policy implications of integrating this transformative technology into the agricultural sector.

**I. Predicting Crop Yields with Machine Learning**

**Algorithms for Yield Prediction**

Several ML algorithms are commonly used for crop yield prediction, each with strengths and weaknesses. Random Forest (RF) handles large datasets well and provides feature importance insights (Shahhosseini *et al*., 2019; Kim *et al*., 2019) but can lack interpretability. Support Vector Machines (SVM) excel in high-dimensional spaces but may be computationally intensive for large datasets (Kim *et al*., 2019; Sun *et al*., 2020). Deep Neural Networks (DNNs), especially CNNs and RNNs, effectively capture non-linear relationships but require substantial data and careful regularization (Khaki *et al*., 2020; Varghese & Kandasamy, 2021; Sabo, 2023). Algorithm selection depends on dataset characteristics, desired interpretability, and computational resources.

**Data and Feature Selection**

Accurate yield prediction relies on diverse data sources, including weather, soil, satellite imagery, and sensor data (Srivastava *et al*., 2022; Peng *et al*., 2018; Elavarasan & Padois, 2020; Wang *et al*., 2020). DNNs benefit from large datasets like satellite imagery, while SVMs may suit smaller, carefully engineered datasets. Feature engineering and selection techniques like PCA and recursive feature elimination are crucial for identifying relevant predictors and improving model performance (Crane-Droesch, 2018; Saravanan & Bhagavathiappan, 2022; Varghese & Kandasamy, 2021).

**Case Studies and Practical Applications**

Studies demonstrate successful ML application in yield prediction. Khaki *et al*. (2020) used a CNN-RNN framework with satellite and weather data, achieving accurate predictions for soybean and corn (Liu *et al*., 2021). Other studies highlight the importance of precise data inputs (Aubakirova *et al*., 2023). However, challenges remain in model generalization across diverse environments (Sabo, 2023; Poudel & Shaw, 2016), necessitating further research. Emerging trends address limitations in interpretability and adaptability. Explainable AI (XAI) is gaining traction (Saravanan & Bhagavathiappan, 2022), offering transparency in predictions. Integrating climate change projections enables robust forecasting under changing conditions (Crane-Droesch, 2018; Juma & Beru, 2021). Combining traditional knowledge with ML further enhances prediction accuracy (Msongaleli *et al*., 2015).

## II. Optimizing Agricultural Practices with Precision Agriculture

### Enhancing Soil Management

ML is transforming soil management through soil classification, nutrient mapping, and fertilizer recommendations. Studies show that algorithms like RF and CNNs effectively classify soil nutrients and pH levels (Bakhtawer *et al*., 2022; Escorcia-Gutierrez *et al*., 2022). Hyperspectral remote sensing further improves soil texture and nutrient predictions, enhancing fertilizer recommendations (Pan, 2023; Raju, 2024). By analyzing large datasets, ML identifies patterns and optimizes fertilizer application, improving yields and minimizing environmental impact (Frey, 2020; Azizan *et al*., 2019; Zhang *et al*., 2021).

### Smart Irrigation Management

ML optimizes irrigation scheduling and water resource management. By processing data from weather forecasts, soil sensors, and crop water requirements, ML algorithms inform irrigation timing and volume (Kovačević, 2023; Drogkoula, 2023). Predictive models based on historical and current conditions improve water allocation efficiency (Yousoufi, 2023; Rozos, 2019). ML also supports adaptive irrigation strategies, crucial in water-scarce regions (Chi *et al*., 2020; Wu *et al*., 2020).

### Advanced Pest and Weed Control

ML, combined with computer vision and robotics, revolutionizes pest and weed control. ML models analyze images to identify infestations, enabling targeted pesticide application and precision weeding (Veeragandham & Santhi, 2020; Yahya *et al*., 2020). This minimizes chemical use and environmental impact. Predictive capabilities also facilitate Integrated Pest Management (IPM) strategies, reducing reliance on chemical treatments (Frey, 2020; Zhang *et al*., 2021).

### Data-Driven Livestock Management

ML extends its benefits to livestock management. Wearable sensors and ML algorithms monitor animal health, enabling early detection of issues and optimized feeding strategies (Veeragandham & Santhi, 2020; Pomperada, 2022). ML also aids in breeding programs by analyzing genetic data to identify desirable traits, improving livestock quality and productivity (Zhang *et al*., 2021).

## III. Early Disease Detection and Management with Machine Learning

### Image-Based Disease Detection

Computer vision and ML have significantly advanced plant disease detection through image analysis. CNNs are widely used for their ability to learn from images, achieving high accuracy in disease classification (Sharma *et al*., 2021; Shilpa *et al*., 2022). While CNNs often outperform traditional methods like SVM, other algorithms such as RF also show effectiveness (Lee *et al*., 2020). These technologies enable automated, real-time disease detection, crucial for timely intervention.

### Sensor-Based Disease Detection

Sensors play a crucial role in early disease detection by monitoring physiological changes in plants (Xiong *et al*., 2019). Integrating sensor data with ML models enhances predictive capabilities. For example, combining multispectral sensor data with RF models can predict nitrogen levels and identify potential disease risks (Zha *et al*., 2020). Non-invasive sensing techniques enable continuous plant health monitoring, allowing for proactive disease management.

**Disease Forecasting and Early Warning Systems**

ML is revolutionizing disease forecasting and early warning systems. By analyzing historical data, ML models predict disease likelihood in specific crops and regions (Sharma *et al*., 2021; Ismael *et al*., 2021). Real-time data analysis enables early warning systems to provide timely alerts, facilitating rapid responses to potential threats. Algorithms like RF effectively predict conditions conducive to outbreaks, improving resource management and crop protection (Jeong *et al*., 2016).

## IV. Challenges and Future Directions

Despite the considerable progress in applying ML to agriculture, several challenges hinder wider adoption and limit the realization of its full potential. One major challenge is the availability and quality of data. ML models require large, high-quality datasets for training, which can be difficult and expensive to acquire, especially in developing regions. Furthermore, data standardization and interoperability remain significant obstacles, limiting the ability to share and combine data from different sources. Another key challenge is the interpretability and explainability of ML models, often perceived as "black boxes." This lack of transparency can erode trust among farmers and policymakers, hindering the adoption of ML-based solutions. Moreover, the scalability and accessibility of ML technologies remain a concern. Deploying and maintaining complex ML systems can be resource-intensive, particularly for smallholder farmers who often lack access to the necessary infrastructure and expertise.

Future research directions should focus on addressing these challenges. Developing methods for data augmentation, transfer learning, and federated learning can help overcome data scarcity and improve model generalization. Explainable AI (XAI) techniques are crucial for increasing transparency and building trust in ML models. Creating user-friendly interfaces and mobile applications can enhance the accessibility of ML tools for farmers. Finally, fostering collaboration between researchers, policymakers, and agricultural stakeholders is essential for developing effective strategies for integrating ML into agricultural practices and realizing its transformative potential for food security.

## CONCLUSION

In conclusion, machine learning offers a powerful toolkit for transforming agriculture and enhancing global food security. This review highlights the demonstrated efficacy of ML in diverse applications, from crop yield prediction and resource optimization to disease detection and livestock management. However, realizing the full potential of ML requires overcoming challenges related to data availability, model interpretability, and accessibility, particularly for smallholder farmers. Future progress hinges on continued research in areas like explainable AI, data augmentation techniques, and user-friendly interface development, coupled with collaborative efforts among researchers, policymakers, and agricultural stakeholders. By addressing these challenges and promoting wider adoption, ML can revolutionize agricultural practices, leading to increased productivity, improved sustainability, and enhanced food security worldwide.

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# INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON SELECTED ENZYME ACTIVITIES IN RELATION TO SELECTED SOIL CHEMICAL PROPERTIES IN RICE FIELD AT BADEGGI NIGER STATE, NIGERIA

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## ABSTRACT

Soil enzyme activities provide an easy, relatively rapid and low cost production to monitor soil health. Integrated soil management effect on urease and acid phosphatase activities was determined by collecting soil samples from four (4) rice farmers field in Badeggi, Niger State. Where; *Control*, Farmers' practice (NPK); 150 kg ha$^{-1}$ NPK (15:15:15), OCP special blend; (NPK 15:15:15 fertilizer fortified with Zn and Ca.), 600 kg ha$^{-1}$, cow dung; (5-ton ha$^{-1}$), ½ cow dung + ½ NPK and ½ cow dung + ½ OCP special blend fertilizer were applied accordingly. The experiment was laid out in a Randomized Complete Block Design (RCBD) replicated four times. Data were collected according to standard and subjected to Analysis of Variance using GenStat (11$^{th}$ Edition). Significant means were separated using Least Significant Difference (LSD) ($p \leq 0.05$). Results showed that Cow dung application consistently resulted in the highest urease activity throughout the growth stages of rice production, indicating its significant role in promoting ammonium volatilization. This was evident with urease activities of 665 µg $NH4^+$ N g$^{-1}$ soil h$^{-1}$, 511 µg $NH4^+$ N g$^{-1}$ soil h$^{-1}$ and 427 µg $NH4^+$ N g$^{-1}$ soil h$^{-1}$ at planting, flowering and at harvest respectively, surpassing all other treatments. Similarly, cow dung application and its combination with NPK and OCP showed notable effect on acid phosphatase activities all through the different growth stages. There was positive relationship between urease activity and pH while it negatively correlated with the other observed nutrients. Whereas, acid phosphatase activity had positive relationship with pH, Organic carbon, Total nitrogen and Available Phosphorus. The observed significant response variation among treatments at different growth stages of rice, highlights the dynamic nature of soil as it influenced the existing microbes (enzyme activity) in the rhizosphere in response to the various soil management practices adopted by farmers. Hence altering soil health and its productivity. Therefore, the use of OCP special blend for improvement of soil available phosphorus should be encouraged while the sole use of cow dung should be discouraged on rice field.

**Keyword:** Urease, Acid phosphatase, Rice, OCP special blend, NPK, Organic manure

## INTRODUCTION

In larger parts of Badeggi, rice is being grown under flooded conditions. Rice-rice cropping system is the most dominant cropping system adopted by rice farmers in Zone – A, of Niger State. Submerged soils ecosystems are predominantly anaerobic and are different from upland soils in several physical and biological properties (Adhya and Rao, 2005). The growth rate of world agricultural production and crop yields have slowed, raising fears that the World may not be able to grow enough foods to meet the needs of the present and future population, and generation (Lal, 2015). Declining trend in productivity due to continuous use of chemical fertilizers alone has been observed in several long term experiments all over Nigeria, which could be attributed to the use of inappropriate agricultural practices and higher dependency on synthetic fertilizers, leading to constant decline in factors of productivity and low yield of crops; hence an adoption of integrated nutrient management (Liu *et al*., 2021).

For soil health/fertility sustainability, integrated soil fertility management (ISFM) is one of the reliable technologies farmers are encouraged to adopt of recent, which implies the combination of different sources of soil amendments in small quantities; to complement the limitations of each component (Ezekiel-Adewoyin *et al*., 2023). Organic manures used in rice cultivation serve as carbon and energy source for proliferation of microorganisms, which may alter the activities of different soil enzymes (Srinivas and Sridhar (2022). Use of chemical fertilizers and organic manures has been found promising in arresting the decline trend in soil-health and productivity through the correction of marginal deficiencies of some macro-nutrients, micro-nutrients, micro-flora and fauna and their beneficial influence on physical and biological properties of soil (Nath *et al*., 2015). Kumar (2018) stated that Integrated Nutrient Management (INM) increased soil urease, phosphatase activities and soil available nutrients. Soil enzymatic activities have been proposed as appropriate indicators because of their intimate relationship to soil biology and rapid response to changes in nutrient management. However, interactions between INM practices, soil chemical properties (nutrient availability, pH), and soil biological properties (microbial communities, enzyme activities) in rice fields are intricate and can vary depending on specific local conditions (Fageria *et al*., 2011; Mandal *et al*., 2019). Urease and phosphatase activity is responsible for N- and P-metabolism in the soil (Nwankwo, 2018). Therefore, the activities of urease and phosphatase play crucial role in N and P cycling, respectively (Garcia-Ruiz *et al*., 2008). Farmers need continuous access to improved rice technologies to boost their rice productivity in Niger State. Enhancing productivity of rice is the major concern to meet the demand for food by the increasing human population. Therefore, addressing the knowledge gap related to INM's influence on soil properties as affected by enzyme activity is vital for sustainable rice production in Baggegi, Niger State, Nigeria.

## MATERIALS AND METHODS

### *Study Area*

***Soil samples were collected from four (4) rice farmers' field in Badeggi according to the applied treatments.*** Badeggi is situated in the Southern Guinea Savanna ecological zone of Nigeria with: Latitude: 9° 33' 22.68"N, and Longitude: 6° 08' 36.83' E with an elevation of 120 m, above sea level. With a mean annual rainfall of about 1128 mm with mean annual minimum and maximum temperature of 26 °C and 32 °C respectively.

### Experimental Design and Treatments

The trial was established on four (4) farmers' fields in the study area. The experiment was laid out in a Randomized Complete Block Design (RCBD) with each of the farmers' field serving as a replicate. The treatments were; Control, Farmers' practice of 150 kg ha$^{-1}$ NPK 15:15:15, OCP special blend (NPK 15: 15:15 fertilizer, fortified with Zn and Ca.) 600 kg ha$^{-1}$ was divided into two equal halves for application at 2 and 4 weeks after transplanting (WATP). Cow dung (5 tons ha$^{-1}$/ 2 weeks after transplanting (WATP)), ½ Cow dung {2.5 tons ha$^{-1}$) + ½ Farmers practice (75 kg ha $^{-1}$ NPK 15:15:15) and ½ Cow dung (2.5 tons ha$^{-1}$) + ½ OCP special blend fertilizer (300 kg ha$^{-1}$).

**Source of Experimental Materials**

Improved seeds of rice (FARO 44) from National Cereals Research Institute (NCRI), farm yard manure (cow dung) from Teaching and Research Farm, Federal University of Technology, Minna and the Nigeria Institute of Soil Science (NISS), Abuja, provided bags of NPK (15:15:15) fertilizer and "Office Cherefien des Phosphates" (OCP) special mix NPK fertilizer (20:10:5+1Zn+2Ca), which is supplemented with calcium and zinc.

**Soil Sampling and Analysis**

Prior to the commencement of the experiment, soil samples from each farmers' field were randomly collected at a depth of 0 – 15 cm using soil auger. The soil samples were carefully collected at intervals of 5 m, in a plastic bucket, bulked and mixed thoroughly with hand-trowel to form a composite from which sub-sample was collected and labelled according to treatments. Before planting at flowering and after harvest. Chemical and biological analysis was done in Soil Science and Land Management Laboratory, Federal University of Technology, Minna.
pH was determined in 1:2 wt/v mixture of soil and water according to Anderson and Ingram (1993). The organic carbon content was determined using according to Walkley - Black wet oxidation method (Walkley and Black, 1934). Total nitrogen was determined by micro-Kjeldahl digestion method. Available phosphorus was extracted using BrayP-1 method of extraction and determined calorimetrically. Also, laboratory characterization was conducted on the collected cured manure (cow-dung) that was used using the standard methodology. For the release of NH4-N from the hydrolysis of urea as described by Tabatabai and Bremner (1972) and acid phosphatase by Tabatabai method (1994).

**Statistical Analysis**

Data collected was subjected to Analysis of Variance (ANOVA) using GenStat (11$^{TH}$ Edition). Significant differences between treatment means were separated using Least Significant Differences (LSD) at 5 % level of significance. Soil enzyme activities were correlated with the selected soil chemical properties using Pearson correlation.

**RESULTS**

**Initial soil analysis of the study site**

The soil of the study site was slightly acidic in nature with pH 6.1. Total Nitrogen (0.04g kg$^{-1}$), Available Phosphorus (5.24 g kg$^{-1}$) and Organic Carbon (g kg$^{-1}$) were all low in the soil of the study area according to Chude *et al.* 2011.

**Effect of integrated nutrient management on urease activity in rice field**

The effect of organic and inorganic fertilizer on soil urease activity is presented in Table 1. The treatments significantly affected urease enzyme activity ($p \leq 0.05$). Application of cow dung recorded the highest urease activity of 661, 511 and 534 µg $NH_4^+$-N g$^{-1}$ dw soil, before planting, at flowering and at harvest of rice respectively. Followed by ½ cow dung + ½ NPK (392, 371, 321 µg $NH_4^+$-N g$^{-1}$ dw soil) respectively. However, OCP special blend also recorded high activity of 469, 301 and 306 µg $NH_4^+$-N g$^{-1}$ dw soil) respectively, followed by control (294, 175 and 184 µgg$^{-1}$) respectively, ½ cow dung + OCP special blend (175, 154 and 147 µg $NH_4^+$-N g$^{-1}$ dw soil) respectively, then NPK (77, 112, 77 µg $NH_4^+$-N g$^{-1}$ dw soil) respectively in that arrangement. Urease activity as a result of ½ cow dung + NPK was significantly higher than that due to the control and application of ½ cow dung + ½ OCP special blend and NPK.

**Table 1: Effect of Organic and Inorganic Fertilizer on Soil Urease activity (µg $NH_4^+$-N $g^{-1}$ dw soil $h^{-1}$)**

| Treatments | Before planting | At flowering | At harvest |
|---|---|---|---|
| Control | 294d | 175d | 184d |
| NPK | 77f | 112f | 77f |
| OCP | 469b | 301c | 305.7c |
| Cowdung | 665a | 511a | 534a |
| ½ Cowdung + ½ NPK | 392c | 371b | 329b |
| ½ Cowdung + ½ OCP | 175e | 154e | 147e |

Means with same letter in a column are not significantly different at 5 % level of probability.

Effect of integrated nutrient management on acid phosphatase in rice field

Table 2 presents the effect of integrated nutrient management on acid phosphatase in rice field. Control treatment recorded the highest phosphatase activity before planting and at harvest, at flowering 5 tons $ha^{-1}$ cow dung recorded (2.35 and 22.7 µg p-nitrophenol released $g^{-1}$ soil $h^{-1}$) at harvest, while ½ cow dung + ½ OCP special blend had 2.26 µg p-nitrophenol $g^{-1}$ soil $h^{-1}$, NPK had (2.24 µg p-nitrophenol released $g^{-1}$ soil $h^{-1}$) before planting and OCP special blend had the lowest activity before planting and at harvest even at flowering it had about the lowest phosphatase activity.

**Table 2: Effect of Organic and Inorganic Fertilizer on Soil Acid Phosphatase activity (µg p-nitrophenol $g^{-1}$ soil $h^{-1}$)**

| Treatments | Before planting | At flowering | At harvest |
|---|---|---|---|
| Control | 2.29a | 2.30b | 2.29a |
| NPK | 2.24c | 1.87e | 2.12d |
| OCP | 1.93e | 2.21d | 2.09e |
| Cowdung | 2.22d | 2.35a | 2.27b |
| ½ Cowdung + ½ NPK | 2.24c | 2.27c | 2.25c |
| ½ Cowdung + ½ OCP | 2.26b | 2.27c | 2.25c |

Means with same letter in a column are not significantly different at 5 % level of probability

Relationship between Selected Enzymes' Activities and Selected Soil Chemical Properties

Table 3 presents the results of the correlation analysis, the result obtained depicted positive relationship between urease activities, acid phosphatase and pH ($H_2O$) but urease activity was negatively correlated with Organic carbon (OC), Total nitrogen (TN) and Available phosphorus (AP), and were significantly different ($P \leq 0.05$). While there was a positive relationship between acid phosphatase activity with pH, OC, TN, AP and significant at $P \leq 0.05$.

**Table 1: Correlation analysis of Enzyme activities with selected soil chemical properties**

| Soil | UA | ACP | pH | OC | TN |
|---|---|---|---|---|---|
| UA | | | | | |
| ACP | 0.310* | | | | |
| pH | 0.261* | 0.233* | | | |
| OC | -0.086* | 0.805 | 0.000 | | |
| TN | -0.537* | 0.290* | 1.182* | 0.524 | |
| AP | -0.574* | 0.324* | 0.429 | 0.544 | 0.908 |

NS: Not significant, *Significant, @$p<0.05$, UA: Urease activity, ACP: Acid phosphatase, OC: Organic carbon, AP: Available phosphorus, TN: Total nitrogen.

## DISCUSSION

### Initial soil analysis of the study site

Slightly acidic soil nature (pH 6.1) is within the pH limit of 5.8 to 6 recommended for availability of most soil nutrients (Onyekwere *et al*., 2023). The low organic carbon, total N and available P is an indication of high nutrient mining of the soil of the study site due to continuous cultivation of rice year in year out and use of inorganic fertilizer. Therefore, rice Farmers need continuous access to improved rice management technologies to boost rice yield and still sustain soil health: hence the adoption of integrated nutrient management for soil fertility and productivity sustainability cannot be ignored.

### Elemental composition of the organic fertilizer (cow dung)

The high alkaline pH of the organic fertilizer was due to high presence of exchangeable bases. The high total N (1.75%) and phosphorus (2.15%) content might be attributed to high proportion of nitrogen and phosphorus as plant nutrients in organic manures. This finding agrees with that of (Onyekwere *et al*., 2023) who reported in their studies that organic manures are always richly high in Nitrogen, Phosphorus and Potassium. The C:N and C:P ratio of 14:1 and 11:1 could be as a result of high content of carbon over low N and high content of carbon over P in the feed taken up by the cow. This finding is in accordance with that of (Midya *et al*., 2021) whose studies stated that feed with high proportion of carbon content is required as energy sources for livestock and its by product always high in carbon. This study also conformed with that of (Lal, 2015) who stated that organic matter serves as a nutrient reservoir, holding essential elements like nitrogen (N), phosphorus (P), and potassium (K) as well as trace elements. As organic materials decompose, nutrients are gradually released, ensuring a steady supply to growing plants. This slow-release mechanism helps prevent nutrient leaching and runoff, thereby reducing the risk of environmental pollution.

### Effect of integrated nutrient management on urease activity in rice field

Urease is an extracellular enzyme involved in the breakdown of soil organic matter into smaller compounds and their measurement has proven to be a powerful tool in evaluating the functionality of soils**.** The importance of urease in N cycle generating accessible N for plant growth is of necessity for quantifying the efficient use of fertilizer applied. Application of cow dung recorded significantly highest urease activity on rice plot, followed by its combination with NPK which was at par with the value recorded on the plot treated with OCP Special Blend. The use of ½ Cow dung + 1/2 OCP and NPK had the lowest urease activity value which was not significantly different from the control.

Soil treatment with cow dung produced the highest urease activity while the treatment with 150 kg $ha^{-1}$ of NPK produced the lowest activity. This is an indication that cow dung supported the reduction in nitrogen availability due to N loss as a result of $NH_4^+$ volatilization in the form of ammonia ($NH_3$). Previous studies have shown that the application of $NH_4$ fertilizer to basic soil converts the $NH_4$ salt to $NH_3$ gas thereby increasing $NH_4$ $^+$ volatilization. Applying cow dung with basic pH of 9.40 most likely moved the initial soil pH of 6.1 to an alkaline/basic value thereby converting $NH_4^+$ N to $NH_3$. . More so, addition of organic materials brings about proliferation of microorganisms leading to increased enzyme activity (Lloyd and Sheaffe, 1973). The application of NPK (15-15-15) which produced the lowest urease activity invariably produced the highest nitrogen availability or the lowest $NH_4^+$ N volatilization. This was probably achieved by lowering the pH of soil and minimizing $NH_4^+$ N volatilization. On the other hand, the addition of OCP special blend to the soil must have altered the initial soil pH of 6.1 to slightly basic value which resulted in urease activity of 306 µg $NH_4^+$ N $g^{-1}$ dw soil that was comparable to urease activity of 329 µg $NH_4^+$-N $g^{-1}$ dw soil due to the application of ½ cow dung + ½ NPK.

**Effect of integrated nutrient management on acid phosphatase activity in rice field**

Soil contains acid phosphatase activity in variable amounts depending on microbial count, types of organic materials, other macroscopic living organisms and their activities, the amount of phosphatase released into the soil can then be directly co-related to soil fertility. This study revealed significant differences in the soil phosphatase of the study area with and without the treatments applied. The control plot had the highest value which was however not significantly ($P \leq 0.05$) different from the plot treated with cow dung, possibly because phosphorus is unavailable in the form of Aluminum and Iron hydroxy phosphates as a result of the soil reaction (pH (6.1)) and less degradation of the substrate in cow dung at the point in time, thereby increasing the acid phosphatase activity (Wu and Ma 2015). This is similar to the report of Anwesha *et a*l., (2012). Who reported that phosphatase which are present in soil must be heterogeneous because they are generated from various macro and microscopic organisms.

The control plot was higher in acid phosphatase indicating that the inherent available P content of 5.24 mg $kg^{-1}$ was the lowest compared to all other treatments. Studies have shown that high phosphatase activity is an indicator of low phosphorus availability (Onyekwere *et al*., 2023). An inclusion of cow dung lowered phosphatase activity compared to the control as a result of the solubilization or mineralization of soil organic and inorganic P, which could make phosphorus more available compared to the control. The C:P ratio of cow dung (11:1) explains partly why phosphorus was solubilized or mineralized (Onyekwere *et al*., 2023).

**Correlation of selected soil enzyme activity with selected chemical properties**

Correlation of Urease activity with selected chemical properties in a negative manner signifies an inverse relationship. This means that as urease activity increases, the concentration of the chemical elements decreases. The result demonstrated that urease activity correlated negatively with total nitrogen implying that increase urease activity resulted in decrease in total Nitrogen content of soil due to Ammonium salt volatilization. These agree with the finding of Uzoma *et al.,* (2018) who reported a negative correlation between urease activity and total nitrogen. Similarly, a negative correlation was also observed between acid phosphatase and available phosphorus implying that as phosphatase activity increases, available phosphorus decreases. Since rice grows in the interactive ecosystem involving soil – microorganism – rice and atmosphere, rice development consequentially affected soil microorganisms and soil enzymatic activities. Among the various enzymes, phosphatase speeds up soil organic phosphorus decomposition and improves soil phosphorous concentration, which is an important index to assess soil phosphorus bio – availability. Phosphatases are capable of catalyzing hydrolysis of esters and hydrides of phosphoric acid. In soil ecosystem, these enzymes are believed to play critical roles in 'P' cycle as evidence shows that they are correlated to 'P' stress and plant growth. Apart from being good indicators of soil fertility, phosphatase enzymes play key role in the soil system. Acid phosphatase provides a potential index of mineralization of soil organic P.

The results emphasize the importance of integrating organic amendments like cow dung alongside balanced inorganic fertilizers (NPK and OCP) to optimize soil health and enhance enzymatic activities crucial for nutrient availability. Understanding these interactions provides valuable insights for sustainable agricultural practices aimed at improving soil fertility, crop productivity, and environmental stewardship. The use of OCP special blend for improvement of soil available phosphorus should be encouraged while discouraging the use of cow dung only. Likewise, NPK or the combination of ½ cow dung + ½ OCP special blend should be used to reduce $NH_4^+$ N loss.

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# INFLUENCE OF DIFFERENT RATES OF CATTLE DUNG MANURE ON THE GROWTH, YIELD AND YIELD COMPONENTS OF ACHA (*Digitaria iburua* Kippis Stapf) AT RIYOM, JOS

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## ABSTRACT

The study was conducted at the experimental farm of the National Cereals Research Institute, Acha Substation Riyom, Plateau State (Latitude $9^0$ 37' 48" E Longitude $8^0$ 46' 11" N) and 1250 meter above sea level. The experiment was to evaluate rate of cattle organic manure on the growth and yield components of Acha (*D. iburua*) during the 2023 and 2024 cropping seasons. The treatments consisted of four different rates of cattle manure (5, 10, 15 and 20 t. $ha^{-1}$) and a control. The experimental Design was a Randomized Complete Block Design (RCBD) with three replications. Plot size was 3.0 x 5.0 m, with 0.5 m and 1.0 m alley ways between plots and replications respectively. Sowing method was by broadcasting of seeds at the rate of 30 kg. $ha^{-1}$ into each plot. The parameters measured were: number of tillers, plant height, number of spikes, number of panicles $m^2$, lengths of spikes and grain yield. It was observed that treatments had significant ($P < 0.05$) effects across all the parameters measured in which treatments applied at 15 t. $ha^{-1}$ in 2023 and at 10 t. $ha^{-1}$ in 2024 gave significantly ($P < 0.05$) higher number of tillers $plant^{-1}$, 20 t. $ha^{-1}$ in 2023 and 15 t. $ha^{-1}$ 20 t. $ha^{-1}$ in 2024 produced taller plants, 5 t. $ha^{-1}$ in 2023 and 10 t. $ha^{-1}$ in 2024 recorded higher number of spikes $plant^{-1}$, significantly ($P <0.05$) higher panicle $m^2$ and lengths of spikes $plant^{-1}$ were obtained at 20 tons $ha^{-1}$ of the treatments and when no treatment was applied in both years of studies. While the application of treatments at 15 and 10 t. $ha^{-1}$ produced significantly ($P <0.05$) higher grain yield in 2023 and 2024 respectively. It can be concluded that15 t. $ha^{-1}$ of cattle dung organic manure is recommended for optimum Acha (*D. iburua*) production in Riyom.

**Key words:** Organic manure, Acha, vegetative variables, yield
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## INTRODUCTION

Cattle dung organic manure is an important source of fertilizer for crop production in the small holder sector. It is a source of nitrogen that can help farmers in reducing input of commercial fertilizer and thus increasing the profit margin of the farmers. The release of nutrients contained in organic manures are more slowly but it stores for a longer time in the soil (Sharma, *et al,* 1991, ) thereby ensuring a long residual effect that supports better root and vegetative development leading to higher crop yield and this also improves the environmental conditions and public health care are also important reasons for advocating increased use of organic materials and the maintenance of soil fertility is essential for optimum and sustained production. The use of inorganic fertilizers is equally important in replenishing soil nutrients and increasing crop yields but are too costly for resource-poor farmers to purchase and the use of mineral fertilizers has been associated with increased soil acidity, nutrient imbalance and soil degradation (Kang and juo, 1980, Ojeniyi, 2000,). Recently, Acha is gaining fast popularity due to its high nutritive and health benefits among masses with an immense potential in domestic and international markets (Dachi, 2014). Acha or *fonio* is a highly prized crop because it contents two vital Sulphur amino acids (methionine and cytesine) that vital to human health and are non-existent in most major crops like maize (*Zea mays.*), (Rice (*Oryza sativa L.*), Sorghum (*Sorghum bicolor*), wheat (*Tritium aestivum* L.) among others. The crop is usually processed into different dishes and recipes such as tuwo, couscous, porridge, Cake, bread, malt drink among others.

The diets consist of relatively free sugar and low in glycemic index. This makes it an adequate diet for diabetic patients. Also, farmers do value Acha because of its unique taste, nutritional value and impressive returns from the products of the crop which has made the grain of the crop gain attractiveness and ample awareness being created among Acha farming communities in the West Africa sub-region and in the whole world (Ndor *et al,* 2016). Although, increased levels of production can be attained by increased use of inorganic fertilizers alone, but it may lead to deterioration in soil quality besides pollution problems. Also, with intensification of cropping, organic matter and N are readily depleted while phosphorous (P) and other nutrient reserves are slowly but readily depleted, the increase pressure on land, with the traditional practices employed to restore the fertility of these soils have been rendered unsuitable as quick fertility of these soils have been rendered unsuitable as quick fertility restorative practices are needed to meet the increasing demand for food crop production (Kang *et al.,* 1986).

In recent years, the focus on soil fertility research has been shifted towards the use of organic and/or combined application of organic matter and other forms fertilizers as a way to arrest the ongoing fertility decline in Sub-Saharan Africa (Vanlauwe *et al,* 2001). The organic sources can reduce the dependency on costly fertilizers by providing nutrients that are either prevented from being lost (recycling) or are truly added to the system. When being applied repeatedly, the organic matter leads to build-up of soil organic matter, thus, providing a capital of nutrients that are slowly released (Muamba and Obashola, 2022). Therefore, the use of organic materials can be one of the main pillars of sustainable agriculture as they provide large amount of macro and micro nutrients for crop growth and eco-friendly besides being renewable alternatives to mineral fertilizers. This has necessitated more research on the use of organic manures. Therefore, the objective of this study was to determine the influence of cattle dung organic manure on the growth, yield and yield component of Acha (*D. iburua spp.*).

**MATERIALS AND METHODS**

The trials were carried out at Acha Research Substation field Riyom, during the cropping seasons of 2023 and 2024. Soil samples were taken at random at the depth of 0-30cm on the experimental site using a soil auger of 8cm diameter. The soil samples were bulked, air-dried and ground. A representative sample of the soil was then taken for laboratory analysis. The experiments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Plots sizes were 3.0 x 4.0m with 0.5 and 1.0 m alley ways between plots and replicates respectively. The treatments consisted of four rates of cattle dung organic manure (5, 10, 15, 20 t. ha$^{-1}$ and a control). During the first year, bonds were constructed round each plot to prevent loss of the applied treatments through runoff and the bounds were maintained in the following year. Also, during the second year, each plot was pulverized and the cattle dung organic manure was broadcast into each plot according to treatments and was then incorporated in the soil two weeks before the seeds were sown. The sowing method was by broadcasting of the seeds into all the plots at the seed rate of 30 kg ha$^{-1}$. A basal of application of 20 kg ha$^{-1}$ of NPK (15:15:15) at 4 weeks after sowing (WAS). Weed management was carried out by manual hand pulling of weeds at 4, 8 and 12 WAS respectively. Data were taken on number of tillers, plant height (cm), number of spikes, number of panicle ($m^2$), length of spikes (cm) and grain yield ($Kg^{-1}$). The data were analyzed using analysis of variance (ANOVA) and means were separated using least significant difference (LSD) at 5% level of probability.

**RESULTS AND DISCUSSION**

All the treatments had significant ($P<0.05$) influence on number of tillers plant$^{-1}$ except for 5 tons ha$^{-1}$ of cattle dung organic manure that produced the lowest numbers of tillers plant$^{-1}$. It was observed that significantly ($P<0.05$) higher number of productive tillers plant$^{-1}$ was obtained when 15 t. ha$^{-1}$ of the treatment was applied and thereafter it declined with increase in treatment, and the lowest member of tillers was recorded when 5 t. ha$^{-1}$ of the treatment was applied. The increase in number of tillers when 15 t. ha$^{-1}$of the treatment was applied could be the optimum quantity of the available nutrients the crop could take for its growth. This finding agrees with Atman *et al.,* (2018,) who reported significant increase in leaf color, number of reproductive tillers, number of grains per panicle and grain yield of organic rice (Table i). It was observed that all the treatments had significant $P<0.05$) effects on plant height in which the application of 20 t. ha$^1$ produced significantly ($P<0.05$) taller plants than the remaining treatments.

The increase observed in plant heights when 20 t. ha$^{-1}$ of cattle dung manure was applied was due to the high concentration of available nutrients at that rate that resulted in continues vegetative growth of the plants and this culminated into the production of taller plants while the shortest plants were obtained when no treatment was applied. This finding is in line with Amos *et al.,* (2015) who reported that growth parameters and final yields, all increased significantly ($P<0.05$) with additional rates of cattle dung organic manure and that the application of 15 t. ha$^{-1}$ increased plant height, by 24%, leaf are by 27% and fresh husk cobs weight by 13% among other parameters in maize (*Zea mays*) (Table 1). While the shortest plants were recorded at when no treatment was applied. It was also observed that all the treatments had significant ($P<0.05$) influence on the number of productive spikes plant$^{-1}$ across all the treatments. This is because increase the available nutrients up 15 t. ha$^{-1}$ might the optimum for production of productive number of spikes for the crop and thereafter, it declined, while the lowest number of productive spikes was recorded when 20 t. ha$^{-1}$ of the treatment was applied. The results obtained in this study agreed with the finding of Singh, and Agarwal, (2001), who reported that the application of high manure rate increased numbers of spikes plant$^{-1}$ that resulted in grain yield of wheat (*Tricium aestivum L.*) (Table 1).

In 2024, treatments showed significant ($P<0.05$) effects on numbers of tillers across all the treatments. The application of 20 t. ha$^{-1}$ of cattle dung organic manure produced the highest number of tillers per plant than the remaining rates. At this rate of treatment, being in the second year of the study there were more available nutrients being mineralized and released into the soil that enhanced the growth and development of the plants that resulted in the production of more tillers. These findings are in accordance with the findings of Ulasa *et al.,* (2017) who reported that the application of farmyard manure at higher rate of 7.5 t. ha$^{-1}$ along with100 percent N equivalent vermicompost to finger millet (*Eluesine coracana Gearnt (L.*) produced significantly ($P<0.05$) higher number of tillers plant$^{-1}$ at harvest, lengthier fingers and higher grain yield plant$^{-1}$. While the lowest number of tillers was recorded in the control (Table 1).

In the second year of the experimentation, plants were observed to be significantly ($P<0.05$) taller when cattle dung organic manure was applied at 20 t. ha$^{-1}$. This could probably be due to the continuous mineralization and release of nutrients from the previous and the added cow dung manure that played essential roles growth and development of the plants through cell division and meristematic elongation that culminated into taller plants. The result of this findings is in the line with Amarjeet *et al.,* (2019) who reported that among the poultry organic manure treatments, the used of 3.2 t. $ha^{-1}$ produced better parameter like plant height and number of spikes $plant^{-1}$ (Table 1) and shortest plants were recorded in the control. While on the other hand, the number of productive spikes $plant^{-1}$ was significantly ($P<0.05$) higher when 15 t. $ha^{-1}$ of the treatment was applied (Table 1). This was attributed to the fact although, there was high concentration of available nutrients at a higher rate of 20 t. $ha^{-1}$, of cow dung organic manure, the spikes produced were unproductive as result of excessive growth and lodging of the plants. The results obtained were not similar to that of Amarjeet *et al.,* (2019) who reported better parameters such as plant height and number of spikes $plant^{-1}$ with the use of 3.2 t. ha $^{-1}$ of poultry organic manure and the lowest number of productive spikes was recorded when 20 t. $ha^{-1}$ of the treatment was applied (Table 1).

**Table 1: Influence of different rates of cattle dung organic manure on number of tillers, plant height and number of spikes $plant^{-1}$ in 2023 and 2024 at Riyom**

| Treatment | 2023 | | | 2024 | | |
|---|---|---|---|---|---|---|
| | No of tillers $Plant^{-1}$ | Plant Height (cm) | No of Spikes | No of tillers $Plant^{-1}$ | Plant Height (cm) | No of Spikes |
| 0 | 34.0 | 39.3 | 7.2 | 28.0 | 34.4 | 6.4 |
| 5 | 33.1 | 47.1 | 7.3 | 32.3 | 36.6 | 6.3 |
| 10 | 31.0 | 44.1 | 7.5 | 44.7 | 68.4 | 6.4 |
| 15 | 42.1 | 49.4 | 7.8 | 53.0 | 86.2 | 7.3 |
| 20 | 36.3 | 51.5 | 6.6 | 58.7 | 92.7 | 5.6 |
| SE+ | 4.8 | 2.2 | 0.3 | 2.3 | 3.4 | 1.0 |
| LSD | 15.6 | 7.1 | 1.0 | 7.1 | 11.2 | 1.1 |
| CV (%) | 23.5 | 8.2 | 7.7 | 12 | 15.5 | 6.6 |

The results in (Table 2) indicated that the application of different rates of cattle dung organic manure also had significant ($P<0.05$) effect on number of panicles $m^{-2}$ across all the treatments in 2023. Significantly ($P<0.05$) higher number of panicles $m^{-2}$ was obtained when 20 t. $ha^{-1}$ of the treatment was used and the lowest number of panicles $m^{-2}$ was produced when no treatment was applied. The increase in panicles $m^{-2}$ recorded at 20 t. $ha^{-1}$ of the treatment over the other treatments could be due to the high concentration of available nutrient which aided vegetative growth of the plant that resulted in the production of primary, secondary tillers and branches and these resulted in the production of more panicles $m^{-2}$. This finding agreed with Jeiran *et al.,* (2010,) who reported that ground mixtures, of urea and dry cow dung manure by compressed close die method produced significantly higher biological yield, grain yield, number of spikes $m^2$, number of grain $spike^{-1}$, grain weight, harvest index, higher number of spikes were produced when 20 t. $ha^{-1}$ was use. While the control treatment gave the lowest number $panicle^{-1}$. It was noted that treatments had significant influence on spike lengths across all the treatments with 20 tons of treatment producing longer spike lengths over the remaining treatments. It is obvious that that the high concentration of available nutrients at that might be responsible for the increase in the spike lengths and the shortest lengths of spikes were obtained when 15 t. ha $^{-1}$ of the treatment was used. It could be that the plants were able to utilize effectively the in situ available nutrients in the soil that resulted in longer length of spikes recorded when no treatment was applied. The results obtained is in line with Dachi (2014) who reported longer lengths of spikes with the application of higher rate of inorganic fertilizer (Table 2).

In 2023, grain yield was observed to increase with increase in cattle dung organic manure rates from 0 to 15 t. $ha^{-1}$ and thereafter it declined. Significantly ($P<0.05$) higher grain yield was obtained when 15 t. $ha^{-1}$ of the treatment was applied. This might be due to increase in available nutrients in which it reached the optimum, the plants could take and further increase in the nutrients led to decrease in yield. This finding corroborated with Mahadi *et al.,* (2016) who obtained the highest grain yield of sorghum (*Sorghum bicolor L.*) when 8 t. $ha^{-1}$ of cow dung organic manure was applied and Atman *et al.,* (2018) also reported that the higher rate of cow dung as organic fertilizer to as much as 1.0 t. $ha^{-1}$ to the soil could cause an increase in grains yield by (0.09) t. $ha^{-1}$ in organic rice (Table 2).

In 2024, the results revealed that the application of 20 t. $ha^{-1}$ of the treatment gave significantly ($P<0.05$) higher number of panicles $m^{-2}$. This is attributed to the high concentration of available nutrients on the manure that led to the continues growth and the development of more such as primary and secondary tillers, leaves and branches that resulted in the production of more panicles $m^{-2}$. The outcome of this studies agreed with the findings of Morteza *et al.,* (2011) who reported higher number of panicle $m^{-2}$ and other yield and yield components at 2.0 t. $ha^{-1}$ of organic fertilizer in rice. While the lowest number of panicles $m^{-2}$ was recorded when no treatment was applied (Table 2). It was also noted that all the treatments had significant ($P<0.05$) influence on lengths of spikes. The longest lengths of spikes were recorded when no treatments were applied and the shortest lengths of spikes were obtained at 5 t. $ha^{-1}$ of cattle dung organic manure treatment. The longest lengths of spikes obtained when no treatment was applied could be that in situ nutrients in the soil was at equilibrium and further application of the cattle dung organic manure had no significant influence on lengths of spikes., similar results have been discussed and reported by Dachi *et al.,* (2016). (Table 2). All the treatments revealed significant ($P<0.05$) influence on grain yield in which cattle dung organic manure applied at the rate of 10 t. $ha^{-1}$ gave the highest grain yield, while the lowest grain yield was obtained when no treatment was applied. This could be due to the fact the treatment applied at 10 t. $ha^{-1}$ to the soil had established an equilibrium level for optimum grain yield and further application of the treatments will not cause any increase in grain yield. This findings is not in agreement with Dachi *et al.,* (2016) who reported that poultry organic manure applied at 15 and 25 t. $ha^{-1}$ under broadcasting and drilling methods of sowing produced significantly (*D.iburua*) (Table 2).

**Table 2: Influence of different rates of cattle dung organic manure on number of panicles, length of spikes, and grain yield of Acha in 2023 and 2024 at Riyom**

| | 2023 | | | 2024 | | |
|---|---|---|---|---|---|---|
| Treatment | No of panicles ($m^2$) | Spike length (cm) | Grain yield (Kg $ha^{-1}$) | No of panicles ($m^2$) | Spike length (cm) | Grain yield (Kg $ha^{-1}$) |
| 0 | 124.07 | 9.4 | 169 | 69 | 17.1 | 338.9 |
| 5 | 127.33 | 9.3 | 314 | 99.3 | 14.1 | 405.6 |
| 10 | 129.33 | 9.7 | 397 | 101 | 15.1 | 471.1 |
| 15 | 132.59 | 9.2 | 433 | 111 | 15.8 | 441.2 |
| 20 | 149.67 | 11 | 339 | 126 | 15.2 | 408.3 |
| SE+ | 9.43 | 1.4 | 14 | 7.5 | 0.6 | 23.8 |
| LSD | 0.42 | 20 | 126 | 25.5 | 1.9 | 77.4 |
| CV (%) | 7.1 | 10 | 20 | 13.1 | 6.9 | 10.1 |

## CONCLUSION

The result of these studies showed that the use of 15 tons ha $^{-1}$ of cattle dung organic manure are optimum for Acha (*D. iburua*) production in Riyom.

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# OCCURRENCE OF MOLDS (FUNGI) IN INDOOR TISSUE CULTURE LABORATORIES

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**ABSTRACT**

Laboratory indoor environments play important roles in human health and laboratory experiments. Contamination wastes time and resources as well as posing serious risks to human health due to toxicity. Fungi (molds), like other microorganisms are ubiquitous in distribution and in complexity towards causing human diseases. However, the awareness of the number and nature of molds in any giving laboratory per time will help to better strategize their control mechanisms. The aim of this study was to evaluate some tissue culture laboratory surfaces and indoor air for fungal contamination in some selected Laboratories in the Federal Capital territory (FCT), Abuja, Nigeria. Using swab and air sampling procedures, fungi were isolated from plantlets, tables, wall and the air of the laboratory rooms of fifteen tissue culture laboratories and cultured on Streptomycin-supplemented Potato Dextrose Agar (PDA). The discrete colonies that developed were identified using morphological and microscopical characterization. The fungal species isolated from these laboratories include; *Aspergillus niger, Alterneria sp., Aspergillus terreus, Aspergillus flavus, Cladosporium sp., Rhizopus sp., Penicillium sp., Fusarium sp.* and *Geotrichum sp.* The results shown that most of the laboratories were highly contaminated and that Aspergillus was the predominant fungal genera and *A. niger* recorded the highest overal occurence. Since using plant tissue culture techniques holds promise in substantially augmenting the number of novel cultivars and genotypes of many fruit crops, adhering to standard operating procedures is highly recommended in the studied areas and Nigeria as a whole.

**Key words**: Tissue culture, Contamination, Molds, Aspergillus, Indoor and human health

## INTRODUCTION

Microbiology and Biotechnology laboratory indoor environments play important roles in human health and laboratory experiments. Obvious research development takes place in most of these laboratories (Chew *et al.*, 2016). Contamination of cultures and experimental procedures often wastes time and resources as well as posing serious risks to human health due to toxicity. Many cases, there are often mold growth where there is high moisture due to water damage or constant high humidity. From these places, invisible spores can be transported indoors on clothing, shoes, or pets, or they may blow in through open doors, windows, or ventilation systems. It is recorded that spores can survive on wood, paper, carpet, soil, plants, fabrics, and other surfaces. When they are right conditions, such as humidity and temperature, mold spores begin to germinate, gradually producing an increasingly expanding network of hyphae (Larenas *et al.*, 2016). One of the symtoms of the presence of mould is that, they may be perceived by the nose as a result of the pungent organic compounds molds release into the air. The presence of musty odor raises suspicion that a major mold contamination is present before they are seen physically. Also, an initial indoor environmental assessment involves a visual inspection of the floor, walls, windows, and air handling system. Any damp areas in the laboratory often ought to be monitored for the presence of molds from where they the spores can move to other parts of the laboratory where contamination of laboratory procedures do take place (Sothern *et al*., 2022).

**Statement of Problem**

Fungi (molds), like other microorganisms are ubiquitous in distribution and in complexity towards causing human diseases. Mold is ubiquitous outdoors, and it is readily introduced or physically transported into the work places and laboratory procedures (Mendell and Adams, 2022). Report has shown that there are approximately 100 indoor molds that have been identified as potentially hazardous to human health. Some of them are found both in the air and dust in indoor experimental laboratory areas.

**Justification**

In most laboratory, the awareness of the number and nature of molds in any giving laboratory per time will help to better strategize their control mechanisms. In indoor mold investigations, air sampling is performed to detect and quantify airborne mold spores and other ill-health associated with their presence such as allergens in order to assess the level and severity of their health effects due to the human exposure. Understanding their presence and prevalence will also help to monitor the effectiveness of control measures during remediation, and for post-remediation clearance testing as well as other control plans that might be required. Air samples analysis of cultured media has been reported as an effective method of studying airborne fungi in an enclosed area (Aktas *et al*., 2018). The aim of this study was to evaluate some tissue culture laboratory surfaces and indoor air for fungal contamination in some selected Laboratories in the Federal Capital territory (FCT), Abuja, Nigeria.

## MATERIALS AND METHODS

Using swab and air sampling procedures, fungi were isolated from plantlets, tables, wall and the air of the laboratory rooms of a tissue culture laboratories and cultured on Streptomycin-supplemented Potato Dextrose Agar (PDA). The discrete colonies that developed were identified using morphological and microscopical characterization.

## RESULTS AND DISCUSSION

The fungi contamination has been reported as a constant problem, which often compromise development of all *in vitro* techniques. This study aimed at investigating the sources of microbial contamination in tissue culture laboratories in FCT, Abuja, Nigeria. Nineteen microbial contaminants (consisting of eleven bacteria and eight fungi) were found associated with the tissue culture plants and the laboratory environments. This result is in agreement with early experiments by Miller *et al*., (2020). The fungal species and the frequency of occurrence is as shown on Table 1 and included; *Aspergillus niger, Alterneria sp., Aspergillus terreus, Aspergillus flavus, Cladosporium sp., Rhizopus sp., Penicillium sp., Fusarium sp.* and *Geotrichum sp.* The results shown that most of the laboratories were highly contaminated and that Aspergillus was the predominant fungal genera and *A. niger* recorded the highest occurrence. Nine species of fungi were found associated with the tissue culture laboratory contamination. High incidence of Aspergillus has been reported in several literatures as a major contaminating mold (Shafiq *et al*., 2015). The rate of occurrence of Aspergillus isolates was higher than that of other fungal isolates in the plant tissue cultures studied (Table 1).

**Table 1: Occurrence of fungi (mold) in the tissue culture Laboratory studied**

| Sample source | Fungi | Frequency of Occurence (%) |
|---|---|---|
| **Plantlets** | | |
| | *Fusarium sp* | 7.3 |
| | *Rhizopus sp* | 17.3 |
| | *Aspergillus terreus* | 27.4 |
| | *Alterneria sp* | 2.7 |
| | *Aspergillus niger* | 45.3 |
| **Table** | | |
| | *Fusarium sp* | 12.5 |
| | *Penicillium sp* | 28.5 |
| | *Cladosporium sp* | 19.8 |
| | *Aspergillus niger* | 39.2 |
| **Wall** | | |
| | *Geotrichum sp* | 14.5 |
| | *Penicillium sp* | 26.1 |
| | *Rhizopus sp* | 22.8 |
| | *Aspergillus niger* | 36.6 |
| **Air** | | |
| | *Aspergillus flavus* | 33.6 |
| | *Alterneria sp.* | 12.0 |
| | *Aspergillus terreus* | 16.9 |
| | *Fusarium sp.* | 21.7 |
| | *Penicillium sp.* | 15.8 |

Plantlet had the highest presence of *A. niger* (45.3). The laboratory walls and tables also harbored fungal contaminants. The laboratory indoor air was found associated with all the contaminating fungi isolated in the work. Saglani *et al.*, 2021 has earlier reported severe contamination of laboratory air space with fungi.

## CONCLUSION AND RECOMMENDATIONS

Since the use of plant tissue culture techniques have several biotechnology advantages, and promise in substantially adding values to the number of novel cultivars and genotypes of many fruit crops, it is noteworthy to adhere to basic standard operating procedures during the laboratory operation as well as designing efficient cleanliness of those laboratories. It is also recommended here that this type of study be extended to other laboratories in Nigeria in order to have more knowledge of the status of contaminating fungi in such laboratories. The knowledge gleaned in this study should be communicated to health care givers for their knowledge and planning purposes. Comparison of levels of contamination of tissue culture laboratories with other non-tissue laboratories should also be carried out in order to have better understanding of the possible sources and movement of contaminating agents. Lastly, reduction of humidity by increasing ventilation, covering cold surfaces such as water pipes with insulation, and increasing the air temperature to reduce surface humidity should be encouraged in the laboratory.

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# SURVIVAL RATE OF YAM VINE NODAL CUTTINGS AS INFLUENCED BY DIFFERENT SUBSTRATES AND GROWTH HORMONES CONCENTRATION

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**ABSTRACT**
Yam *(Dioscorea* spp.) is a vital tuber crop widely cultivated in tropical and subtropical regions, particularly in West Africa but the production has been limited by cost of seed yam as the large percentage of the tuber harvested is usually planted back as seed. This study was therefore conducted at the horticultural nursery of the Federal University of Technology Minna to evaluate the potential of obtaining yam seed from nodal vine cuttings of yam using different substrates and hormones. The treatments included eight substrates viz: (i) topsoil, (ii) topsoil and carbonated rice husk at 1:1 (iii) and 1:2, (iv) topsoil and sawdust at 1:1 (v) and 1:2, (vi) topsoil and poultry manure 6:1, (vii) topsoil and milled groundnut husk 1:1 and (viii) 1:2. The hormones used were Indole-3-butyric Acid (IBA) at 1000, 500 and 250 ppm as well as Alovera gel extract, and coconut water at 100, 50, and 25% concentration and a control. These were factorially combined and arranged in Completely Randomized Design (CRD) with four replicates. Data were collected on survival percentage at different weeks after planting and were subjected to Analysis of Variance (ANOVA). The results revealed that the substrate and hormone types significantly ($P \leq 0.05$) affected the percentage survival of the vine cutting. At the early stage (2-4 weeks after planting) there was no significant difference in survival percentage of the yam nodal cutting with respect to the substrate type and growth hormone types and concentration. At 6 (WAP), the survival percentage was highest in vines sown in carbonated rice husk and topsoil at ratio 1:1 (42.5%). The value was however similar to what was obtained in vine sown in top soil alone (36.5%) and those sown in top soil mixed with milled groundnut shell (35.0%) at 1:2. Simlilar trend was observed at 8WAP. At 10 WAP however, the survival of the vines was better sustained in carbonated rice husk at 1:1 (30 %) and those sown in soil plus poultry manure had the least survival rate (2.5%), similar to those sown in top soil alone (5%). Treatment with coconut water consistently produced the highest survival rate from 6 -10 WAP similar to treatment with 100 % aloevera and 500 ppm IBA. This indings suggests that the use of carbonated rice husk and coconut water can be a sustainable approach to improving the propagation of yam vine to obtain yam seeds.

**Keywords**: yam vine, yam seed, nodal cutting, growth hormones, substrates.

## INTRODUCTION

Yam (*Dioscorea rotundata* L.) is a monocotyledonous plant, closely related to lilies and grasses. They are perennial herbaceous vines native to Africa, Asia, and the Americas. They are cultivated for their starchy tubers in many temperate and tropical regions. (Adepoju *et al.*, 2021). Yams vary in size from that of a small potato to a record of 130 kg. Nigeria is by far the world's largest producer of yams, accounting for over 70–76% of the world production (Zaki, 2020). According to the Food and Agriculture Organization report, in 2019, white yam is the leading root crop in Nigeria, both in terms of land under cultivation and in the volume and value of production (FAO, 2019). It also has an important social status in gatherings and religious functions, which is assessed by the size of yam holdings one possesses (FAO, 2019). In many yam-producing areas, it is said that "yam is food and food is yam". However, the production of yam in Nigeria is substantially limited and cannot meet the growing demand at its present level of use.

Yam (*Dioscorea spp*) is propagated from tubers or sections of tuber and corms. Planting of the vines of the growing yam is an emerging technology (Leaky *et al.,* 2015). Traditional propagation methods, (primarily through tubers), often face challenges such as disease transmission, limited planting material, and variable yields. Seed tubers are expensive, bulky to transport and the multiplication rate in the field is very low, shortage of seed tubers for planting is one of the major constraints for yam production in Africa (Degras and Coste, 2013). Farmers continue to use traditional methods and save seed from a previous harvest to plant the crop. Only the mini sett technique, which uses 80–200 g tuber pieces, is currently used at farmer level, although on a limited scale (FAOSTAT, 2024). While tissue and organ culture techniques are the most rapid methods of multiplying disease-free propagules, their limitations include high costs, need for skilled personnel and specialized equipment. Use of yam vine cutting to obtain yam seed similarly allows for a cheap and rapid multiplication of yam plant but the survival rate is unpredictable. Vine cutting technology was developed to improve the multiplication rate of yam as well as reduce the impact of pests and diseases on seed tubers (Ayankanmi *et al.,* 2010).

Substrate plays a crucial role in vegetative propagation as it provides the necessary support, nutrients, and environment for survival and root development. The choice of substrate can significantly influence the survival rate in vine cuttings. An ideal substrate should have the following characteristics: good aeration, adequate moisture retention, nutrient availability, and low pathogen load (Hartmann *et al.,* 2013). Many substrates have been identified for use in agriculture.  Carbonated rice husk is a byproduct of rice milling and is valued for its high porosity and low bulk density (Akom et al., 2015), Saw dust and milled groundnut shell is an organic material that provides moderate aeration and moisture retention. They are lightweight and can improve the physical properties of the substrate when mixed with other materials. The use of vine cuttings as a planting material gives a higher multiplication rate that is about 30 times more than in the traditional system (Ayankami *et al.,* 2010). However, this method is often associated with low survival rate due to poor rooting ability. Hormones have been reported to promote rooting ability of cuttings. This study therefore aimed to enhance the survival rate of yam nodal vine cutting using various substrates and hormones

## MATERIALS AND METHODS

The experiment was conducted at the Horticultural Nursery, Federal University of Technology, Minna located in the southern Guinea savanna of Nigeria. The climate of Minna is sub humid with mean annual rainfall of about 1284 mm and a dry season of about five (5) months duration occurring from November to March. The mean maximum temperature (about 33.5 ºC) remains high throughout the year (Ojanuga, 2016). The treatments were eight substrates viz: (i) topsoil, (ii) topsoil and carbonated rice husk at 1:1 (iii) and 1:2, (iv) topsoil and sawdust at 1:1 (v) and 1:2, (vi) topsoil and poultry manure 6:1, (vii) topsoil and milled groundnut husk 1:1 and (viii) 1:2. The hormones used were Indole-3-butyric Acid (IBA) at 1000, 500 and 250 ppm as well as Alovera gel extract, and coconut water at 100, 50, and 25% concentration and a control. These were factorially combined and arranged in Completely Randomized Design (CRD) with four replicates.

Healthy, disease-free white yam (*D. rotundata*) tubers weighing around 200 was cut into four. The cut surfaces were rubbed with wood ash, air-dried under shed for 24 hours and planted in sacks for the purpose of multiplication for yam vine. Vines was collected at eight (8) weeks after emergence. The vines were cut to have a node on each and treated with the various rooting substances by dipping the cut end into the rooting substances for 30 minutes before planting in poly bags measuring 3 x 5 cm filled with the different substrates. These were watered every other day and the survival rate of the vine cuttings were recorded at 2, 4, 6 ,8 and 10 WAP

**Table 1: Effects of substrates and hormone types on yam vine cuttings survival Weeks after Planting**

| | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|
| Substrates (S) | | | | | |
| Soil | 55.00a | 42.50a | 37.50ab | 22.50abc | 5.00c |
| Soil + SD 1:1 | 57.50a | 35.00a | 27.50abc | 17.50bc | 5.00c |
| Soil + SD 1:2 | 57.50a | 42.50a | 20.00abc | 12.50bc | 10.00bc |
| Soil + CRH 1:1 | 52.50a | 50.00a | 42.50a | 35.00a | 30.00a |
| Soil + CRH 1:2 | 50.00a | 42.50a | 27.50abc | 22.50abc | 20.00ab |
| soil + PM 6:1 | 52.50a | 42.50a | 15.00c | 7.50c | 2.50ab |
| soil + MGH 1:1 | 62.50a | 47.50a | 30.00abc | 25.00ab | 10.00bc |
| Soil + MGH 1:2 | 65.50a | 55.00a | 35.00abc | 7.50c | 7.50bc |
| SE+_ | 7.50 | 7.79 | 7.36 | 6.17 | 5.05 |
| Hormone (H) | | | | | |
| Alovera 100% | 62.50a | 53.13a | 34.38ab | 21.88ab | 18.75ab |
| Alovera 50% | 46.88a | 43.75a | 28.13ab | 25.00ab | 12.50ab |
| Alovera 25% | 50.00a | 34.38a | 21.88ab | 9.38b | 6.25b |
| Coconut water 100% | 68.75a | 53.13a | 46.88a | 34.38a | 25.00a |
| Coconut water 50% | 62.50a | 43.75a | 25.00ab | 12.50b | 6.25 |
| Coconut water 25% | 59.38a | 43.75a | 28.13ab | 15.63ab | 9.38ab |
| IBA 1000PPM | 65.63a | 56.25a | 21.88ab | 12.50b | 6.25b |
| IBA 500PPM | 56.25a | 46.88a | 37.50ab | 25.00ab | 9.38ab |
| IBA 250PPM | 46.88a | 37.50a | 28.13ab | 21.88ab | 12.50ab |
| Control | 46.88a | 34.38a | 21.88ab | 9.38b | 6.25b |
| SE+_ | 8.48 | 8.71 | 8.23 | 6.89 | 5.65 |
| Interaction | | | | | |
| S x H | * | NS | NS | NS | NS |

Means in column followed by different letters are significantly different (P≤0.05) using Duncan Multiple Range Test

SD-sawdust, CRH-carbonated rice husk, MGH-milled groundnut husk, IBA- Indole-3-Butyricc acid, *-significant (p<0.05), NS-Not significant (p>0.05), Error means ( SE+_)

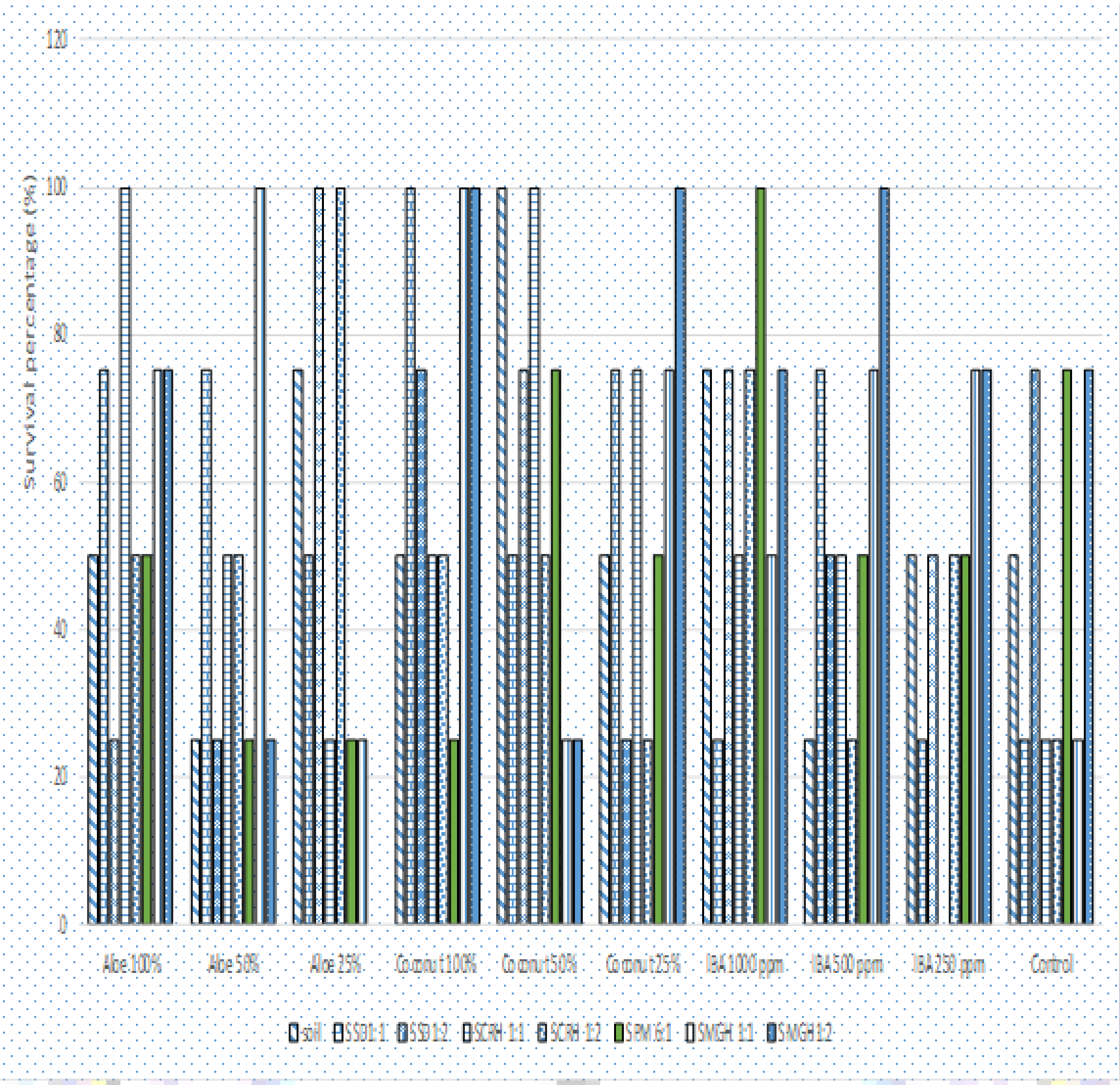


**Fig 1: Interaction effect of hormone and substrates on survival percentage of yam nodal Fig 1. Interaction effect of hormone and substrate on survival of yam vine cuttings**

SD-sawdust, CRH-carbonated rice husk, MGH-Milled groundnut husk, IBA- Indole-3-Butyricc acid.

## RESULTS AND DISCUSSION

### Results

At two (2) and four (4) weeks after planting all the vines treated with substrates and different hormones and do not differ significantly from each other. At six (6) weeks soil mixed with carbonated rice husk at 1:1 had the highest survival rate (42.50%). This is followed by Top soil (37.50), soil mixed with milled groundnut husk 1:2 (35.00), soil mixed with milled groundnut husk (30.00), soil mixed with sawdust 1:1 (27.50) similar to soil mixed with carbonated rice husk 1:2, soil mixed with mixed with sawdust 1:2 (20.00). The least was obtained in vines treated with soil mixed with poultry manure 6:1 (15.0). At eight weeks after planting, vines treated with soil mixed with carbonated rice husk 1:1 (35.00) had the highest survival rate followed by soil mixed with carbonated rice husk 1:1 (25.00), topsoil (22.50), similar to soil mixed with carbonated rice husk 1:2 (22.50), soil mixed with sawdust 1:1 (17.00), soil mixed with carbonated sawdust 1:2 (12.50). The least was obtained in the poultry manure mixed with topsoil 6:1 (7.50) similar to soil mixed with milled groundnut husk 1:2. At 10 weeks after planting, the highest survival rate was obtained in the soil mixed with carbonated rice husk 1:1 (30.00), this was followed by soil mixed with carbonated rice husk 1:2 (20.00), soil mixed with sawdust 1:2 (10.00), similar to topsoil mixed with milled groundnut husk 1:1, topsoil mixed with milled groundnut husk 1:2 (7.50), topsoil mixed with sawdust 1:1 (5.00) similar to topsoil. The least survival rate was obtained from vines treated with poultry manure mixed with topsoil 6:1 (2.5) (Table 1).

Similarly, at two (2) weeks after planting, all the vines treated with the hormones do not differ significantly from each other and similar to four (4) weeks after planting. At Six (6) weeks vines treated with 100% coconut water had the highest survival rate (46.88). This was followed by IBA at 500ppm (37.50), Alovera gel at 100% (34.38), IBA 250ppm (28.13), similar to Alovera 50%, Coconut water 25%, Coconut water 50% (25.00). The least was obtained in the IBA 100% plant at (21.88) similar to IBA the control plant. At eight (8) weeks after planting, vines treated with coconut water 100% (34.38) had the highest survival rate, this is followed by Alovera at 50% similar to IBA 500ppm, Alovera 100% (21.88) similar to iba 250ppm, Coconut water 25%, Coconut water 50% similar to IBA 1000ppm, the least survival rate was obtained in Alovera 25% (9.38) similar to the control plant. The highest survival rate of yam vine cuttings at 10 weeks after planting was obtained at 100 % coconut water (25.50). This is followed by Alovera 100% (18.78), Alovera 50% (12.50) similar to IBA 250ppm, coconut water 25% (9.38) similar to IBA 500ppm. The least was recorded at Alovera 25% (6.25) similar to Coconut water 50% and IBA 1000ppm. This result indicates potentials for the use of coconut water as a hormone for yam vine cuttings planting. Means with the same letter do not differ significantly while means with different letters differs significantly at p ≤0.05) level of significance, at various weeks' interaction exist between the hormones and substrates types (Table 1). Significant interaction exists between hormone and substrate types used in this study.

**DISCUSSION**

The results of this study demonstrated that the choice of substrate and hormone significantly influenced the survival rate of yam vine cuttings. Among the tested substrates, carbonated rice husk mixed with soil at a 1:1 ratio proved to be the most effective in promoting vine survival and subsequent root development. Carbonated rice husk consistently demonstrated superior performance, particularly in the later stages, topsoi generally effective, it showed a decline in performance compared to carbonated rice husk, organic materials (groundnut husk, sawdust) exhibited moderate performance, with variations depending on the specific mixture while Poultry manure consistently yielded the lowest survival rates, indicating its potential negative impact. This superior performance of carbonated rice husk can be attributed to the unique properties such as its excellent water retention capacity, porosity, and nutrient-rich composition (Ahmad *et al.,* 2020; Singh *et al.*, 2019). These properties create an ideal environment for root growth and development, leading to higher survival rates. In terms of hormonal treatments, cconut water emerged as the most effective hormone treatment, significantly boosting survival rates, it exhibited the highest efficacy in enhancing vine survival. This can be explained by the presence of various plant growth hormones, including auxins, cytokinins, and gibberellins in coconut water (Hartmann *et al.*, 2013). These hormones play crucial roles in stimulating cell division, elongation, and differentiation, thereby promoting root initiation and growth (Okoro, 2020). While Aloe vera gel and IBA also have growth-promoting properties, their effectiveness may have been limited by factors such as concentration, application method, their performance was more variable (Leaky, 2015). In conclusion, the findings of this study provide valuable insights into the factors affecting yam vine survival, the significant interaction between substrates and hormones underscores the complex nature of plant growth and development. The use of carbonated rice husk as a substrate and coconut water as a hormonal treatment can significantly improve the survival rate of yam vine propagation, thereby contributing to increased yam production and food security.

## CONCLUSION

It can therefore be concluded that the use of carbonated rice husk and coconut water can be a sustainable approach to improving the propagation of yam vine to obtain yam seeds

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# INTELLIGENT RECOGNITION OF MATURED BEAN POD (*VIGNA UNGUICULATA* L.): A DEEP LEARNING-BASED APPROACH

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## ABSTRACT

This study presents a robust framework for predicting bean pod maturity (Vigna Unguiculata L.) using Artificial Intelligence (AI) and computer vision, focusing on the YOLO model's real-time object detection capabilities. Beans are a globally significant crop, yet traditional methods for determining maturity rely heavily on manual observation, which is subjective, inconsistent, and unsuitable for large-scale applications. The proposed system leverages annotated datasets, advanced preprocessing techniques, and Convolutional Neural Networks (CNNs) to automate and standardize maturity detection. YOLO's grid-based architecture ensures precise detection of pod features, including color, size, and texture, enabling accurate classification across diverse agricultural conditions. The methodology integrates supervised learning with expert knowledge to address the limitations of existing techniques, providing a scalable, efficient solution for farmers and agronomists. The preliminary outcome shows promising results after 20 epochs with an F1-score of about 66%. However, challenges such as dataset size, diversity, computational demands, and annotation overhead remain, which the study will addresses through data augmentation, lightweight model variants, and modular system design. This research aligns with global efforts to enhance food security and sustainability through AI-driven agricultural innovations.

**Keywords:** Bean Pod, Artificial Intelligence (AI), Computer Vision, YOLO, Precision Agriculture, and Sustainability

## INTRODUCTION

Beans are among the most widely cultivated crops globally, serving as a crucial source of protein, vitamins, and income for millions of households (Lu et al., 2022). The timing of harvest is critical to maintaining quality and maximizing yield. However, maturity determination is largely dependent on manual observation, which varies significantly based on individual expertise, environmental factors, and inherent crop variability. These challenges underscore the need for a standardized, scalable, and objective system to ensure consistency across different contexts (Hassanzadeh et al., 2020). AI and computer vision advances offer a transformative potential to address these issues. These technologies enable automated maturity detection, improving precision while minimizing human error. The growing accessibility of computational resources and imaging devices makes such solutions increasingly feasible for adoption in agriculture (Moeinizade et al., 2022).

The variability in bean pod appearance due to environmental conditions such as soil fertility, climate, and farming practices complicates the determination of maturity stages. Though effective in localized settings, traditional methods often fail to generalize across regions. AI provides a unique opportunity to analyze diverse datasets and identify patterns that are not immediately apparent to the human eye. This study is motivated by the potential of AI to bridge this gap, leveraging computer vision to standardize and automate bean pod maturity prediction (Bazrafkan et al., 2023; Moeinizade et al., 2022).

The study's primary objectives are to propose a very effective AI-based system model for bean pod maturity recognition and investigate the effectiveness of the computer vision techniques that have been used in several studies. These objectives align with the broader goals of precision agriculture, emphasizing efficiency and sustainability. This research holds significant implications for agricultural productivity and sustainability. Accurate maturity prediction can minimize pre- and post-harvest losses, ensuring that crops are harvested at their optimal state. This has a direct economic benefit for farmers by improving market readiness and reducing waste. Moreover, by promoting resource-efficient farming practices, the system contributes to environmental conservation. The innovative contribution of this study lies in its integration of agricultural knowledge into AI decision-making. Unlike purely data-driven approaches, this model aims to combine the precision of machine learning with the nuanced insights of experienced agronomists. Furthermore, while the focus is on bean pods, the methodology can be adapted for other crops, broadening its impact across the agricultural sector.

## LITERATURE REVIEW

Over the years, researchers have proposed various methods for predicting bean pod maturity, which can be broadly categorized into manual visual inspection, traditional machine learning techniques, and modern deep learning models. Manual visual inspection relies on human experts to assess maturity based on visual cues like pod color, size, and texture. While this approach is straightforward and inexpensive, it is prone to subjectivity, inconsistency, and scalability issues, making it impractical for large-scale applications where precision and efficiency are critical (Rani et al., 2023).

Traditional machine learning techniques introduced a level of automation by employing algorithms like Support Vector Machines (SVM), Random Forest (RF), and k-nearest Neighbors (k-NN). These approaches rely heavily on feature engineering, extracting attributes such as morphological features (pod length, width, shape), color features (RGB, HSV histograms), and texture features (Haralick features from GLCM) (Bazrafkan et al., 2023; Ljubobratović, 2022; Sharifi, 2021). While these methods are relatively simple to implement and perform well on small datasets, they require significant manual effort for feature selection and lack the scalability and generalizability needed for diverse agricultural conditions.

Deep learning models represent the most advanced category, offering state-of-the-art performance by automating feature extraction and enabling high levels of accuracy and robustness. Architectures like Convolutional Neural Networks (CNNs) are particularly effective for spatial and textural feature extraction, with models such as AlexNet, ResNet, and YOLO widely used for image analysis tasks. Recurrent Neural Networks (RNNs) add sequential analysis capabilities, while multi-modal fusion models integrate visual, hyperspectral, and thermal data for enhanced robustness (Rani et al., 2023). Despite their strengths—such as scalability, high precision, and adaptability—these models require substantial computational resources and large annotated datasets for effective training, presenting challenges in resource-constrained settings (Faisal et al., 2020; Moeinizade et al., 2022). Despite significant advancements, there remain notable research gaps in the field of bean pod maturity recognition. Many existing models are trained on limited and often non-diverse datasets, which hampers their ability to generalize effectively to the complexities of real-world agricultural conditions (Rahim, 2021; Rani et al., 2023). Additionally, the scarcity of readily accessible literature and publicly available datasets further exacerbates this challenge, creating barriers to replication, validation, and broader adoption of these techniques. A comprehensive meta-analysis of recent studies, as illustrated in Table 1, provides a synthesized overview of current efforts. This analysis examines the system architectures, mathematical foundations, range of dataset sizes, and performance evaluation metrics of existing methods, highlighting areas of progress while underscoring the need for more robust and inclusive research initiatives.

Bazrafkan et al. (2023), He et al. (2023), and Batista et al. (2022) highlight the effectiveness of machine learning algorithms, such as Random Forest and Support Vector Machines (SVM), and advanced deep learning models like YOLOv5, in predicting crop maturity stages for crops like dry peas and soybeans, with feature selection methods (e.g., backward feature elimination) enhancing accuracy by identifying key variables like spectral bands and crop height. Advanced imaging technologies, including hyperspectral sensing and autofluorescence-spectral imaging, further improve precision by leveraging specific wavelengths to detect subtle maturity differences, and their integration with AI models enables real-time monitoring for timely interventions and better agricultural decision-making. Hassanzadeh et al. (2020) emphasize the practical benefits of these advancements, such as more reliable yield predictions, reduced food waste, and improved crop management, while Bazrafkan et al. (2023) also note the accessibility of cost-effective tools like RGB cameras combined with multispectral imaging for resource-limited farmers.

Key insights from Table 1 reveal important trends in the performance and capabilities of bean pod maturity recognition methods from several studies. Deep learning models like ResNet and YOLO consistently outperform traditional machine learning approaches in accuracy and robustness, particularly when trained on larger datasets. These advanced models leverage sophisticated optimization techniques such as backpropagation and activation functions, unlike traditional methods that rely on simpler mathematical frameworks like kernel functions. Performance tends to improve with larger and more diverse datasets, though data augmentation and multi-modal fusion techniques can effectively address the limitations of smaller datasets. Notably, multi-modal fusion models and hybrid approaches integrating expert knowledge show strong potential for generalizing to diverse real-world conditions, making them valuable for agricultural applications.

**Table 1: Analysis of Several Techniques Used in Maturity Detection/Recognition and Prediction.**

| S/No | System Architecture | Method | Dataset Size | Performance Metrics | Gaps |
|---|---|---|---|---|---|
| 1 | Human observation | Manual/ Visual Inspection | - | Accuracy: ~60-70% | Inexpensive but subjective and inconsistent. |
| 2 | Traditional ML | SVM | 500-2000 images | Accuracy: ~75% | Requires extensive feature engineering. |
| | | Random Forest | 500-2000 images | Accuracy: ~78% | Limited generalizability to complex datasets. |
| | | k-NN | 500-1000 images | Accuracy: ~70% | Performance degrades with high-dimensional data. |
| 3 | Deep Learning | AlexNet | 10,000 images | Accuracy: ~85% | Early CNN architecture, struggles with complex textures. |
| | | ResNet | 20,000 images | Accuracy: ~93% | Excellent feature extraction capabilities. |
| | | YOLO (v3-v8) | 20,000 – 200,000 images | mAP: ~92 - 95%, Speed: 30 - 300 FPS | highly modular and scalable framework |
| 4 | CNN with hyperspectral data integration | Multi-Modal Fusion | 10,000 images | Accuracy: ~95%, mAP: ~94% | Combines complementary information from multiple data modalities. |
| 5 | Deep Learning + Expert Systems | Hybrid AI Models | 5,000 images | Accuracy: ~90-93% | Balances data-driven and expert knowledge approaches. |

## MATERIALS AND METHODS

This section outlines the step-by-step methodological approach proposed for predicting bean pod maturity using the You Only Look Once (YOLO) model. YOLO, a state-of-the-art deep learning model for object detection, offers real-time prediction capabilities with superior accuracy and robustness, making it well-suited for this task (Junos et al., 2021). The methodology comprises five key components, starting from Image acquisition, Image

Processing, Feature Extraction, Model Development, and Model Evaluation as shown in Figure 1.

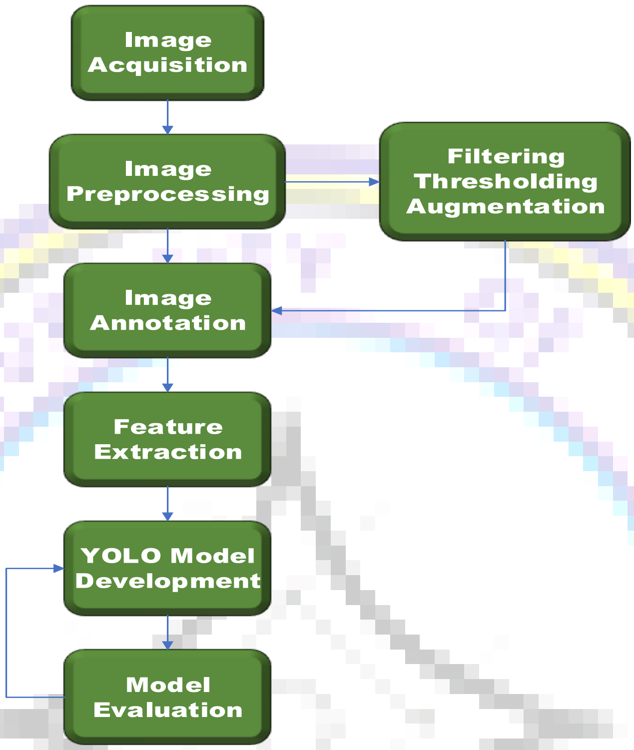


**Figure 1: Proposed model for the recognition/detection of bean pod maturity.**

### Image Acquisition

The first step involves collecting high-quality images of bean pods in diverse lighting, environmental, and growth conditions. These images serve as the dataset for training and testing the YOLO model. The photos must capture pod color, size, shape, and texture variations to ensure the model's ability to generalize effectively. The dataset will also include annotations that label maturity stages to guide supervised learning. A well-annotated dataset is critical to YOLO's performance. The dataset denoted as D, consists of N images:

$$D = \{(x_i, y_i) \mid i = 1, 2, \ldots, N\} \quad (1)$$

where $x_i$ represents an image, and $y_i$ represents the corresponding annotated bounding boxes and class labels. Annotation is essential for YOLO's object detection capabilities, as the model simultaneously predicts bounding boxes and class probabilities (Chen et al., 2024; Junos et al., 2021; Li, 2024).

Figure 2 shows images of some collected samples. The samples were collected from a farm at the Gidan Kwanu campus of Federal University of Technology, Minna.

Figure 2: Bean Pod *(Vigna Unguiculata L.)* Dataset at different maturity stages

**Image Preprocessing**

Preprocessing enhances image quality and ensures consistency across the dataset. This step includes techniques such as filtering, thresholding, segmentation, and annotation. Filtering removes noise using filters like Gaussian or median filters (Tao, 2024). For an image *I*,

Annotating segmented regions assigns labels for maturity stages, essential for supervised learning in YOLO. Figure 3 shows preprocessed images.


**Figure 3: Preprocessed images**

**Model Design**

YOLO version 8 was selected for the experiments. It employs a Convolutional Neural Network (CNN) backbone for feature extraction, transforming input images into high-dimensional feature maps (Liu et al., 2022). This process involves several convolutional, pooling, and activation layers.

For an input image *I* with dimensions $H \times W \times C$, convolution is defined as:

$$O(i,j,k) = \sum_{m=0}^{M=1} \sum_{n=o}^{N=1} I(i+m, j+n) \cdot K(m,n,k) \qquad (4)$$

where *O* is the output feature map, *K* is the kernel, and $M \times N$ is the kernel size.

YOLOv5, for example, incorporates residual blocks for deeper architectures, expressed mathematically as:

$$Y = f(x) + x \qquad (5)$$

where x is the input and f(x) represents convolutional transformations. This structure helps prevent gradient vanishing during training. The extracted features include edges, textures, and patterns indicative of pod maturity. These features are passed through subsequent layers to detect objects and predict bounding boxes.

The YOLO model predicts bounding boxes and class probabilities in a single forward pass. Its architecture divides the image into an $S \times S$ grid. Each grid cell predicts *B* bounding boxes and class probabilities for *C* classes. The final predictions are defined as:

$$P(class) \times IoU(b_{pred}, b_{true}) \times C_{xywh} \qquad (6)$$

where *IoU* is the Intersection over Union, a measure of bounding box overlap, and $C_{xywh}$ represents the center coordinates, width, and height of the predicted box.

The YOLO loss function combines three components:

$$L = L_{coord} + L_{conf} + L_{class} \qquad (7)$$

Where, $L_{coord}$ Penalizes bounding box coordinate errors.

$L_{conf}$ Penalizes confidence score errors.

$L_{class}$ Penalizes classification errors.

This integrated approach ensures accurate detection and classification of bean pods across maturity stages (Tao, 2024).

**Model Evaluation**

The model's performance will be evaluated using metrics like accuracy, precision, recall, and F1-score. The metrics are defined as:

$$Precision = \frac{TP}{TP + FP} \qquad (8)$$

$$Recall = \frac{TP}{TP + FN} \qquad (9)$$

$$\text{F1} - \text{Score} = 2 \text{ x } \frac{\text{Precision x Recall}}{\text{Precision} + \text{Recall}} \tag{10}$$

where *TP, FP*, and *FN* denote true positives, false positives, and false negatives, respectively. These metrics will assess the YOLO model's ability to predict maturity stages accurately and reliably, ensuring its effectiveness in real-world applications.

## RESULTS AND DISCUSSION

Preliminary results obtained from training and testing Yolov8 model. Table 2 shows a summary of the training results showing the epoch, learning rate, the precision, recall and F1-score. The results showed that as the epoch increased, the F1-score improved while the precision and recall fluctuated.

Table 2: Summary of Training results for YOLOv8

| Epoch | Learning Rate | Precision Score (%) | Recall Score (%) | F1 Score (%) |
|---|---|---|---|---|
| 1 | 0.00018 | 0.7 | 90.8 | 1.5 |
| 2 | 0.000342 | 0.8 | 94.8 | 1.6 |
| 3 | 0.000465 | 0.8 | 94.8 | 1.6 |
| 4 | 0.000548 | 100 | 4.3 | 5.7 |
| 5 | 0.000592 | 46.2 | 42.9 | 44.4 |
| 6 | 0.000596 | 48.9 | 26.5 | 34.4 |
| 7 | 0.000560 | 47.4 | 59.7 | 52.8 |
| 8 | 0.000485 | 58.8 | 46.9 | 52.2 |
| 9 | 0.000370 | 54.8 | 56.1 | 55.5 |
| 10 | 0.000266 | 66.4 | 58.6 | 58.4 |

At 20 epoch, the performance improves for precision-recall and F1-score as shown in Figure 4.

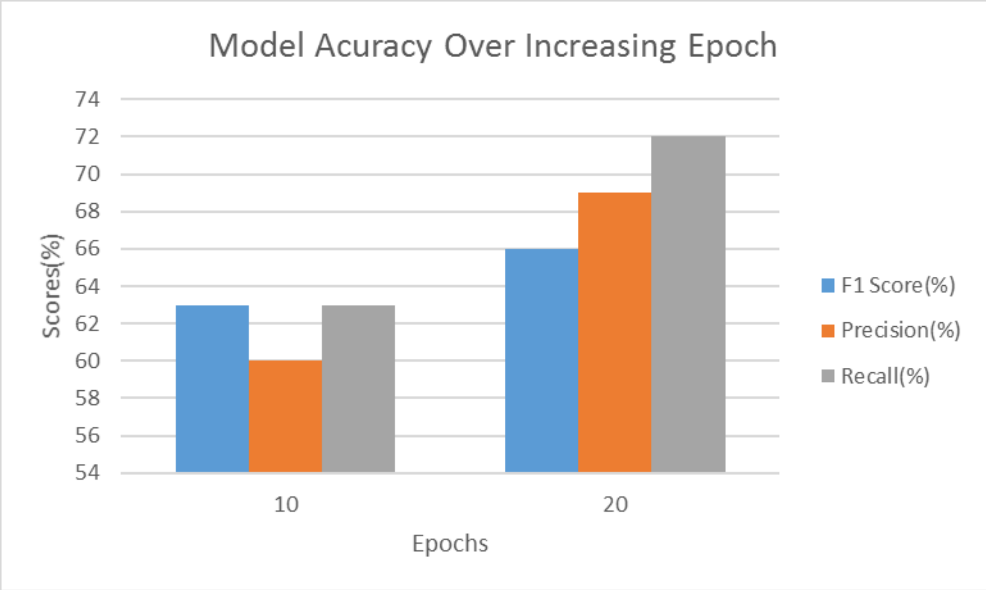


Figure 4: Precision-Recall and F1-score for 10 and 20 epoch.

The Streamlit interface was used to test the model on images collected from the farm, providing users with immediate feedback on the model's predictions. It allowed users to upload images directly and view the predicted maturity level of the pods with minimal delay. 10 images were uploaded on the web app using and the results were shown in Table 3.

Table 3:

| Images | No of Mature Pod Present | No of Detected pod |
|---|---|---|
| 1 | 3 | 2 |
| 2 | 7 | 6 |
| 3 | 5 | 2 |
| 4 | 3 | 3 |
| 5 | 2 | 2 |
| 6 | 1 | 1 |
| 7 | 7 | 5 |
| 8 | 3 | 1 |
| 9 | 5 | 0 |
| 10 | 2 | 2 |

Figure 6: Screenshot of the Streamlit interface displaying the uploaded image and model prediction results.

## CONCLUSION

This study presents an innovative approach to recognizing bean pod *(Vigna Unguiculata L.)* maturity by utilizing the YOLO model, recognized for its exceptional accuracy, speed, and real-time detection capabilities. Through the integration of annotated datasets, advanced preprocessing methods, and sophisticated computer vision techniques, the proposed system seeks to overcome the shortcomings of traditional manual methods. Some benefits include improved precision in maturity detection, more informed agricultural decision-making, and significant economic and environmental advantages for stakeholders. Furthermore, the framework has potential applications beyond bean pods, offering a versatile solution for various precision agriculture tasks, contributing to global efforts toward sustainable farming and enhanced food security. More images are expected to be collected and high computing systems are expected to be used to further improve the performance of the system before deployment.

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# IMPACT OF SOIL PARENT MATERIALS ON LAND SUITABILITY FOR PRODUCTION OF SELECTED CROPS IN NIGER STATE

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## ABSTRACT
This study evaluated the suitability of some soils developed under two geological formations (that is, basement complex rocks and the sedimentary rocks) in Niger State, for maize (*Zea mays*) production. Four sites two each under the formations were selected for the study. Gidan Mangoro (GDM) and Mutun Daya (MTD) represented the basement complex while Enagi (ENG) and Ndayako (NDY) represented the sedimentary rocks. In each site, a mini profile pit (100 cm x 100 cm x 100 cm) was dug, described and sampled according to FAO guidelines. The samples were analysed in the laboratory following the standard analytical procedures. Square root method was used in the suitability evaluation of the soils. The results showed that, the texture of GDM, was loamy sand at topmost horizon (Ap), underlain by sandy clay loam at Bt horizon over sandy loam texture at Btv horizon. The texture of MTD was sandy loam at topmost horizon (Ap), underlain by sandy clay loam at Btv1 and Btv2 horizons. ENG, and NYK were sandy loam all through. The current (actual) status of the sites revealed temporally not suitable (N1) with indices of 21, 20, 22 and 17 for GDM, MTD, ENG and NYK respectively due to soil fertility and nutrient retention limitations. After correcting the limitations, the sites showed potentials for the production of maize with indices of 31 (S3), 28 (S3), 47 (S2) and 43 (S2) for GDM, MTD, ENG and NYK respectively. The soils under the sedimentary rock formation showed more potential for maize production.
**Key Words**: Parent materials; basement complex and sedimentary rocks, Land suitability evaluation, maize production.

## INTRODUCTION
Parent material is the material from which soil is thought to have been derived from (Shakeel, 2020). Predominantly, soils developed on basement complex rocks, have impervious subsurface horizons due to plinthization processes (Lawal *et al*., 2023). Productivity of a soil is a function of its physical and chemical properties. These properties are as a result of the interaction among the soil forming factors and processes, hence, making soil to be heterogeneous (Lawal *et al*., 2014). Evaluation of soils is increasingly becoming necessary as the need for precision agriculture increases (Adeyolanu *et al*., 2020). Land is an essential natural resource, comprises of physical component of the Earth, which is permanently not covered with water, and vital both for the survival and prosperity of humanity (FAO/UNEP, 1999). It is important that agricultural land be used according to its capacity for optimal and sustainable production (Adeboye, 1994, Afolabi *et al*., 2014). Land suitability evaluation is the process of assessment and classification of land units according to their suitability for a particular use (Nguyen *et al*. 2020). Therefore, the objectives of this study were to characterize the soils derived from different parent materials in Niger State, Nigeria and to evaluate their suitability for maize production.

## MATERIALS AND METHODS

Niger State is underlain by two geological terrains namely the Basement complex rocks and the sedimentary rock formations. The study covered the four sites, two from the basement complex and two from sedimentary rock geological formation. The sites were Gidan Mangoro (Longitude: $6^0$ 29′ 30.570″ E and Latitude: $9^0$ 34′ 29.652″ N). Mutun Daya (Longitude: $7^0$ 03′ 03.090″ E and Latitude: $9^0$ 33′ 34.188″ N), Enagi (Longitude: $5^o$ 32' 8.220" E and Latitude: $9^o$ 7' 24.630" N) and Ndayako (Longitude: $5^0$ 00′ 49.440″ E and Latitude: $9^0$ 22′ 19.002″ N), all within the southern Guinea savanna agroecological zone of Nigeria. Niger State is sub-humid tropical and experiences two distinct wet season and dry seasons. Rainfall is bi-modal with mean total annual rainfall of 1,600 mm in the southern part and decreased to 1,200 mm in the northern part of the state, distributed from the months of May to October. The dry season is about 5 months' duration from November to March. The mean annual maximum rainfall is about 1600 mm. The average minimum and maximum temperatures are 20 ℃ and 37 ℃ respectively while the mean annual relative humidity is between 39% to 70%. Geomorphologically, Niger State was characterized by undulating landscape, upland, lowland, plains, flood plains, and rolling dissected plains (Alabi 2011).

**Field work and soil sampling.**
One profile pit measuring 1 m × 1 m × 1 m (or to permissible depth), was dug in each of the locations and were described according to FAO guidelines (FAO, 2006). Soil samples were collected from the identified genetic horizons, from bottom to the top of the profile. The following materials were used for the field study; handheld GPS device, Munsell Colour Chart (2009 version), a plastic bucket, zip-lock bags, digger, shovel, hand-trowel, hand note book, writing pen, permanent marker, stapler, and masking tape. The well-labelled soil samples were taken to the laboratory for processing and routine analysis.

**Laboratory Analysis**
The air-dried soil samples were passed through a 2 mm mesh and analysed according to standard laboratory procedures (IITA, 2015). Briefly, particle size distribution was determined by Bouyoucos hydrometer method, using sodium hexametaphosphate as the soil dispersing agent. The textural classes of the soils were determined using IUSS soil textural triangle. Soil pH was determined in a 1:2.5 soil / water suspension using a standard pH meter and electrodes. Exchangeable acidity ($H^+$ and $Al^{3+}$) was determined by titrimetric method, while organic carbon (C) was determined by Walkley-Black method of wet combustion involving oxidation of organic matter with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid ($H_2SO_4$). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1N NH4OAc. Calcium and Mg in the soil extract were determined using atomic absorption spectrophotometer while K and Na were determined by flame photometry. Cation exchange capacity (CEC) was determined by the neutral 1N $NH_4OAc$ saturation method. Base saturation was determined by calculation, dividing the sum of exchangeable bases by their CEC and then multiplied by 100.

**Land Suitability Evaluation for Maize**
Suitability evaluation was performed for production of maize using the square root method (Khiddir, 1986) as expressed in equation (1) below:

$$S_i = R_{min} \text{ x } \sqrt{\frac{A}{100} \text{X} \frac{B}{100} \text{X} \frac{C}{100} \ldots\ldots}, \text{ ………… equation (1)}$$

where, $Si$= suitability index, $R_{min}$= connotes the factor that has minimum rating; and A, B, C… are ratings of other factors besides the minimum. The land suitability evaluation took into consideration the soil characteristics related to land qualities affecting the land use types.

Four (4) land quality groups: climate (c), soil physical properties (s), wetness (w) and fertility (f) were used in the evaluation. Final suitability for each crop was defined by applying the computed index values converted to its corresponding land suitability classes. According to suitability ranking of Sys *et al*. (1991), land suitability index of 0-12.5% connotes permanently not suitable (N2), 12.5-25% is currently not suitable (N1), 25-50% is marginally suitable (S3), 50-75 % is moderately suitable (S2) and 75-100% is highly suitable (S1). The soil and environmental requirements for maize production used in the evaluation are shown in Table 1.

**Table 1: Factor Rating of Land Use Requirements for Maize Production (Sys, 1991)**

| Land Qualities | Unit | Class, degree of limitation and rating scale | | | |
|---|---|---|---|---|---|
| | | S1 (100) | S2 (85) | S3 (60) | N (40) |
| Climate (c) | | | | | |
| Annual rainfall | (mm) | >800 | 700-800 | 600-700 | <600 |
| Mean temp | (C$^o$) | 24-30 | 30-32; 20-24 | 32-35; 15-20 | >35; <15, |
| Soil drainage (w) | Drainage class | Well | Moderately well | Imperfect | Poor, very poor |
| Soil characteristics (s) | | | | | |
| Effective soil depth | (cm) | >100 | 75-100 | 30-75 | <30 |
| Soil Texture | | CL, L | SL, LS | LCS | CS |
| Nutrient availability (f) | | | | | |
| Soil reaction | pH | 6.0-6.5 | 5.5-6.0; 6.5-7.0 | 5.0-5.5;7.0-8.2 | <5.0; >8.2 |
| Topsoil organic carbon | (g kg$^{-1}$) | >2.0 | 1.0-2.0 | 0.5-1.0 | <0.5 |
| Total N content | (g kg$^{-1}$) | >0.2 | 0.1-0.2 | 0.02-0.1 | <0.02 |
| Available P content | (mg kg$^{-1}$) | >40 | 10-40 | 3-10 | <3 |
| Topsoil K content | (cmol kg$^{-1}$) | >0.3 | 0.2-0.3 | 0.1-0.2 | <0.1 |
| Nutrient retention capacity (n) | | | | | |
| Base saturation | (%) | >80 | 40-80 | 20-40 | <20 |
| Topsoil CEC | cmol kg$^{-1}$ | >25 | 13-25 | 6-12 | <6 |
| Sodicity ESP | (%) | <10 | 10-15 | >15 | - |
| Soil angle (Erosion hazard) | (%) | <4 | 4-8 | 8-16 | >16 |
| Soil angle (Erosion hazard) | (%) | <4 | 4-8 | 8-16 | >16 |

L=Loamy, SL=sandy loam, CL=clayey loam, SC=sandy clay, LS=loamy sand

## RESULTS AND DISCUSSION

### Morphological Properties of the Soils

The study showed that the soils from GDM and MTD were moderately-deep to deep, having 70-100 cm effective soil depth, with coarse fragments. The dominant colour spectral of the indicated a range of 7.5YR and 10YR hues which impacted the soils with colour variations such as dark yellowish brown, strong brown, brown, pale brown. According to Brady and Weil (1999) and Aki *et al*. (2014), these group of colours may be indicative of the presence of migmatite, gibbsite, goethite and haematite minerals in the soils. The presence of mottle colouration in the subsoils may be an indication of internal drainage problem due to presence of plinthic layers which restricted free movement of water within the soil body, during the rainy season. This causes the soils to be imperfectly to poorly drained during the rainy season.

The soils from ENG and NDY were deep to very deep effective soil depth of 75-105 cm and were relatively free from course fragments and were well-drained. Similar to soils described under the basement complex, the colour features of soils of ENG and NDY indicated a range of 2.5YR to 10YR which impacted them with red, dark yellowish brown, dark red, dark yellow brown and dark reddish brown.

**Physical Properties**

The physical properties of the soils ot the four sites are presented in Table 2. The soils from GDM and MTD developed from basement complex, which have their textures to be loamy sand in surface horizons while sandy clay loam in sub-surface horizons respectively. The sand content followed the same pattern in all the soils of these sites, it decreased with soil depth. The silt content of these sites increased and decreased with soils depth except for MTD that decreased with depth. The clay content of MTD increased with soil depth while GDM increased and decreased with depth. The high sand fraction in surface horizon was also influenced by the parent material from which the soils are formed (Akpan-Idiok (2012); Peter and Umweni, 2021). The texture of ENG and NDY were sandy loam both in surface and sub-surface horizons. The sand content followed a particular pattern in all the soils, it decreased and increased with depth. Silt fraction from ENG and NDY were less in the topsoils than in the sub soils, while clay content increased with depth except for ENG that increased and decreased with depth. The relative high sand content in the area was the reflection of the effect of parent material such as Nupe sandstones. According to (Akamigbo and Asadu, 1983), the parent materials have been noted to influence the texture of the soils derived from them. The lower silt content in the soils may also be attributed to the effect of parent materials on the soils, as it has been reported by Akamigbo. (1984) that silt content is low in most soils of Guinea savanna of Nigeria.

**Chemical properties**

The chemical properties of the soils of study areas are presented in Table 3. Soil reaction was slightly acid to neutral with pH values of the surface soil as 6.3, 6.4, 6.9 and 6.5 for GDM, MTD, ENG and NDY respectively and were classified as slightly acid to neutral. Organic carbon (OC) in GDM ranged from 1.46 to 2.33 g $kg^{-1}$ and rated high. OC in MTD ranged from 3.61 to 7.05 g $kg^{-1}$, and rated very high. OC in ENG ranged from 0.51 to 4.24 g $kg^{-1}$, and rated low to high. OC in NDY ranged from 6.72 to 9.01 g $kg^{-1}$, and rated very high. Organic carbon is an essential component of soil chemical parameter for tropical soils, contributing to aggregate stability, permeability, water holding capacity, nutrient retention, and other desirable soil properties. (Ravindra. *et al*.2017). Total N in the soils of all sites was very low to low. Except in NDY, where available phosphorus was low, other sites had moderate to high values. The cation exchange capacity (CEC) values for all sites were generally low, except for MTD that was moderate. According to (Chude, *et al.* 2011) rating, the concentration of exchangeable $Ca^{2+}$ in GDM, MTD, and NDY were rated to be low, and exhibited the pattern of increased and decreased with the profile depth. While it concentration in ENG was rated to be moderate and increased and decreased with soil depth. The concentration of exchangeable Mg in GDM and ENG were rated to be moderate both in surface and sub-surface horizons and also exhibited increased and decreased pattern with soil depth. While it concentration in MTD and NDY were rated to be low, both in surface and sub-surface horizons and exhibited increased and decreased with soil depth. The concentration of exchangeable K in GDM, MTD, and NDY were rated to be very low both in surface and sub-surface horizons, and also exhibited increased and decreased pattern with soil depth. The concentration of exchangeable Na in GDM, MTD, and NDY were rated to be moderate in both surface and sub-surface horizons, and exhibited increased and decreased with soil depth. While the concentration of Na in ENG was rated to be low, both in the surface and sub-surface horizons, and also exhibited the pattern of increased and decreased with soil depth.

**Land Characteristics/Quality Attributes of the Soils**

Results of land characteristics and soil quality attributes of GDM, MTD, ENG, and NDY essential for suitability evaluation are presented in Table 4. The sites characteristics were based on particle size distribution (texture), effective soil depth, topography, drainage formed, fertility status and nutrient retention status for maize production respectively.

**Land Suitability Evaluation for Maize**

The assessment of the fitness of the study sites for maize production followed the suitability criteria laid down by the Sys et al. (1993), for both actual and potential suitability. The actual suitability evaluation involved the assessment of the land in its current status, while the potential suitability evaluation was carried out after imposing corrective management measure to correct the limitation (especially fertility related). The outcome of matching the land and environmental requirement (Table 1) with the land characteristics/ soil quality of the sites (Table 4) for each site covered both the actual (current) and potential suitability of the sites after correcting the limitations) and results are presented in Table 5.

The actual suitability indices were 21, 20, 22 and 17% for GDM, MTD, ENG and NDY respectively, suggesting that all the sites were not suitable (N1) for maize production in their current status due to limitations of soil fertility (particularly P and K) and nutrient retention (low organic matter and CEC). Low K content in GDM, ENG and NDY and moderate in MTD was the major fertility limitation. NDY also had moderate P content in the soil. In addition to fertility limitation, the soils of MTD had limitation of wetness (imperfectively drained subsurface) as a result of presence of plinthic horizon which induced perched water-table. The index suitability for MTD was 20% for actual and 28% for potential which translated to currently not suitable (N1) and marginally suitable (S3) respectively. After imposing corrective measures to correct the fertility limitation through application of mineral fertilizer, the index of suitability upgraded to 31, 28, 47 and 43 for GDM, MTD, ENG and NDY respectively. These values corresponded to marginally suitable (S3) for maize production.

**Table 2: Physical properties of the soils**

| Site | Horizon | Soil Depth (cm) | Sand | Silt (g kg$^{-1}$) | Clay | Textural Class | Bulk density (g cm$^{-3}$) | Total porosity (%) |
|---|---|---|---|---|---|---|---|---|
| GDM | Ap | 0 – 30 | 774 | 160 | 66 | LS | 1.45 | 45 |
| | Bt | 30 – 46 | 614 | 140 | 246 | SCL | 1.50 | 43 |
| | Btv | 46 – 75 | 674 | 200 | 126 | SL | 1.67 | 37 |
| MTD | Ap | 0 – 16 | 681 | 200 | 119 | SL | 1.46 | 45 |
| | Btv1 | 16 – 27 | 601 | 140 | 259 | SCL | 1.63 | 39 |
| | Btv2 | 27- 70 | 641 | 80 | 279 | SCL | 1.57 | 41 |
| ENG | Ap | 0 – 30 | 679 | 146 | 175 | SL | 1.41 | 48 |
| | AB | 30 – 50 | 699 | 146 | 155 | SL | 1.51 | 43 |
| | B1 | 50 – 66 | 619 | 206 | 175 | SL | 1.37 | 48 |
| | B2 | 66 – 85 | 599 | 206 | 195 | SL | 1.30 | 51 |
| | B3 | 85 – 105 | 619 | 206 | 175 | SL | 1.48 | 44 |
| NDY | Ap | 0 – 20 | 721 | 180 | 99 | SL | 1.32 | 50 |
| | Bt1 | 20 – 75 | 761 | 120 | 119 | SL | 1.47 | 45 |
| | Bt2 | 75 - 100 | 721 | 160 | 119 | SL | 1.48 | 44 |

LS=loamy sand, SL= sandy loam, SCL= sandy clay loam.

**Table 3: Chemical properties of soils**

| Areas | Soil Depth (cm) | pH ($H_2O$) | OC | N (g kg$^{-1}$) | P (mg kg$^{-1}$) | Ca | Mg | K (cmol kg$^{-1}$) | Na | EA | CEC | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gidan Mangoro | 0 – 30 | 6.3 | 1.46 | 0.46 | 12.65 | 2.88 | 0.96 | 0.07 | 0.83 | 0.04 | 8.40 | 56.43 |
| | 30 – 46 | 6.1 | 2.33 | 0.48 | 7.19 | 3.20 | 2.08 | 0.08 | 0.67 | 0.03 | 9.01 | 66.93 |
| | 46 – 75 | 6.2 | 1.46 | 0.36 | 9.51 | 2.40 | 1.12 | 0.07 | 0.58 | 0.04 | 7.11 | 58.65 |
| Mutun Daya | 0 – 16 | 6.4 | 7.05 | 0.74 | 14.39 | 2.08 | 0.80 | 0.14 | 0.45 | 0.14 | 14.41 | 24.08 |
| | 16 – 27 | 6.3 | 3.61 | 0.50 | 20.25 | 2.40 | 0.80 | 0.09 | 0.51 | 0.13 | 17.41 | 21.83 |
| | 27 -70 | 6.4 | 3.93 | 0.52 | 21.41 | 2.40 | 1.44 | 0.09 | 0.61 | 0.10 | 18.85 | 24.08 |
| Enagi | 0 – 30 | 6.9 | 1.87 | 0.34 | 26 | 5.04 | 0.72 | 0.14 | 0.20 | 0.05 | 7.40 | 82.43 |
| | 30 – 50 | 6.5 | 0.85 | 0.56 | 43 | 5.70 | 1.04 | 0.11 | 0.22 | 0.08 | 8.60 | 82.21 |
| | 50 – 66 | 6.9 | 4.24 | 0.46 | 28 | 6.64 | 1.28 | 0.14 | 0.23 | 0.04 | 11.08 | 78.82 |
| | 66 – 85 | 6.6 | 1.19 | 0.56 | 21 | 5.20 | 1.52 | 0.12 | 0.26 | 0.05 | 8.40 | 84.52 |
| | 85 – 105 | 6.4 | 0.51 | 0.23 | 30 | 5.60 | 0.40 | 0.07 | 0.20 | 0.05 | 7.20 | 87.08 |
| Ndayako | 0 – 20 | 6.5 | 6.72 | 0.36 | 9.33 | 1.60 | 0.96 | 0.05 | 0.50 | 0.11 | 10.40 | 29.90 |
| | 20 – 75 | 6.5 | 7.70 | 0.46 | 7.24 | 2.08 | 0.80 | 0.09 | 0.56 | 0.13 | 13.86 | 25.47 |
| | 75 – 100 | 6.6 | 9.01 | 0.42 | 2.83 | 1.92 | 0.96 | 0.05 | 0.53 | 0.15 | 11.88 | 29.12 |

Table 4: Land characteristics/quality attributes of the sites

| Parameter | Gidan Mangoro | Mutun Daya | Enagi | Ndayako |
|---|---|---|---|---|
| Mean Temp (°C)(Growing Season) | 26.2 | 26 | 26.4 | 27 |
| Rainfall (mm) | 1256 | 1328 | 1,226.3 | 1,259.5 |
| Dry months | 5 | 5 | 5 | 5 |
| Slope (%) | 3.0 | 4 | 3.0 | 3.0 |
| Soil depth (cm) | 75 | 70 | >100 | >100 |
| Drainage | Mod. | Imperf. | Well | Well |
| Soil texture | LS | SL | SL | SL |
| Soil reaction (pH) | 6.3 | 6.4 | 6.9 | 6.5 |
| Organic carbon (g $kg^{-1}$) | 1.46 | 7.05 | 1.87 | 6.72 |
| Total Nitrogen (g $kg^{-1}$) | 0.46 | 0.74 | 0.34 | 0.36 |
| Phosphorus (mg $kg^{-1}$) | 12.65 | 14.39 | 26 | 9.33 |
| Potassium (cmol $kg^{-1}$) | 0.07 | 0.14 | 0.14 | 0.05 |
| CEC (cmol $kg^{-1}$) | 8.40 | 14.41 | 7.40 | 10.40 |
| Base saturation (%) | 56.43 | 24.08 | 82.43 | 29.90 |
| Flooding | F1 | F1 | F0 | F0 |
| Exchangeable Sodic percentage (%) | 2.70 | 12.35 | 9.88 | 9.99 |
| Gravel (%) | 4 | 4 | 2 | 2 |

F0 = non-flooding, F1 = moderately flooding, F1= Flooding, F3= highly flooding,

Table 5: Suitability Assessment of the study sites for maize production

| | Gidan Mangoro | Mutun Daya | Enagi | Ndayako |
|---|---|---|---|---|
| Annual Rainfall | 100 | 100 | 100 | 100 |
| Mean temp (growing season) | 100 | 100 | 100 | 100 |
| Soil drainage (w) | 85 | 60 | 100 | 100 |
| Soil characteristics (s) | | | | |
| Effective soil depth | 85 | 60 | 100 | 100 |
| Soil Texture | 85 | 85 | 85 | 85 |
| Slope | 100 | 85 | 100 | 100 |
| Nutrient availability (f) | | | | |
| Soil reaction (pH) | 100 | 100 | 85 | 100 |
| Topsoil organic carbon | 85 | 100 | 85 | 100 |
| Total N | 100 | 100 | 100 | 100 |
| Available phosphorus | 85 | 85 | 85 | 60 |
| Potassium | 40 | 60 | 40 | 40 |
| Nutrient retention (n) | | | | |
| Base Saturation | 85 | 60 | 100 | 60 |
| Topsoil CEC | 60 | 85 | 60 | 60 |
| ESP | 100 | 100 | 100 | 100 |
| Aggregate Suitability: | | | | |
| **Actual** | **N1fn (21)** | **N1wfn (20)** | **N1fn (22)** | **N1fn (17)** |
| **Potential** | **S3n (31)** | **S3wn (28)** | **S3n (47)** | **S3n (43)** |

S3= Marginally Suitable, N1= currently not Suitable, fn=fertility limitations, wfn=wetness and fertility limitations, wn=wetness limitation, n=no limitations

## CONCLUSION AND RECOMMENDATIONS

From the results of this study, it can be concluded that climate was not a constraint for the production of maize in the study sites. The low organic matter, phosphorus and potassium content in all the site can be amended by adopting management practices that can encourage return of plant/crop residues into the soil as well as application of mineral fertilizers to improve phosphorus and potassium. Also planting on ridges will corrects problem of improve rooting condition in Mutun Daya.

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# VARIATION IN SEED QUALITY OF SESAME (*SESAMUM INDICUM* L.) PRESERVED IN DIFFERENT STORAGE CONTAINERS AND TEMPERATURE REGIME

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## ABSTRACT

This study evaluated the effects of storage materials and temperature regimes on the germination and seedling vigor of sesame seeds (Sesamum indicum L.) over a 14-week period. A factorial experiment was conducted using four storage materials—glass bottles, plastic containers, polythene bags, and paper envelopes—under three temperature regimes: room temperature (25–27°C), refrigerated conditions (8°C), and incubator conditions (33°C). Key parameters assessed included germination percentage (GP), germination energy (GE), radicle length (RL), plumule length (PL), and seedling vigor index (SVI). Results revealed that glass bottles provided the best preservation conditions, achieving the highest GP (68.40%) and SVI (295.13), followed by plastic containers. Polythene bags and paper envelopes demonstrated significantly lower performance. Refrigerated storage maintained better seed quality compared to room temperature and incubator conditions but could not prevent long-term deterioration. Seed viability and vigor were highest in the early storage period but declined sharply after six weeks, regardless of storage conditions. The findings underscore the importance of selecting optimal storage materials, maintaining controlled environments, and minimizing storage durations to preserve sesame seed quality. These insights have practical applications for improving seed storage practices in tropical agricultural systems.

**Keywords:** Storage Materials, Temperature, Storage, Final Germination Percentage (FGP), Germination Energy (GE), Seedling Vigour Index (SVI), Plumule Length, Radicle Length

## INTRODUCTION

Sesame (*Sesamum indicum* L.) is one of the world's oldest oil seed crops grown mainly for its seeds, which contain approximately 50 to 60% oil and 25% protein, it belongs to the Pedaliaceae family, Sesame seed has an excellent source of quality oil which is close in quality to olive oil, and often referred to as "queen of the oil seeds" (Gebregergis *et al.,* 2024). The seed is edible due to presence of antioxidants including sesamolin, sesamin, and sesamol, three natural antioxidants (Zerihun, 2012).  The crop is native to the tropics and certain temperate regions, it does well in well drained soils with moderate fertility and with an optimum temperature for growth in the range of 27 °C to35 °C (Baraki and Berhe 2019). One of the critical factors affecting sesame seed production is storage, lack of high-yielding and well-adapted varieties, vulnerability to capsule shattering, the frequency of biotic and abiotic challenges, and lack of contemporary production technology, such as storage facilities, are the important factors contributing to sesame's low yield. (Berhe *et al.* 2022; Usman *et al.* 2022). Boakye Boadu and Siaw (2019) reported decrease in germination percentage under longer seed storage periods, because longer periods of storage denature the protein content, reduce enzyme activity and carbohydrate contents of seeds. Seed longevity can be determined by moisture content, humidity and temperature, one percent increase in moisture content, longevity diminish by half. In crop seeds like sesame, deterioration is even faster immediately after harvest, because of its high oil content and rapid cellular respiration (Oyekale *et al.,* 2014). Proper storage containers are crucial to preserve seed quality, alongside natural ageing. Different containers vary in their ability to maintain optimal storage conditions, such as temperature, humidity, and air circulation. Inadequate storage can worsen seed deterioration (Teixeira *et al.* 2018). Abass *et al.* (2018) reported that polypropylene bags are commonly used by farmers to store their grain in sub-Saharan Africa. Although these bags generally fail to protect seeds from postharvest losses. The bag is a common packaging material for sesame storages lasting over a year in Nigeria. Baldaniya *et al*. (2018), observed that nine months after storage, seeds stored in plastic bags maintained a germination percentage above the Indian minimum seed certification standard of 70%. Thus the objective of this study was to evaluate the effect of different storage containers on the storage of sesame seeds, and to examine the effect of different temperature regime on seed quality of sesame.

## MATERIALS AND METHODS

The experiment was carried out in the laboratory of the Department of Crop Production Federal University of Technology, Minna situated within the Northern Guinea Savannah ecological zone of Nigeria (latitude $09^0$ 40'N and longitude $06^0$ 30'E).

### Source of Experimental Materials

One cultivar of sesame seed will be obtained from National Cereals Research Institute, Badeggi.

### Treatments and experimental design

The treatments were a factorial combination four storage containers i.e. (paper envelop, glass bottles, polythene bags and plastic containers measuring) and three temperature regimes i.e. (refrigerator 8 ºC room temperature and incubator) (3x4x3) arranged in a Completely Randomized Design (CRD) and replicated four times.

### Observation and data collection

### Seed storage and germination percentage

After collection, seeds were cleaned and dried immediately before storage at ambient temperature (29 ºC) for 14 days in the laboratory. Two hundred seed (200) were placed in each of the storage containers i.e. (Paper envelops, plastic containers (300 ml), polythene bags, and glass bottles) and exposed to three temperature regimes i.e. (room temperature at about 25-27 ºC, incubator running at 33ºC and a relative humidity of 85%, and refrigerator at 8 ºC) with the aim of accelerating the ageing of the seeds. The seeds will be stored in the various storage environments for 14 weeks. Seed samples will be drawn for germination test prior to storage and subsequently at two weeks' intervals for 14 weeks. This will be done by counting four replicates of 50 seeds in each of the treatment combinations and will be placed on filter paper moistened with distill water in plastic Petri-dishes. The Petri-dishes will be carefully arranged in seed germination chamber at a constant temperature of 30 ºC. Germination counts will be taken every-other-day and results will be expressed in percentages. Incubation period for each germination test will be 28 days. The following formula of by Ellis and Robert (1981) will be adopted for determination of the percentage germination:

$$\mathbf{GP} = \frac{SNG}{SNO} \times 100\%$$

Where, SNG is the number of germinated seeds and SNO is the number of experimental seeds with viability (Scott *et al*., 1984).

Where n is the number of seed germinated on each day and g is total number of germinated seed (Ellis and Robert, 1981).

**Germination energy**
Is a measure of how quickly and efficiently seeds begin to germinate after planting. High germination energy indicates strong, healthy seeds that are likely to perfume well when planted. It is calculated as the percentage of the seeds that germinate within a specific period out of the total number of seeds tested.

$$\text{GE: }\% = \frac{\text{Number of germinated seeds}}{\text{Number of total per treatment after germination for 13 days}} \text{X } 100 \qquad \textbf{(3.4)}$$

(Samir *et al*., 2019).

***Seedling vigour parameters***
**Radicle Length:** The length of the radicle was measured with the aid of a metre rule and values will be expressed in centimetres (cm)

**Plumule length:** The length of the plumule was measured with the aid of a metre rule and values will be expressed in centimetres (cm)

**Seedling Vigour Index (SVI):** It was calculated using the formular below:
**SVI = (**Mean Root Length + Mean Shoot Length) X germination percentage.

**RESULTS**
The study examined the impact of various storage materials on the preservation of sesame seeds. Results revealed that seeds stored in bottles achieved the highest germination rate (68.40%), significantly outperforming plastic containers (65.54%), polythene bags (62.75%), and paper envelopes (62.54%) (Table 1). This advantage is likely attributable to the superior protection offered by bottles against environmental factors such as humidity and temperature fluctuations, which are crucial for sustaining seed viability. Additionally, bottles and plastic containers recorded significantly higher germination energy (GE) values of 387.41 and 378.67, respectively, compared to polythene bags (359.24) and paper envelopes (349.79). Seeds stored in bottles also exhibited the longest radicle length (4.82 cm), followed by paper envelopes (4.68 cm), while polythene bags resulted in the shortest radicle length (4.02 cm). This suggests that bottles provided optimal conditions for radicle development, whereas polythene bags may have caused seed desiccation or oxidative stress, hindering growth. However, there was no significant variation in plumule length across the storage materials, indicating that storage conditions had minimal influence on plumule development compared to the radicle. Bottles also demonstrated the highest seedling vigour index (295.13), significantly exceeding the value observed for plastic containers (239.18).

**Table 1 effect of storage materials on the germination and seedling vigour of sesame seeds**

| Storage materials | FGP | GE | RL | PL | SVI |
|---|---|---|---|---|---|
| **Bottle** | 68.40a | 387.41a | 4.82a | 3.45a | 295.13a |
| **Paper envelop** | 62.54a | 349.79b | 4.68b | 3.36a | 263.45ab |
| **Plastic container** | 65.54a | 378.67a | 4.21bc | 3.20a | 239.18b |
| **Polythene bag** | 62.75a | 359.24 | 4.02c | 3.17a | 239.97ab |
| **SE** | 1.5589 | 2.2388 | 0.676 | 0.0511 | 8.2017 |

Any two means within each column not shearing a letter differ significantly from each other at 5% probability level

**Effect of storage duration on the germination and seedling vigour of sesame seeds**

FGP remained stable during the early stages of storage, consistently exhibiting high percentages ranging from 94.50% to 96.75% (Table 2). However, a sharp decline in germination was observed between weeks 8 and 10, with FGP dropping to 52.71% at 8 weeks and further decreasing to 41.54% at 10 weeks. This decline reflects the onset of seed viability loss, likely due to the increasing effects of aging and the deterioration associated with seed metabolic activity. From weeks 12 to 14, there was a drastic decline in germination, with FGP reaching 30.79% at 12 weeks and 32.66% at 14 weeks. Although week 2 recorded the highest GE (396.73), it was not significantly different from week 0 (389.58) and week 6 (393.58). Seeds stored for more than 6 weeks, however, showed impairment, reducing their ability to germinate rapidly. Sesame seeds exhibited the longest radicle length at 4 weeks (5.58 cm), but this significantly reduced by week 6 (3.87 cm), with further declines at weeks 12 (3.69 cm) and 14 (3.52 cm). While the highest PL was recorded at week 4 (4.25 cm), significant reductions were observed after 6 weeks. SVI reached its peak at week 4 (466.75), but there was a sharp decline by week 6, with SVI as low as 100.49 at week 14.

Table **2 Effect of storage duration on the germination and seedling vigour of sesame seeds**

| **Storage weeks** | **FGP** | **GE** | **RL** | **PL** | **SVI** |
|---|---|---|---|---|---|
| **0** | 96.25a | 389.58a | 5.00b | 3.07bc | 388.55b |
| **2** | 94.50a | 396.73a | 5.05b | 3.38b | 398.88b |
| **4** | 95.00a | 379.21b | 5.58a | 4.25a | 466.75a |
| **6** | 96.75a | 393.58a | 3.87c | 4.04a | 382.65b |
| **8** | 52.71b | 368.41c | 4.98b | 3.37b | 222.47c |
| **10** | 41.54c | 344.07d | 3.76c | 2.81c | 136.64d |
| **12** | 30.79d | 339.66d | 3.69c | 2.89c | 101.67e |
| **14** | 32.66d | 352.76cd | 3.52c | 2.41d | 100.49e |
| **SE** | 1.5589 | 2.2388 | 0.676 | 0.0511 | 8.2017 |

Any two means within each column not shearing a letter differ significantly from each other at 5% probability level

**Effect of temperature of storage on the germination and vigour of sesame seeds**

At zero storage the FGP was the highest (92.25%), suggesting that storage temperature affects seed viability and vigour (Table 3). Storage at room temperature, incubator, and refrigerator showed significantly lower FGPs, recording around 61–66%, with no significant difference among the treatments. GE also showed that zero storage was the highest (389.84), followed by room temperature (368.45) showing no significant difference with seed stored in the incubator and refrigerator (2365.41 and 36946) indicating slower germination rates in these environments. At zero storage, radicle length was 5.0 cm, which was significantly longer than those observed under room temperature, incubator and refrigerator. The incubator and refrigerator showed comparable radicle lenght (4.39 and 4.47 cm), which were slightly higher than at room temperature (4.18 cm). However, plumule length remained similar across all storage conditions (around 3.0–3.4 cm) implying that temperature had minimal impact on plumule. SVI was highest at zero storage (388.55), although room temperature, incubator, and refrigerator recorded (255–263), which was relatively lower value compared to the zero temperature.

**Table 3 Effect of temperature of storage on the germination and vigour of sesame seeds**

| TEMPERATURE OF STORAGE | FGP | GE | RL | PL | SVI |
|---|---|---|---|---|---|
| **0** | 92.25a | 389.84a | 5.0a | 3.07a | 388.55a |
| **Room temp.** | 66.30b | 368.45b | 4.18b | 3.40a | 263.93b |
| **Incubator** | 61.91b | 365.41b | 4.39ab | 3.20a | 255.08b |
| **Refrigerator** | 62.05b | 369.46 | 4.47b | 3.32a | 256.56b |
| **SE** | 1.5589 | 2.2388 | 0.676 | 0.0511 | 8.2017 |

Any two means within each column not shearing a letter differ significantly from each other at 5% probability level

**DISCUSSION**

Quality and longevity of sesame seeds were significantly affected by the choice of storage material and temperature. Glass bottles were the most effective storage containers, preserving the highest germination percentage (68.40%) and seedling vigor index (295.13), due to their superior protection against environmental factors such as humidity and temperature fluctuations. This is contrary to the study Kartoori and Patil (2018) who investigated the effect of different storage containers on storage of onion seeds and reported that polythene bags and aluminium foil were more effective than cloth bags to retain seed quality parameters during storage. Plastic containers also performed well but were less effective than glass bottles. Polythene bags and paper envelopes were the least effective, with lower germination rates and seedling vigor indices. Seed viability and vigor were highest during the initial storage period but declined rapidly after six weeks, especially under ambient and incubator conditions. Zero stored seeds exhibited the highest germination percentage and vigor indices, underscoring the importance of minimizing storage duration. Refrigeration, while maintaining better germination energy and radicle length than other conditions, still resulted in a decline in seed quality over time. Storage temperature had a notable impact on seed longevity and vigor. Seeds stored at refrigerated temperatures (8°C) exhibited better germination energy and radicle length compared to room temperature (25–27°C) and incubator conditions (33°C). However, the refrigerator did not fully halt the decline in seed quality over time, highlighting that temperature management alone is insufficient without proper containers. Room temperature and incubator conditions accelerated the deterioration of seed viability due to increased metabolic activity and potential moisture-related damage. The duration of storage significantly affected seed quality. Initially, the seeds maintained high germination percentages (above 90%), but a sharp decline was observed after six weeks, with a drastic reduction in germination rates by the 10th to 14th week. This trend was consistent across all storage conditions, emphasizing the natural aging process and deterioration due to enzymatic and oxidative damage. Radicle length and seedling vigor index followed a similar pattern, peaking early in storage and declining sharply with time.

## CONCLUSION

The quality and longevity of sesame seeds were significantly influenced by the choice of storage material and temperature regime. Glass bottles were the most effective storage containers, preserving the highest germination percentage (68.40%) and seedling vigor index (295.13), due to their superior protection against environmental factors such as humidity and temperature fluctuations Plastic containers also performed well but were less effective than glass bottles. Polythene bags and paper envelopes were the least effective, with lower germination rates and seedling vigor indices. The critical impact of storage duration and temperature. Seed viability and vigor were highest during the initial storage period but declined rapidly after six weeks, especially under ambient and incubator conditions. Zero-storage seeds exhibited the highest germination percentage and vigor indices, underscoring the importance of minimizing storage duration. Refrigeration, while maintaining better germination energy and radicle length than other conditions, still resulted in a decline in seed quality over time.

## RECOMMENDATION

The study recommends glass bottle as better option for storing sesame seed, this may be due to its superior ability to prevent moisture absorption, therefore maintain seed viability and vigor. While Plastic containers can be a secondary option where glass bottles are unavailable. Storing seeds in the refrigerator is advised to minimize seed quality loss, especially for long-term storage. However, for shorter durations, room temperature can be managed effectively with proper containers.

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# EFFECTS OF HIGH TEMPERATURE AND ELEVATED $CO_2$ CONCENTRATIONS ON GROWTH AND PHYSIOLOGY OF CACAO (*Theobroma cacao*) SEEDLINGS

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## ABSTRACT

Temperature rise of 0.3°C per decade has been predicted which culminates into approximately 1 and 3°C above the present temperature by 2025 and 2100 AD, respectively. This will be accompanied by an increase in $CO_2$ concentration in the atmosphere to 700ppm concentration. Very little is known about how these changes in climate will effect cocoa cultivation. Under this study, the impacts of elevated $CO_2$ and high temperature conditions were examined on one variety of cocoa (SCA 9) in a compartmentalized greenhouse. Each compartment had a different combination of temperature regimes and $CO_2$ concentrations. Compartment 1 had "high" temperature (a set point minimum of 24°C and maximum of 33ºC) and high $CO_2$ concentration (a set point of 700ppm), compartment 2 had "normal" temperature (a set point minimum of 21°C and a maximum of 30ºC; which is similar to a Ghana environment) and high $CO_2$ concentration (a set point of 700ppm), compartment 3 had "high" temperature and ambient $CO_2$ (400ppm) and compartment 4 which is the control had ambient $CO_2$ and "normal" temperature. The result showed significant difference in temperature effect under elevated $CO_2$ for parameters like plant height, stem water content, stem dry weight, fresh stem weight, stomata number, stomata conductance. Positive responses to temperature and $CO_2$ treatments were observed under the measured parameters. The increase in transpiration under high temperature was lessened at elevated $CO_2$ compared to ambient $CO_2$. Water use efficiency was greater under elevated $CO_2$ compared to ambient. Higher rates of photosynthesis were observed in high temperature under elevated $CO_2$. The experiment has confirmed that an increase in temperature of 3°C above current Ghana conditions will favour the growth of cocoa plant under elevated $CO_2$ in the event of the predicted climate change.

**Keywords**: Climate, CO2, temperature, cocoa, warming

## INTRODUCTION

Cocoa (*Theobroma cacao*) belongs to the genus Theobroma, sub-family Sterculioidea and family Malvaceae and is a tropical crop of high value which is cultivated in the tropics (Motamayor et al., 2002; Argout 2011; Afoakwa 2012). It is one of the highly ranked perennial crops in importance among others (Almeida and Valle, 2007). It originates from the Amazon region and is cultivated between latitudes of 10ºN and 10ºS of the equator (Motamayor et al., 2002). The cocoa plant is tender and a relatively difficult crop to cultivate. There are conflicting reports as regard the potential of cocoa in affecting conservation. Guiltinan et al., (2008) reported that the agro-forestry ecosystem nature of cultivating cocoa can have a positive impact on the environment since it preserves the biodiversity in ecologically sensitive areas of the world. However, Moser et al., (2010) asserted that Cocoa production has resulted in deforestation in regions of Indonesia where forested areas have been cleared to plant cocoa and to avoid problems of pest and diseases in old plantation regions. Eskes, (2011) cited that in 1983 to 1984, production of cocoa increased from ca. 1.5 million tonnes to ca. 3.8 million tonnes in 2005-2006. This increase in production has been attributed to increase in farm area and not yield increase of old plantation (Eskes, 2011). This increase was adjudged unsustainable as it encourages deforestation which in turn may bring about adverse environmental consequences. The planting of high yielding and disease-resistant varieties with best management practices by farmers may be helpful as measures to limit the impact of deforestation. Deforestation is one of the major causes of climate change (IPCC, 2007).

Various work has been done on rise in temperature in relation to cocoa or elevated $CO_2$ on cocoa plant, however none has been done to date on the interaction of high temperature and elevated $CO_2$ on cocoa seedling. The desire to fill this gap informed this research. Therefore, the main objectives of this research are; -To verify the impact of elevated $CO_2$ compared to ambient $CO_2$ on cocoa seedlings; -To bear out the possible influence of high temperature predicted to result by 2100 due to climate change on cocoa seedlings and compare it to that of current atmospheric temperature. To examine the interaction between temperature and $CO_2$ on the growth and physiology of cocoa seedlings.

## MATERIALS AND METHODS

### Experimental setup

One variety of cocoa, a progeny of SCA 9 (a Peruvian wild genotype) was sown in a sand: gravel: vermiculite (ratio 1:2:2) mixture and grown for five months at the University of Reading's International Cocoa Quarantine Centre before being transferred to glasshouses at the University of Reading campus. The cocoa plants were arranged in the greenhouse, seven treatment plants in each compartment and staked to prevent them from bending over. The experiment was set up in a factorial design of 1x2x2; i.e one variety of cocoa, 2 temperatures and 2 levels of $CO_2$ concentration. A quantum light sensor was used to check the light balance in each compartment so the plants were exposed to equal amounts of sun light for photosynthesis. Each compartment had a different combination of temperature regimes and $CO_2$ concentrations. Compartment 1 had "high" temperature (a set point minimum of 24°C and maximum of 33°C ;) and high $CO_2$ concentration (a set point of 700ppm), compartment 2 had "normal" temperature (a set point minimum of 21°C and a maximum of 30°C; which is similar to a Ghana environment) and high $CO_2$ concentration (a set point of 700ppm), compartment 3 had high temperature (a set point minimum of 24°C and maximum of 33°C) and ambient $CO_2$ (400ppm) and compartment 4 which is the control had ambient $CO_2$ and ambient temperature similar to Ghana environment i.e $CO_2$ (400ppm) and temperature (a set point minimum of 21°C and a maximum of 30°C).

The plants were irrigated every two hours between 8am to 6pm. The irrigation solution used contained essential macro and micro nutrients needed for the growth of cocoa in the proper proportion. The stock solutions contained Potassium Nitrate ($KNO_3$) 6048 g, Ammonium Nitrate ($NH_4NO_3$) 5.5 ltr, Potassium Sulphate ($K_2SO4$) 1680g, Magnesium Sulphate($MgSO_4$) 3312g, Potassium dihydrogen phosphate ($KH_2PO_4$) 2112 g, EDTA 480 g, Nitric acid 500 ml in 227 litres of water. The micronutrients contained in the solution are**:** Boric acid ($H_3BO_3$) 120g, Manganous sulphate ($MnSO_4$) 68g, Zinc sulphate 324 g, Ammonium molybdate 10.4g, Copper sulphate 9.6g. There was a separate acid stock solution which contained 2.5 litre Nitric acid, 1.25 litre Orthophosphoric acid was mixed with 80 litres of water. Acid solution was added to the stock tank to give a pH of 5.6, which is optimal for cocoa growth. The stock solutions were added to water in a mixing tank to give an electrical conductivity of 2 m/S. The plants were grown under experimental conditions for 10 weeks

**Data collection**

**Light saturated photosynthesis measurements**

A portable infra-red gas analyser was set up with the temperature and carbon dioxide level adjusted to that of the corresponding compartment. Measurements were taken between 26-05-14 and 30-05-15 and a youngest fully matured and hardened leaf on each plant which had fully developed under experimental conditions was selected. Measurements were made using an LCpro+ infrared gas analyser fitted with a light attachment and an internal $CO_2$ source (ADC BioScientific, Great Amwell, Herts, UK). Measurements were made between 9:00 and 14:00. The average $CO_2$ concentration in the IRGA compartment for each of the cocoa plant in different chambers were; 704 ppm (687ppm minimum, 722ppm maximum, compartment 1), 715ppm (minimum 701ppm, maximum 729ppm compartment 2), 395ppm (minimum 390 ppm, maximum 399 ppm, compartment 3), 409ppm (minimum 396ppm, maximum 421ppm compartment 4). The temperature in the IRGA compartment ranged from 30 – 33˚ C during measurements. The photosynthetic rate was allowed to stabilise before a measurement was recorded. The chamber was clamped on the leaves and the record taken for the stomatal conductance, transpiration and photosynthesis rate. After the measurement, intrinsic water use efficiency (iWUE) was calculated by dividing photosynthesis rate by stomatal conductance value.

**Chlorophyll fluorescence measurements**

Following four weeks' growth the chlorophyll fluorescence was measured early in the morning between 09am and 10am using a leaf chlorophyll fluorescence meter (Handy PEA, Hansatech Instruments). The leaves were dark adapted by clamping light-exclusion clips on the leaf surface of a matured and fully photosynthesising leaf for twenty minutes after which the fluorescence meter was placed on the clip, which was then opened to take the reading.

**Stomata count**

The stomata count was done by first taking the epidermal peel off the abaxial surface of fully photosynthesising leaves from each of the replicated treatment plants with a clear nail varnish to get a clear epidermal imprints. A nail vanish paint was painted lightly such that the stomata can be seen clearly when viewed under microscope and peeled off with the aid of a cello tape. The stomata imprints were observed under a Leitz Dialux 20 microscope mounted with EOS 600D single-lens reflex camera with the EOS software for live viewing and image capturing. For each of the replicated plant, 3 images per imprint were taken. The count was done with the aid of ImageJ software.

**Plant height and leaf number measurements**

Leaf numbers were counted and plant heights measured and recorded once a week. Leaves of 1 cm length and above were counted on each replicated treatment plant. Plant height was measured from the base to the budding tip with the aid of a measuring tape. This was repeated for ten weeks. At the end of the experiment on July 14$^{th}$, the exact increase in height under the experimental condition was calculated by deducting plant height at week one from plant height at week 10. This was repeated for leaf number as well.

**Destructive harvest**

After ten weeks in the greenhouse treatments, the plants were harvested by cutting from the base with the aid of a secateurs after which the leaves, petioles and roots were separated from the stem and weighed separately. The fresh weight of the stems was recorded having been chopped into sections. The samples were oven-dried for 5 days at 70$^0$C and the dry weight was measured. The water content for leaves, petioles, stems and roots were determined by subtracting the fresh weight from the dry weight. The percentage water content of the plants was also calculated (TPFW – TPWC) / TPFW x 100, Where TPFW = Total plant fresh weight; TPWC = Total plant water content). Total leaf area was measured for each tree using a WD3 WinDIAS leaf area meter (*Delta-T Devices Ltd.*, Cambridge, UK).

**Statistical analysis:** Analysis of variance was carried out on the data using GenStat 13$^{th}$ edition.

## RESULTS

**Growth parameters and biomass measurements**

Observations from statistical analysis of recorded parameters on the effects of $CO_2$ and temperature treatments showed significant effects for some parameters while it was not significant for other parameters (Table 1). There were no significant effects of the two treatments ($CO_2$ and temperature treatments) on number of new leaves produced, leaf fresh weights (g), petiole fresh weight (g) and leaf area (cm$^2$). Other parameters where there were no significant effects of the two treatments ($CO_2$ and temperature treatments) includes fresh roots weight, total plants fresh weight, leaf dry weight, petioles dry weight, root dry weight, shoot dry weight and total dry weight. Furthermore, parameters like leaf water content, petiole water content, roots water content and percentage water content (Table 1) were also not significant. However, total plant fresh weight slightly increased under $CO_2$ treatments with plant under elevated $CO_2$ having slight increase in weight by 18% over ambient $CO_2$; the results were on the borderline of significance ($p = 0.096$; Table 1). Total fresh shoot weight was greater under the elevated $CO_2$ treatment by 20% compared with the ambient $CO_2$ treatment ($p = 0.098$; Table 1).

Temperature and $CO_2$ treatments had significant impacts on plant height ($CO_2$ $p = 0.029$, temperature $p = 0.002$ Fig. 1). Plants height under elevated $CO_2$ was 25% greater compared with ambient $CO_2$. High temperature treatment resulted in a 38% increase in height compared to normal temperature treatments. There was a significant increase ($p = 0.032$) in fresh stem weight at elevated $CO_2$. The interaction between $CO_2$ and temperature was also significant ($p = 0.048$ Fig. 1). Overall the elevated $CO_2$ resulted into 32% weight increase over the ambient $CO_2$ treatment. The interaction results showed that at ambient $CO_2$ the temperature effect was not noticeable on plant height, however effect of high temperature resulted in increased plant height at elevated $CO_2$. Analysis of data showed significant difference in the stem water content under $CO_2$ treatment (p = 0.028) and the interaction between the temperature and $CO_2$ treatment (p = 0.051, ). The difference in stem water content weight for $CO_2$ showed that water content of ambient $CO_2$ – grown plants is lower by 14.51g to that under elevated $CO_2$. Interaction effect between high temperature and elevated $CO_2$ led to an increase in stem water content by 39% over high temperature under ambient $CO_2$ condition. The elevated $CO_2$ treatment resulted in a slight increase in the overall water content of 20% compared with ambient $CO_2$ (p = 0.091).

$CO_2$ had a significant impact (p = 0.049) on the stem dry weight; there was a 35% weight increase at elevated $CO_2$ compared to the ambient $CO_2$ treatment. The interaction effects between $CO_2$ and temperature was also significant (p = 0.046 Fig. 4) for oven-dried weight of stem. High temperature, under elevated $CO_2$ treatment increased the oven – dried weight of stem with a difference of 8.51g (46%) over normal temperature at ambient $CO_2$.

**Stomata conductance (mol m$^{-2}$ s$^{-1}$)**

$CO_2$ or temperature treatment alone did not have any effect on the stomata conductance (Table 1). Nevertheless, there was interaction effect of the treatments on the cocoa plants (p = 0.012, Fig. 6). Temperature treatment increased stomata conductance (mol m$^{-2}$ s$^{-1}$) at ambient $CO_2$ but this was reduced under the influence of elevated $CO_2$. The increase in stomata conductance as a result of high temperature interacting with ambient $CO_2$ was approximately 70% in comparison with temperature treatment under elevated $CO_2$.

**Stomata count**

Analysis of variance showed significant differences (p = 0.003) in the effect of temperature on the stomata number per 0.5mm$^2$ of leaf area. Normal temperature had stomata count higher by 24% compared to high temperature. There was a significant interaction between $CO_2$ and temperature on stomata count (p = 0.049,). In the interaction, the effect of temperature was greater at elevated $CO_2$. Stomata count under ambient $CO_2$ and normal temperature was lesser by 68 stomata per 0.5mm$^2$ compared to normal temperature at elevated $CO_2$.

**Intrinsic water use efficiency (IWUE)**

A highly significant effect (p = <.001) for the intrinsic water use efficiency of cocoa seedlings was observed under $CO_2$ treatment. Intrinsic water use efficiency of cocoa seedlings in elevated $CO_2$ was higher by 36% in relation to ambient $CO_2$ (Table 1).

**Transpiration rate**

Each one of $CO_2$, and temperature and their interaction produced significant impacts on the transpiration rate of cocoa seedling ($CO_2$ treatment, p = 0.001; temperature treatment p = <.001; interaction effect of $CO_2$ and temperature treatment, p = 0.005). This rate of water loss is higher (1.389 mmol m$^{-2}$ s$^{-1}$) at ambient $CO_2$ than at elevated $CO_2$ (0.893). Transpiration rate at high temperature was higher (1.398) than at normal temperature (0.842). Under the interaction effect of the treatments (Fig. 8), it was observed that the effect of high temperature on transpiration rate was greater by 84% at ambient $CO_2$ than at elevated $CO_2$.

Chlorophyll fluorescence

There were no significant effects of the treatments on chlorophyll fluorescence for cocoa seedlings.

**Table 1:** Plant growth parameters measured after 10 weeks of growth at "high" and "normal" temperature, ambient and elevated $CO_2$ treatment. The plant height and leaf data refers only to growth recorded during the experiment.

| | **Normal temperature** | **High temperature** | **Ambient $CO_2$** | **Elevated $CO_2$** | **P** | | |
|---|---|---|---|---|---|---|---|
| | | | | | $CO_2$ | Temperature | $CO_2$ x Temperature |
| **Increase in plants height (cm)** | 41.39 ±6.1 | 57.33 ±2.2 | 44.47 ±5.1 | 55.71 ± 3.8 | 0.029 | 0.002 | 0.198 |
| **Increase in leaf numbers** | 19.27 ±6.5 | 15.57 ±2.1 | 14.42 ±2.7 | 20.62 ±1.8 | 0.120 | 0.335 | 0.981 |
| **Leaf area ($cm^2$)** | 4824 ±760.2 | 5799 ±628.4 | 5354 ±676.7 | 5385 ±524.1 | 0.987 | 0.147 | 0.601 |
| **Fresh Shoot weight (g)** | 147.6 ±21.9 | 149.5 ±10.9 | 134.5 ±15.6 | 161.7 ±14.4 | 0.098 | 0.893 | 0.150 |
| **Fresh roots weight (g)** | 51.11 ±7.9 | 45.36 ±8.4 | 42.42 ±5.5 | 52.94 ±9.2 | 0.186 | 0.488 | 0.158 |
| **Fresh petiole weight (g)** | 9.863 ±1.4 | 9.849 ±1.8 | 9.495 ±1.0 | 10.165 ±0.78 | 0.580 | 0.984 | 0.412 |
| **Fresh stem weight (g)** | 67.96 ±9.7 | 67.88 ±7.8 | 58.05 ±8.2 | 77.01 ±7.4 | 0.032 | 0.989 | 0.048 |
| **Fresh leaf weight (g)** | 69.80 ±11.4 | 71.76 ±7.6 | 66.97 ±6.8 | 74.52 ±8.7 | 0.392 | 0.817 | 0.560 |
| **Total fresh plant weight (g)** | 198.7 ±43.2 | 194.8 ±27.1 | 176.9 ±20.8 | 214.6 ±21.9 | 0.096 | 0.876 | 0.123 |
| **Stomata conductance (gs)** | 0.03500 ±0.007 | 0.04429 ±0.009 | 0.04385 ±0.004 | 0.03615 ±0.003 | 0.212 | 0.136 | 0.012 |

## DISCUSSION

Temperature sensitivity is expressed in cocoa plants and may even differ in different genotypes of the crop (Daymond and Hadley, 2004, 2008). This temperature sensitivity influences where cocoa can be grown (Daymond et al., 2004). Temperature affects almost all growth stages of cocoa from the seedling stage to flowering (Omolaja et al., 2009) and flushing and can greatly impart the plant in terms of its physiological and developmental activities (Hadley et al., 1994). The same thing is applicable to $CO_2$ which is required for plant growth at all stages. $CO_2$ is highly important to plant for photosynthesis through which the plant acquires and stores chemical energy and is able to get its carbon skeletons for organic molecules which give plants its structure. The cocoa plant is a $C_3$ plant and its photosynthetic rate increases with elevated $CO_2$ concentration (Lahive et al., 2012). The results of this experiment is consistent with the above cited literatures as the cocoa seedling plant height increased under elevated $CO_2$ treatment. This is similar to other crops. Grain amaranth, grapevine, cotton, wheat and common bean have also shown increase in photosynthetic activities as $CO_2$ increases (Harley and Ehleringer, 1987; Morgan and LeCain 1991; Pettigrew and Turley 1998; Santos et al., 2009).

Significant increases were consistently obtained under elevated $CO_2$ for plant height, fresh shoot weight and total plant fresh weight compared to ambient $CO_2$. This agrees with Baligar et al., (2005, 2008), and Lahive et al., (2012) whereby a consistent increase in cocoa shoot growth, stem weight and plant height were obtained under increased $CO_2$ concentration. This indicates that the predicted increase in $CO_2$ from current 400ppm to 700ppm by 2100 (IPCC, 2007; Solomon, 2007), may be an advantage for cocoa growth as it gives more room for higher availability of $CO_2$ for increased photosynthesis and consequent plant growth. Oven-dried-stem weight increased under $CO_2$ treatment. It's interaction with high temperature is an indication of good skeletal structure for the plant which supports other above ground biomass where the plagiotropic jouquette and second chupons develop from (Carr, 2012) and fruit bearing in the later stage of growth.

The possibility of high temperature affecting the physiology and morphology of cocoa (including photosynthetic activities (Daymond et al., 2004) is also observed from the result of this experiment. Overall, in the plotted graph for cocoa seedling growth increase at each week of the experiment, it was observed that elevated $CO_2$ and high temperature promotes growths. It can be concluded from this study that plant's growth will be affected positively under influence of high temperature (33ºC for current study) with increase $CO_2$ concentration (700ppm for this study) and promote growth in the future effect of climate change. This is supported by the fact that chlorophyll fluorescence, an indication of stress was not significant for the treatment- meaning that increased temperature under this experiment did not put the plant under stress.

Higher water content in the stem observed under elevated $CO_2$ compared to ambient $CO_2$ is thought to be due to greater growth rates in cocoa seedlings at elevated $CO_2$. Another reason that may be attributed to higher water content in the stem is the possibilities of the leaf stomata closing at high temperature (Matsui et al., 1997). It is logical to think that stem dry weight was not significant under temperature treatment alone because, even though the plant conserves water in the presence of high temperature, there was no abundant $CO_2$ to make use of the water in the presence of sunlight and convert it to dry matter content in the stem. This result reflects the assertion by Taub (2010) whereby it was cited that one of the most notable effects of elevated $CO_2$ on crops is increase in photosynthetic carbon fixation rates by leaf. The photosynthetic carbon fixation rates by leaf makes up approximately 95% of the total dry mass for most plant (Marschner, 1995).

## CONCLUSION

In conclusion, this experiment has confirmed that elevated $CO_2$ will favour the growth of cocoa plant under increased temperature of the predicted climate change. However, further work still need to be done to understand the response of different genotypes to elevated $CO_2$ and high temperature. This becomes important due to the fact that many morphological and physiological traits in cocoa are genotype specific. The experiment also need to be observed for a longer period of time so as to see what happens to further development of the cocoa plants under this experimental condition. It will be desirable to see if it affects flower initiation, fruit development, and its influence as related to pest and diseases developments.

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# EVALUATION OF SOILS AND SOCIO-ECONOMIC CHARACTERISTICS OF RICE FARMERS AROUND RIVER CHANCHAGA FLOODPLAIN IN NIGER STATE, NIGERIA

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## ABSTRACT

The study assessed the socio-economic characteristics of rice farmers and also evaluate the suitability of floodplain soils along the River Chanchaga floodplain in Niger State, Nigeria, for sustainable rice production. The socio-economic characteristics of farmers within the study area was evaluated through the use of structured questionnaires to analyse demographic profiles, socio-economic factors, and land use characteristics. The selection was based on geological differences and extensive floodplain rice cultivation. The site was delineated into three physiographic units (upper, middle, and lower slopes) were identified within the floodplain, profile pits were dug and sampled at each location according to FAO guidelines. Standard laboratory procedures were use to determined soil properties. Results revealed that the majority of farmers were male (95%), aged 36-45 (64%), married (95%). Predominantly, Faro 44 rice variety was grown, with seeds sourced primarily from local markets. Farmers achieved significantly higher average rice yields (20T) likely due to the use of both organic and inorganic fertilizers. Land acquisition was mainly through inheritance (64%). The soils exhibited sandy loam, loamy, and loamy sand textures, with a dominance of sand (402-842 g $kg^{-1}$). Soil pH ranged from slightly acidic to neutral (5.5-6.8), while organic carbon was low across all sites. Nitrogen and phosphorus distribution varied with depth. Calcium was the dominant exchangeable base, while potassium was moderate (<0.30 cmol $kg^{-1}$). Cation exchange capacity (CEC) and percentage base saturation (BS) were moderate to high (63-89%). The study highlights the need for government and stakeholder support to enhance existing adaptive strategies, improve soil conditions through fertilizer application and land preparation, and increase rice output for sustainable livelihoods and food security. The findings suggest that improving soil nutrient availability and land preparation are crucial for enhancing rice production in the region.

**Keywords:** Floodplain Soils, Socio-economic characteristics, Physical and Chemical properties

## INTRODUCTION

Floodplain soils, prevalent in tropical regions, offer significant agricultural potential, particularly for rice cultivation terraces (Ibrahim and Omotosho, 2012). In West Africa, 47% of floodplain soils are used for rice, and Nigeria, a leading rice producer, utilizes 7.2% of its land area (65,783 ha) for this purpose (Wakatsuki, 2004). Niger State plays a significant role in Nigeria's rice production, contributing substantially to national agricultural productivity (Akande, 2003).

**Study Site**

The study, conducted in Niger State, Nigeria, focused on two locations along the River Chanchaga floodplain. The area experiences a sub-humid tropical climate with 1200-1600 mm annual rainfall (May-October), a five-month dry season (November-March), and high temperatures (34-37°C), with relative humidity of over 80% in the morning and falls to between 40 and 70% in the afternoon

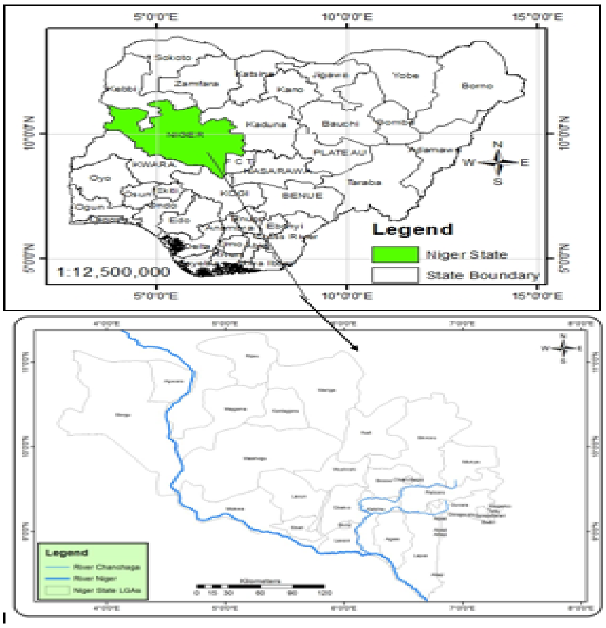


**Figure 1: Nigeria indicating Niger State and the Study Area**

**Site selections**

The sites selection was attributed to differences in their geology and vast land mass of floodplain which was used for rice productions. The upstream falls under Paikoro Local Government Area on latitude 09° 31.59′ N and longitude 06° 34.51′ E with average elevation of 216m above sea level in Niger State.

**Data Collected and Sources**

The data required include; Digital Elevation Model (DEM), and Topographic map of the study area. The socio-economic characteristics of farmers within the study area was evaluated through the use of structured questionnaires to elicit information from rice farmers along River which was used for analysis to derived information on demographic characteristics, socio- economic characteristics in addition to the land use characteristics. Profile pits were dug to specification of 2m by 2m by 1.5m and described according to guidelines for soil profile description. The genetic horizons were identified on the basis of the observed differences in some morphological characteristics of the soils which include colour, texture, structure, depth of horizons, and topography which was used to establish the soil boundaries Soil samples were analyzed for some physical and chemical properties following the procedures.

**Aim and Objectives of the Study**

The aim of the study was to evaluate Evaluation of Soils and Socio-Economic Characteristics of Rice Farmers around River Chanchaga Floodplain in Niger State, Nigeria
The objectives of the study are to:

i. examine socio-economic characteristic of rice farmers within the study area.
ii. assess the land use characteristics of the study area
iii. assess the physical and Chemical properties of the soils

## RESULTS

**Demographic profile of rice farmer around River Chanchaga**
The result showed that the dominant gender among farmers were male which accounts for 95% as compared to 6% who were female in the communities (Table 1). Analysis by age revealed that majority 63% of the respondents were aged between 36-45 years, twenty-three (23%) were within the age of 46-55 respectively, 6% are youths below 35 years with only 1% are above 66 years. Regarding the farmers' marital status, majority 95% were married with only 1% been widowers and divorcees. On their source of income, 65% of the respondents listed rice farming as their major occupation and source of income throughout the year, while 30% practice farming alongside civil service job with 5% named other sources of income to include dry season farming of vegetables, Artisanal, fishing and other manual jobs in addition to Rice farming. It further shows the number of years' farmer were involved in rice farming and other crops. The results of the study showed that majority of respondents had 10-20 years of farming experience 72% followed by those with 10 years which account for 22%. While 6% experience 20-30 years of farming. For rice cultivation only the result depicts that 64.6% started farming rice alone for the past 10 years, 35.4% starts within 10-20 years back. Hence 100% of farmers apply fertilizers on their farm for more yields.

**Table 1: Demographic Profile of Rice farmer around River Chanchaga Floodplain**

| S/N | DEMOGRAPHIC CHARACTERISTICS | UPSTREAM | |
|---|---|---|---|
| | | F | % |
| 1 | Gender | | |
| | Male | 86 | 94.5 |
| | Female | 5 | 5.5 |
| | Total count | 91 | 100 |
| 2 | Age | | |
| | < 35years | 6 | 6.6 |
| | 36-45years | 58 | 63.7 |
| | 46-55years | 21 | 23.1 |
| | 56-65years | 5 | 5.5 |
| | Above 66years | 1 | 1.1 |
| | Total count | 91 | 100 |
| 3 | Marital status | | |
| | Single | 3 | 3.3 |
| | Married | 86 | 94.5 |
| | Widowed | 1 | 1.1 |
| | Divorced | 1 | 1.1 |
| | Total count | 91 | 100 |

| | | | |
|---|---|---|---|
| 4 | Occupation | | |
| | Farmers | 68 | 74.7 |
| | Civil Servant | 20 | 22.0 |
| | Others | 3 | 3.3 |
| | Total count | 91 | 100 |
| 5 | Do you apply fertilizer | | |
| | Yes | 91 | 91.0 |
| | No | 0 | 0.0 |
| | Total | 91 | 91.0 |
| 6 | Why do you apply this fertilizer? | | |
| | For more yield | 91 | 100.0 |
| | Total | 91 | 100.0 |
| 7 | Years of rice farming | | |
| | 10 | 63 | 70.0 |
| | 10-20 | 26 | 28.9 |
| | 20-30 | 1 | 1.1 |
| | Total | 90 | 100.0 |

F = frequency, T = Total.

**Distribution by production (land use characteristics) of the study areas**

The result of Figure 2 Showed that land acquisition is mainly through inheritance 60.4% with smaller proportions renting or buying. Also, in terms of farm sizes figure 3, shows that sizes are predominantly small to medium (1-4 ha). Faro 44 is the most popular rice variety 87.9% figure 4 highlighting the preference for high-yielding varieties.

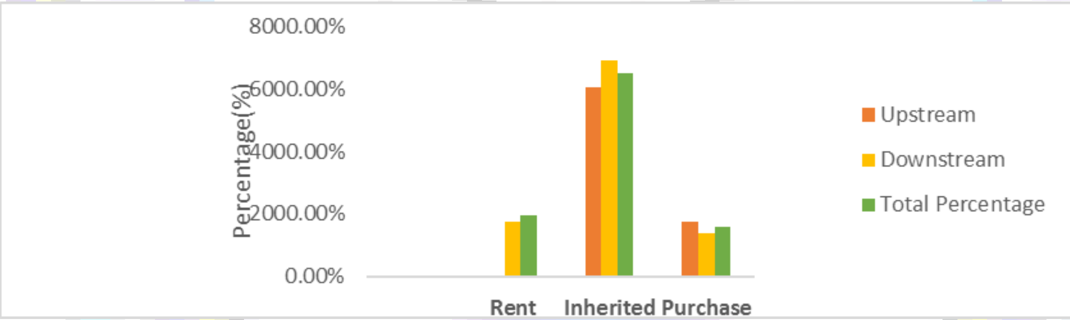


**Figure 2: Land Tenure System at the Study Area**

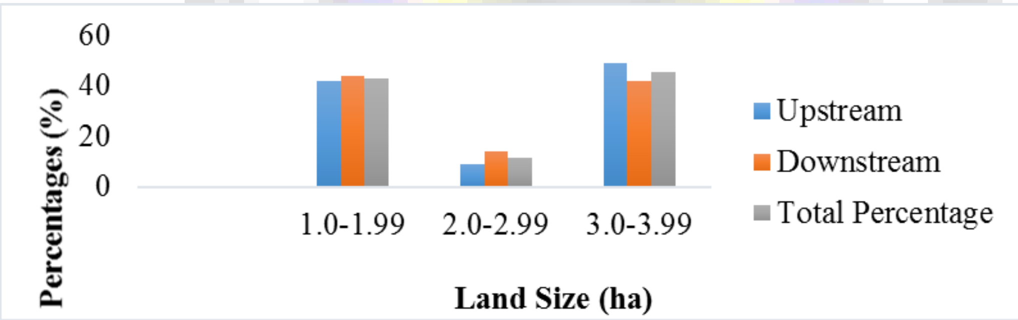


**Figure 3: Land Size (ha) of the Farmlands at the Study Area**

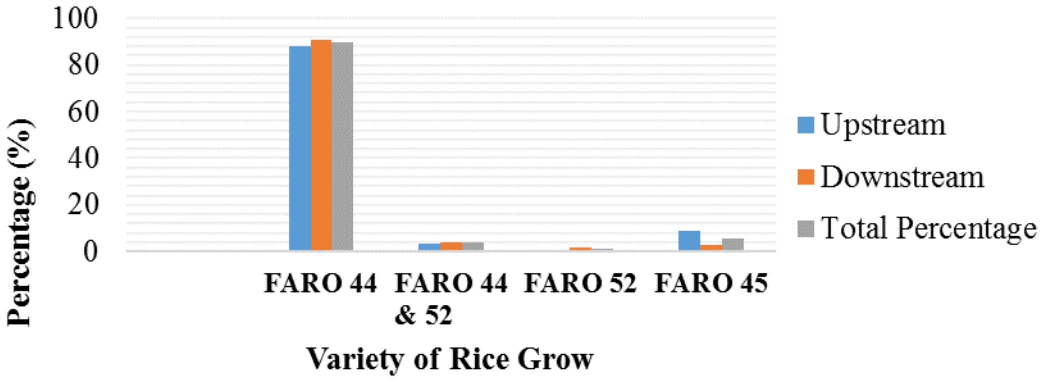


**Figure 4: Variety Rice grown at the Study Area**

The results of the study showed that (Figure 4) majority of respondents' plant different variety 92%. as it enhances food security and income generation to the farmers. Good quality seed is the main key to component of rice production. The studies reveal that farmers at the study site obtain their seed from local market (69.2%) with 6.6% get theirs from the government (grant)/ support organizations while 24.2% of farmers obtain theirs from their previous seeds (Figure 5).

Regarding season of rice cultivation (Figure 6), farmers cropped rice in different seasons. In this survey, most of the farmers cultivated rice twice a year. The farmers practice either single (rainfed) or double season (rain-fed and irrigation) rice farming. Larger percentage of the farmers 54.9% cultivating during raining season. While 41.8% cultivate in both seasons. In contrast 3.3% farm rice in dry season only. Figure 7 reveals the quantity (Yield) of rice obtained at the study area, which depicts that the average yield recorded was 20T at downstream which is significantly higher than upstream. Output of rice (Figure 8) is explained by variation in fertilizer application and the varieties of rice planted. 51.6% of farmers use organic fertilizer, 20.9% use inorganic fertilizer while 27.5% indicate that they use both the organic and inorganic on the farmland.

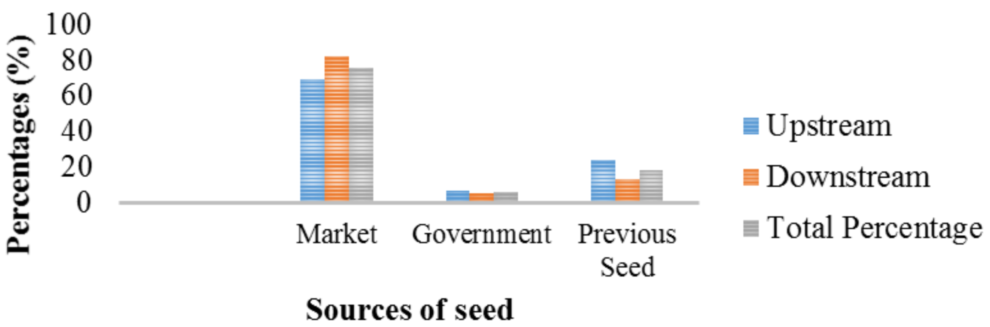


**Figure 5: Sources of Seed**

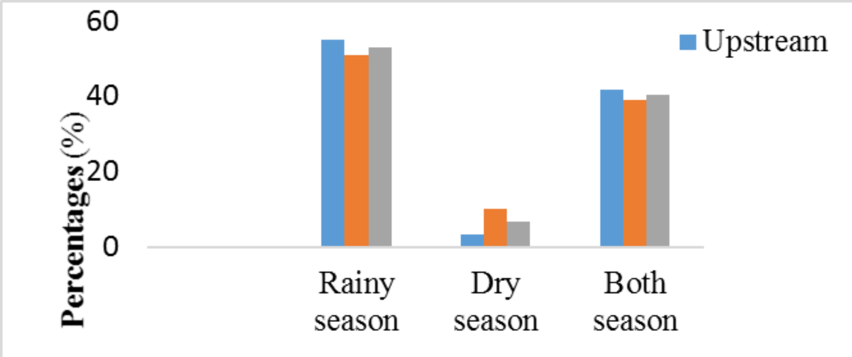


**Figure 6: Season of Cultivating Rice at the Study Area**

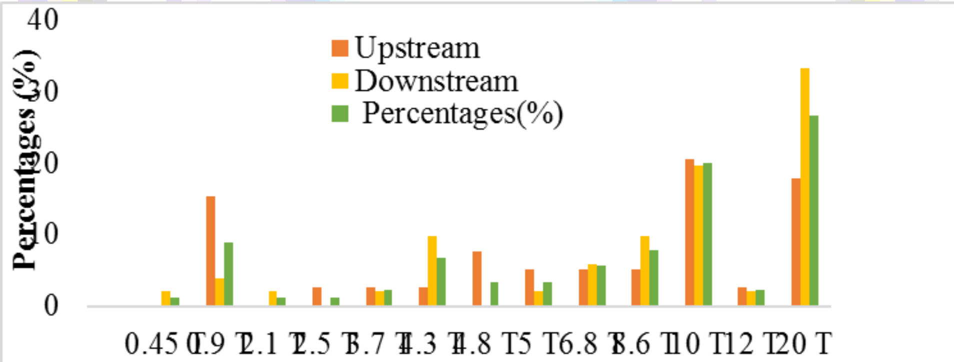


**Figure 7: Quantity of Rice Obtained at the Study Area**

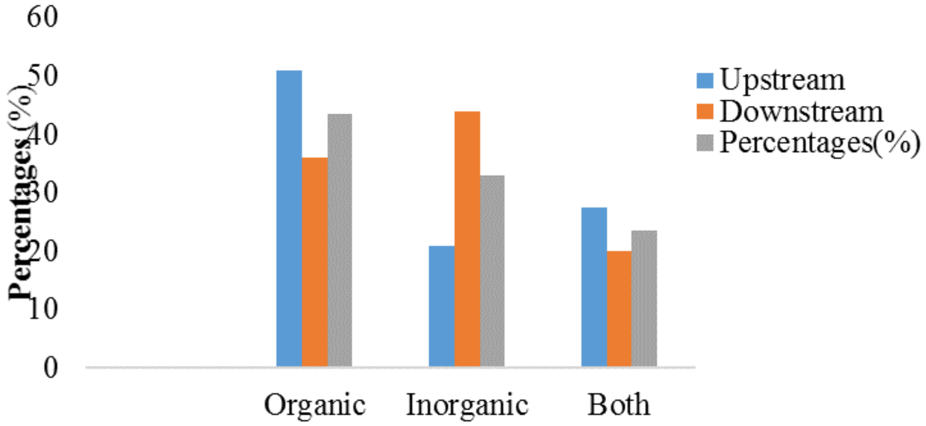


**Figure 8: Type of Fertilizer Used at the Study Area**

**Table 2: Particle Size Distribution of the Upstream Soils**

| Horizon | Soil Depth (cm) | Sand<br>g $kg^{-1}$ | Silt | Clay | Silt/Clay ratio | Textural Class |
|---|---|---|---|---|---|---|
| | | | **UPPER SLOPE** | | | |
| Ap | 0 – 25 | 712 | 213 | 75 | 3.08 | Sandy Loam |

| | | | | | | |
|---|---|---|---|---|---|---|
| Btg1 | 25 – 52 | 532 | 343 | 125 | 2.74 | Sandy Loam |
| Btg2 | 52 – 100 | 492 | 323 | 185 | 1.75 | Loam |
| Btg3 | 100 – 140 | 562 | 303 | 135 | 2.24 | Sandy Loam |
| BC | 140 – 200 | 632 | 253 | 115 | 2.20 | Sandy Loam |
| | | | **MIDDLE SLOPE** | | | |
| Ap | 0 – 21 | 632 | 293 | 75 | 3.90 | Sandy Loam |
| Btg1 | 21 – 41 | 662 | 193 | 145 | 1.33 | Sandy Loam |
| Btg2 | 41 – 83 | 752 | 153 | 95 | 1.61 | Sandy Loam |
| Btg3 | 83 – 125 | 682 | 183 | 135 | 1.36 | Sandy Loam |
| BC | 125 – 200 | 402 | 393 | 205 | 1.92 | Loam |
| | | | **LOWER SLOPE** | | | |
| Ap | 0 – 19 | 822 | 133 | 45 | 2.96 | Loamy Sand |
| Btg1 | 19 – 52 | 632 | 283 | 85 | 3.32 | Sandy Loam |
| Btg2 | 52 – 90 | 612 | 243 | 145 | 1.67 | Sandy Loam |
| Btg3 | 90 – 130 | 582 | 323 | 95 | 3.40 | San Loam |

The soil texture across all slopes was predominantly sandy loam to loam, with high sand content (402-822 g $kg^{-1}$) attributed to parent material (Araujo et al., 2017). Silt content (133-393 g $kg^{-1}$) varied with depth due to flooding, while clay content (45-205 g $kg^{-1}$) was higher in subsoils due to eluviation and illuviation (Adeboye et al., 2009). Soil pH (5.5-6.8) was slightly acidic to neutral. Organic carbon (2.7-8.1 g $kg^{-1}$) and total nitrogen (0.04-0.25 g $kg^{-1}$) were low to moderate, potentially due to factors like gaseous loss and leaching (Usman, M. 2021). Available phosphorus (1-32 mg $kg^{-1}$) varied, reflecting soil pH and parent material. Calcium (2.56-5.20 cmol $kg^{-1}$) and magnesium (0.16-3.60 cmol $kg^{-1}$) were moderate to high, likely influenced by parent material. Potassium (0.19-0.30 cmol $kg^{-1}$) was moderate, while sodium (0.15-1.41 cmol $kg^{-1}$) was moderate to high. Cation exchange capacity (5.40-8.40 cmol $kg^{-1}$) and base saturation (63-89%) were moderate to high.

## CONCLUSION

The study area's soil is predominantly sandy loam to loam, with high sand content influencing drainage and water retention. Flooding impacts silt distribution, while clay accumulation reflects typical soil formation processes. Slightly acidic to neutral pH indicates moderate nutrient availability, although low organic carbon and nitrogen, potentially from leaching and gaseous losses, may limit productivity. Moderate to high levels of Calcium and Magnesium suggest overall fertility. The interplay of traditional farming practices and modern inputs, particularly applications of fertilizers by farmers, is crucial for improving rice yields and farmer livelihoods in this socio-economic context.

## RECOMMENDATIONS

To improve rice farmers' livelihood and socio-economics status, Sustainable Land Management Practices should be ensured and eextension Services should be encouraged to educate farmers on improved soil management practices, including water conservation, fertilization, and sustainable land management techniques. This will ensure the effective adoption of recommended practices. By addressing these aspects, the inherent fertility of the soil can be maximized, leading to improved rice yields and enhanced farmer livelihoods through Regular soil testing and balanced fertilization.

**Table 3 Chemical Properties of Upstream Soils of River Chanchaga Floodplain**

| Horizon | Soil Depth (cm) | pH | EC µS/cm | TN (gkg) | TOC (g $kg^{-1}$) | Avail. P (mg $kg^{-1}$) | Exch. Bases Ca | Mg | K | Na (cmol $kg^{-1}$) | Exch. Acid | CEC | BS % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **UPPER SLOPE** | | | | | | | |
| Ap | 0 – 25 | 6.1 | 0.07 | 0.15 | 8.10 | 1 | 4.00 | 2.20 | 0.21 | 0.28 | 0.07 | 9.30 | 72 |
| Btg1 | 25 – 52 | 6.1 | 0.07 | 0.12 | 7.30 | 2 | 3.40 | 2.00 | 0.22 | 0.27 | 0.05 | 8.80 | 67 |
| Btg2 | 52 – 100 | 6.2 | 0.12 | 0.10 | 3.90 | 1 | 5.00 | 2.40 | 0.29 | 0.20 | 0.04 | 8.90 | 89 |
| Btg3 | 100 – 140 | 6.2 | 1.25 | 0.16 | 2.70 | 1 | 4.70 | 2.10 | 0.28 | 0.16 | 0.05 | 9.40 | 77 |
| BC | 140 – 200 | 5.5 | 0.15 | 0.06 | 4.20 | 32 | 3.90 | 2.30 | 0.24 | 0.15 | 0.07 | 9.30 | 71 |
| | | | | | | **MIDDLE SLOPE** | | | | | | | |
| Ap | 0 – 21 | 6.3 | 0.04 | 0.07 | 2.70 | 1 | 4.96 | 0.16 | 0.23 | 0.20 | 0.04 | 6.50 | 85 |
| Btg1 | 21 – 41 | 6.8 | 0.04 | 0.04 | 3.70 | 1 | 3.52 | 1.12 | 0.19 | 0.28 | 0.05 | 7.00 | 73 |
| Btg2 | 41 – 83 | 6.7 | 0.06 | 0.08 | 4.20 | 1 | 2.56 | 1.12 | 0.20 | 0.33 | 0.08 | 6.70 | 63 |
| Btg3 | 83 – 125 | 6.6 | 0.0 | 0.08 | 4.80 | 3 | 3.00 | 1.80 | 0.21 | 1.19 | 0.04 | 9.40 | 66 |
| BC | 125 – 200 | 6.8 | 0.32 | 0.18 | 4.20 | 7 | 4.40 | 2.70 | 0.30 | 1.41 | 0.07 | 10.80 | 82 |
| | | | | | | **LOWER SLOPE** | | | | | | | |
| Ap | 0 – 19 | 6.5 | 0.09 | 0.25 | 3.60 | 9 | 3.36 | 2.64 | 0.19 | 0.30 | 0.03 | 7.40 | 88 |
| Btg1 | 19 – 52 | 6.7 | 0.06 | 0.22 | 3.40 | 5 | 4.80 | 2.20 | 0.22 | 0.29 | 0.04 | 9.40 | 80 |
| Btg2 | 52 – 90 | 6.6 | 0.27 | 0.20 | 5.00 | 1 | 4.00 | 2.60 | 0.27 | 0.43 | 0.02 | 10.10 | 72 |
| BC | 90 – 130 | 6.5 | 0.23 | 0.13 | 5.90 | 2 | 5.20 | 3.60 | 0.29 | 0.49 | 0.03 | 13.00 | 74 |

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# INCIDENCE AND SEVERITY OF *TOMATO YELLOW LEAF CURL VIRUS* DISEASE AND WHITE FLY ABUNDANCE ON TOMATO (*Solanum lycopersicon* L.) IN SELECTED GROWING AREAS OF KEBBI STATE

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## ABSTRACT

A field survey was conducted in December-February 2020/2021 during the dry season farming, three growing Local government areas of Kebbi State were surveyed to assess the incidence, severity of *Tomato yellow leaf curl virus disease* and whitely population on tomato (*Solanum lycopersicon*) In selected tomato growing areas of Kebbi State. Asymptomatic and symptomatic tomato plants were randomly assessed While whiteflies were counted in apical terminal leaves of each plant assessed for disease. Disease incidence was high in Aliero Local Government area with 41.6% compared to Jega (38.67%) which was ranked second in term of disease incidence, while Maiyama Local Government was the least (32.22%). Aliero recorded high symptom severity (1.8%), Jega ranked second and Maiyama was the least 1.61% and 1.46% respectively. While vector population was high in Aliero (8.18), Maiyam ranked second (5.26), and was in Jega (4.28).

**KEYWORDS:** *Bemisia*, Pepper, Tomato, Survey and *TYLCD*

## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a popular vegetable crop in many countries of the world. According to FAO, 2016) in world, vegetable production ranks 2nd in the world's vegetable production next to potato. Wilcox *et al*. (2003) studied the importance of tomato in human nutrition, because of its rich source of lycopene, minerals, and vitamins such as ascorbic acid (Vitamin-C) and β-carotene (Vitamin-A) which are antioxidants and promote good health. However, *Tomato yellow leaf curl virus* (TYLCV) *Begomovirus c*auses severe crop losses in tomato cultivars up to 100% (Czosnek and Laterrot, 1997). It has a broad host range with various plant families such as Solanaceae (tomato, peppers, and ornamental plants), Malvaceae (cheeseweed), and Fabaceae (beans). (TYLCV) causes yellow leaf edges, upward leaf curling, leaf mottling, small leaf, and flower drop. The infected plants in early stages do not bear fruit and stunting; depend on seasonal conditions and level of susceptibility. *TYLCV* genome consists of circular, single- stranded DNA (ssDNA) approximately 2.7 kb long (Gronenborn, 2007). *TYLCV* occurs primarily by movement of infected plant material or by wind dispersal of whiteflies, acquiring the virus (Torre *et al.,* 2018). The virus, was first discovered in 1939 in Israel and Jordan (Avidov, 1944), and was officially named *Tomato yellow leaf curl virus* (*TYLCV*) and consists of different strains; *Tomato yellow leaf curl Israel* (*TYLCSV-Is*), *Tomato yellow leaf curl virus-Mild* (*TYLCV-Mld*), Sardinia (*TYLCV-Sa*), *Tomato yellow leaf curl Sicily* (*TYLCSV-Sic*), *Tomato yellow leaf curl virus-Morocco* (*TYLCV-Mo*), *Tomato yellow leaf curl Malaga* (*TYLCV-Mal*) *Tomato yellow leaf curl Axarquia* (*TYLCV-Ax*), *Tomato yellow leaf curl China* (*TYLCV-*

*Ch*) and *Tomato yellow leaf curl Thailand* (*TYLCV-Th.*) (Abhary *et al.,* 2006; Fauquet *et al.,* 2008). The virus is graft transmitted, transmitted by whitefly (*Bemisia tabaci*) in the field by phloem-feeding and indirect damage by transmission of *begomoviruses* (Brown and Czosnek, 2002; Jones, 2003; Navas-Castillo *et al.,* 2011). Hence, the current assessment of *TYLCV* and whitely prevalence in Nigeria is immensely important to reduce crop loss through understanding the cultivar of Tomato that is resistant to disease, so that the cultivation of tomato could be profitable for farmers, as the disease caused heavy loss to tomato in many Nigeria.

TYLCV is the most economical important virus among viruses that infect tomato plants (Czosnek, 2007). It severely limits tomato production (Hanssen *et al.,* 2010). The incidence of *TYLCV* may reach up to 100% in protected and open fields causing economic losses that could range from 50% to 90% of the crop production (Hamilton *et al.,* 2015). *TYLCV* results in lower income for tomato crop producers and higher prices for consumers (Lapidot and Friedmann, 2002). Tomato is among the most important crops in Nigeria considering their edible parts which provides vitamins and minerals however, it generates income to the farmers. The research work reports of this study could provide a greater understanding of *TYLCV* transmitted by *Bemisia. tabaci,* which will contribute immensely to the development of control strategies, thus improving crop production in the study area. The study is of great benefit to plant breeders, pathologists, entomologists, plant virologists, virus transmission studies, and plant disease epidemiologists.

## MATERIALS AND METHODS

### Field Survey

A field survey was conducted in a dry season of February 2020/2021 in Kebbi State, three local governments areas were selected and considered as sample sites during the survey; 10km from each field was maintained.

### Materials

The materials used were mainly survey materials which included Global Positioning System (GPS Gemini) receptor for taking coordinates (Longitude, Latitude, and Altitude) while Temperature and Relative humidity were recorded using sensor in the survey area.

### Methods

#### Whitefly Count

Whitefly count was done in the morning and evening when the insects are least mobile, whiteflies were directly counted on fully expanded terminal leaves of random plants in each surveyed field, and Means were recorded.

### Disease Incidence Assessment

Thirty (30) asymptomatic and symptomatic plants were randomly assessed during the survey while disease incidence was calculated according to the method developed by **(**Sseruwagi *et al.,* 2004)

Disease Incidence (%) $\frac{\text{Number of plant with PMV symptom}}{\text{Number of plant assessed}} \text{x}100$

**Severity Status**

Thirty (30) severity status was assessed based on the severity scale of 1-5 developed by **(**Sseruwagi *et al.,* 2004)

**Data Analysis**

Data on incidence, severity and mean whitefly population were subjected to descriptive statistic Microsoft Excel (version 2007) bar chart were used to present the analyzed data.

**RESULTS**

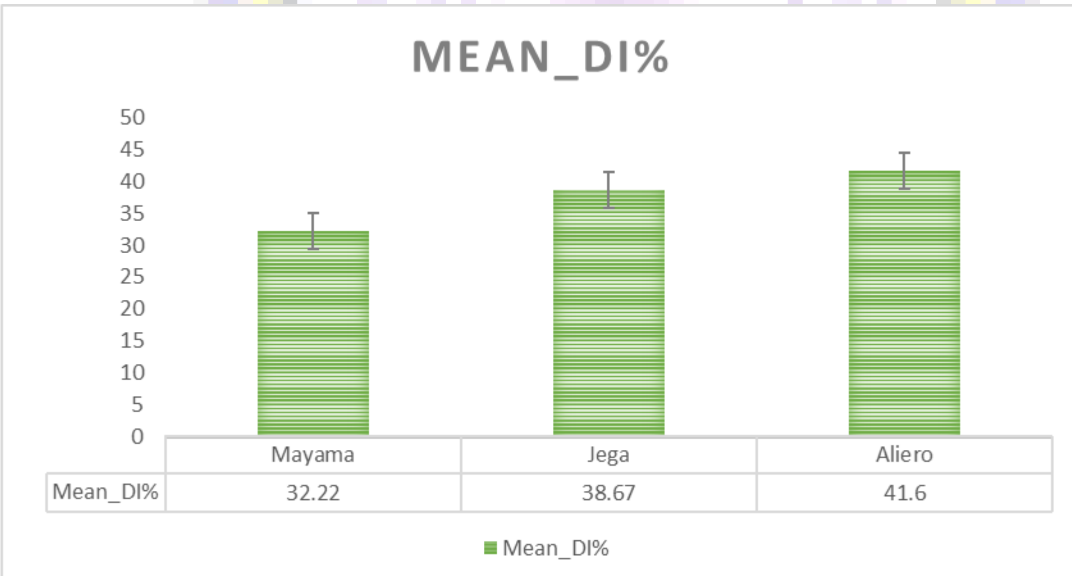


**Figure 1:** *Incidence of virus (*Begomovirus*)* in *Aliero, Jega and Mayama Local Government Areas of Kebbi State during the 2021 dry season. Bars indicate standard error of means at 5 % probability level.*

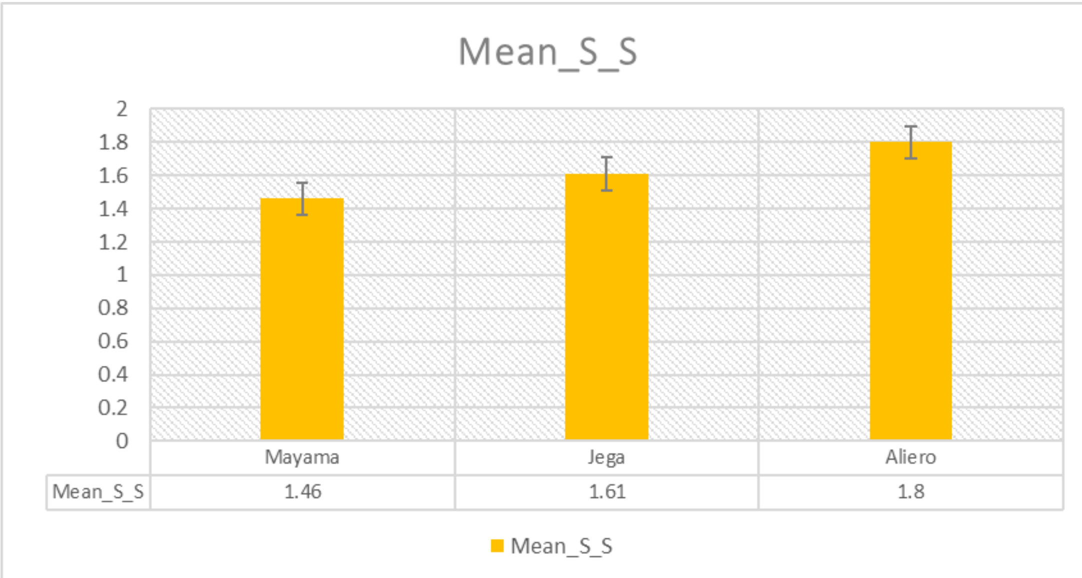


**Figure 2:** *Mean symptom severity* of (Begomovirus) in *Aliero, Jega and Mayama Local Government Areas of Kebbi State during the 2021 dry season. Bars indicate standard error of means at 5 % probability level.*

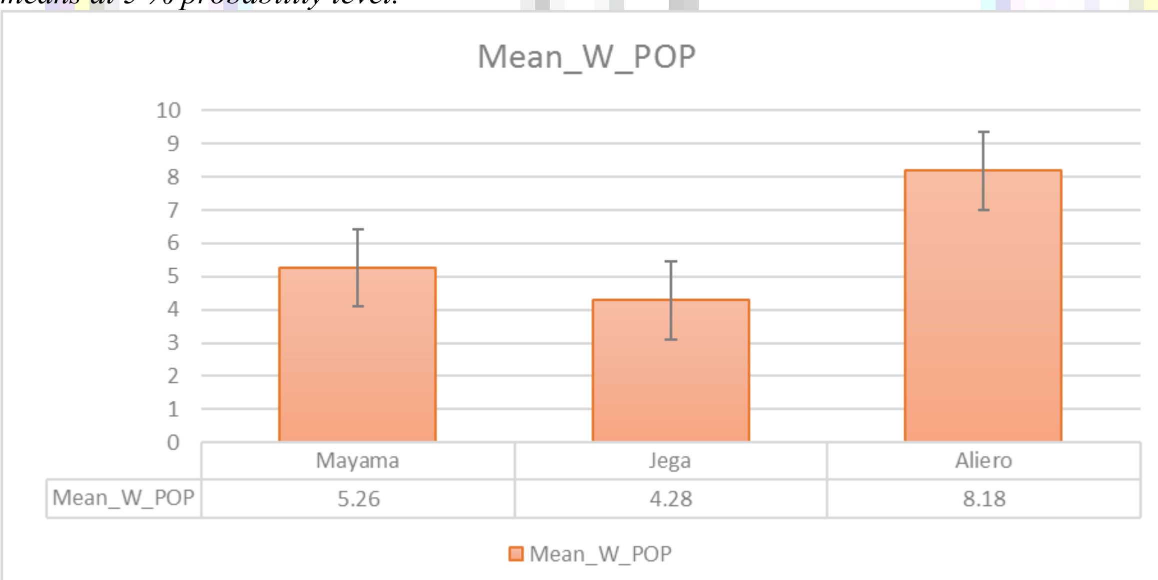


**Figure 3:** *Mean whitefly abundance infesting tomato plant in Aliero, Jega and Mayama Local Government Areas of Kebbi State during the 2021 dry season. Bars indicate standard error of means at 5 % probability level.*

## DISCUSSION

This study constitutes the most current survey of incidence, severity of TYLCV and whitely vector population on tomatoes in the three (3) Local Government Areas of Kebbi State. The survey was carried out in December- February 2021 in dry season farming. The study was designed to assess the incidence, symptom severity, and whitefly population in the study area. Disease Incidence was high in Aliero Local Government area (41.6%) compared to Jega

(38.67%) which was ranked second in terms of disease incidence, while Maiyama Local Government was the least (32.22%), this is in line with findings of (Lapidot and Friedmann, 2002). Whose eported that high disease incidence in their work. However, the lower symptom severity recorded in all locations visited during the survey work, Aliero showed high symptom severity with (1.8%) while Jega and Maiyama Local Government areas revealed1.61% and1.46% respectively. This could be attributed to the judicial use of pesticides by the farmers in the study area which may reduce vector population and minimize transmission of TYLVC.

Similarly, a high population of whitefly vector was recorded in Aliero Local Government area of Kebbi State with population of 8.18 Maiyama was ranked second with 5.26 while Jega recorded the lowest population (4.28). The higher whitefly population might be due to climatic conditions, and vector preferences of the crop in the surveyed area. These supported the earlier findings by Asiwe *et al.* (2002) Who reported that the whitefly population increased with favourable temperature and palatability of the crop. Similarly, the cultivation of different crop species that are vulnerable to whitefly attack and the frequent use of agrochemicals by the farmers in the Area could also contributes greatly to the high population of whiteflies in the study area. This was not in line with the finding of (Maruthi *et al.,* 2004) who reported that high temperature and nutritional quality of the host plant in the Area might have contributed to the success of the high mean whitefly population in the Area, further More, agronomic practices coupled with other climatic factors such as relative humidity could be the reason for low whitefly population.

## CONCLUSION

It is concluded that the effects of (TYLCVD) and whitely abundance coupled with their polyphagous feeding habits can seriously lead to the emergence of damage to the crops in the study area. However, farmers should adopt good agronomic practices such as regular weeding, and rouging of infected plants to reduce the menace caused by the vector. Therefore, developing an effective control of whitely that transmits (TYLCVD) is significant, so to minimize menace in the study Area. Furthermore, similar research should be conducted in other parts of the States to investigate the status of the TYLCVD and their vectors. These could provide more avenues to assure protection against economic losses.

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# RESPONSE OF SWEET POTATO (*Ipomoea batatas* L.) ECOTYPES TO SWEET POTATO LEAF CURL VIRUS (SPLCV) IN ALIERO, KEBBI STATE, NIGERIA

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**ABSTRACT**

Experiment was conducted to evaluate the response of sweet potato (*Ipomea batatas* L.) ecotypes to *Sweet potato leaf curl virus* (SPLCV) infection at the Screen House of Kebbi State University of Science and Technology Aliero, Nigeria during the 2020/2021 dry seasons. The treatments consisted of three ecotypes of *I. batatas* (Dangote, Dangoronyo, and Danmadakali) domiciled and commonly cultivated in Kebbi State. The experiment was laid out in Completely Randomized Design (CRD) with three (3) replications. A single diseased-free vine of 30 cm was used for each treatment during the transplanting. The transplanting was carried out in a plastic pot containing a well-drained clay-loam soil. The uppermost leaves of each sweet potato ecotypes were mechanically inoculated with SPLCV at 2 weeks after transplanting using Carborundum powder and cotton wool. Control plants (Plants inoculated with buffer alone served as controls) for each ecotypes were included. Data were collected at 2, 4 and 6 weeks after inoculation (WAI) on disease incidence and disease severity from sap-inoculated and control plants of each ecotype. The results showed that the ecotypes screened had *Sweet Sweet potato leaf curl* disease (SPLCD) incidence range of 77. 79 – 100 % at 6 WAI with ecotype Dangote having the highest (100 %) SPLCD. The SPLCD was found to be generally mild (2 out of 5 rating scale) across all the ecotypes screened, however, Dangote was shown to significantly (P≤0.05) have highest disease severity (2.88 %) at 6 WAI compared to the other ecotypes. The results of the present study could be of importance to breeder for possible improvement of sweet potato ecotypes against SPLCD for increased production. There is need to determine the effect of SPLCD on the yield of the potato ecotypes screened in the study area.

**Keywords:** Ecotypes, screening, sweet potato, Dangote

## INTRODUCTION

The sweet potato (*Ipomoea batatas* L.) is a dicotyledonous plant that belongs to the bindweed or morning glory family, Convolvulaceae. It's large, starchy, sweet-tasting with tuberous roots (Woolfe and Jennifer 1992). *Ipomoea batatas* is native to the tropical regions in the

Americas.The plant is an herbaceous perennial vine, bearing alternate heart-shaped or palmatelobed leaves and medium-sized sympetalous flowers **(**Liu and Chen 2018)**.** The edible tuberous root is long and tapered, with a smooth skin whose colour ranges between yellow, orange, red, brown, purple and beige. Its flesh ranges from beige through white, red, pink, violet, yellow, orange, and purple (Jiang and Huang, 2019**).** Sweet potato is the seventh most important food crop in the world in terms of production. They are grown on about 9 million hectares, yielding about 140 million tons; with an average yield of about 14 ton/ha Liu and Chen (2022)**.** They are mainly grown in developing countries, which account for over 95% of world output. Roughly 80% of the world's sweet potatoes are grown in Asia, about 15% in Africa, and only 5% in the rest of the world (IPC, 2022). The cultivated area of sweet potato in China, about 6.6 million ha, accounted for 70% of the total area of sweet potato cultivation in the world. China produces about 100 million tons, circa 70% of the total world production (FAO, 2023)**.** However, sweet potato yields are heavily reduced by viruses, which are carried from generation to generation through recycling of infected cuttings (Gibson and Kreuze, 2015). The most common viruses found infecting sweet potato in Africa are *Sweet potato feathery mottle virus* (SPFMV), *Sweet potato chlorotic stunt virus* (SPCSV) and *sweet potato leaf curl virus* (SPLCV) (Loebenstein, 2015), the combination of *potato feathery mottle virus* and *sweet potato chlorotic stunt virus* (SPCSV) or *Sweet potato leaf curl virus* (SPLCV) viruses have synergistic effect and cause *Sweet potato virus disease* (SPVD) which is the main 'virus disease' affecting the crop, often leading to 56–98% yield losses (Ndunguru *et al.,* 2009). In addition, a group of gemini viruses, collectively known as sweet potato viruses, is increasingly being recognized as damaging and common worldwide, including Africa (Rey *et al.,* 2012). Managing such a complex set of viruses is challenging, especially as many of them show no, or only minor transient symptoms when infecting sweet potato, making it difficult to identify infected plants (Valderde *et al.,* 2007).

There are three major alternatives in managing viruses in sweet potato: (i) deploying resistant cultivars, (ii) using clean (virus-tested) seed, and (iii) employing proper on-farm management practices. Deployment of resistant cultivars is viewed as the most effective strategy in Sweet potato virus disease management (Maule *et al.,* 2007). In this context, the term 'seed' refers to quality (virus-indexed) cuttings or storage roots that have been selected for use in generating new plants; Moreover, producing such planting material is expensive. Although this may work well in countries where sweet potato is grown as a cash crop and large-scale farmers can make the investments necessary to obtain such planting material, this has not been economically feasible for smallholder farmers producing mostly for subsistence. On-farm management strategies such as rogueing and positive selection for clean seed are therefore important. Rogueing is the removal of plants that have virus symptoms whereas positive selection is selection of vigorous healthy-looking plants as planting material/seed for the next season (Muturi *et al.,* 2007). The two approaches reduce virus inoculum and hence disease incidence.

Selection of planting material from symptomless plants has also been reported to reduce virus incidence (Aritua *et al.,* 2003). However, these methods require good farmer knowledge about disease identification. Alternatives that could enable farmers, or specialized local vine multipliers, to maintain a high sanitary status of planting material at low cost and minimum technical input exist. One such technology is a low-cost insect-proof net tunnel that can be constructed from locally sourced materials (Schulte-Geldermann*et al.,* 2012). This technology enables farmers to maintain a nuclear stock of high phytosanitary status vines, by protecting them against the virus vectors such as whiteflies and aphids (Loebenstein, 2015). Vines produced in the net tunnels can be harvested and used either directly, or after one or more cycles of field multiplication for root production and/or sale as quality planting material (Ogero *et al.,* 2015). However, it is important to know how well net tunnels perform in maintaining the phytosanitary status of sweet potato vines under farmer-multiplier management. In Nigeria, the virus occurrence is distributed in the Northern and South-Western States of the country where up to 30% yield reduction may occur if the infection is severe (Alegbejo, 2015). It is transmitted by whitefly (*Bemisia tabaci*).

Although over thirty (30) viruses were known to infect sweet potato worldwide, but few of these viruses (SPFMV, SPMMV, SPCSV and SPLCV) have been reported in Nigeria (Odu and Abang, 2022). These viruses are however, among those considered to be of major global economic importance to sweet potato production, therefore the economic concern to sweet potato farmers in Nigeria for better alternatives is paramount (Nwankiti and Idoko, 2021). There is a need for diagnosis of economically important viruses of sweet potato in the country as a prerequisite for their management; this could be done through the use of resistant varieties, management of the virus vectors and tactical manipulation of the routine cultural practices of sweet potato against viruses or their vectors. Hence, the objective of this study was to screen some ecotypes of sweet potato for resistance to *Sweet Potato Leaf Curl Virus* in Aliero, Kebbi State, Nigeria. This research work may provide base line information on resistant cultivars to SPLCV that could be harnessed by breeders for potato improvement against the menace cause by SPLCV on sweet potato production (Smith and Brown, 2020).

## MATERIALS AND METHODS

### Experimental Site

The experiment was conducted in dry season of 2020/2021 at Screen House of Kebbi State University of Science and Technology Aliero. Aliero is located at the (Latitude N $12^{0}18'17.6158''$ and Longtitude E $4^{0}29'37.188''$ Altitude: 268m) Oni, and Adebayo (2020) The climate of the area is characterized by the temperature ranging between March and May with annual temperature varying between 38 to 42ºC mostly with cold between late November and early February. The area lies in Sudan Savannah agro ecological zone of Nigeria with annual rainfall between 500mm to 850mm that support Agricultural activities **(**Peters and Nwankwoala, 2019)**.**

### Experimental Treatment, Design and Inoculation

The treatments consisted of three (3) sweet potato ecotypes (Dangote, Dangwaranyo and Danmadakali). The treatments were laid out in a Completely Randomized Design (CRD) with three replicates. Each replicate consisted of three plants of one ecotype giving a total number of nine plants in each replication. The healthy vines were identified and sourced from the local farmers around Gindi and Mayalo Villages of Jega and Mayama local government areas of Kebbi State respectively. The leaves of sweet potato infected with SPLCV were mechanically inoculated into the healthy sweet potato plants by the use of Carborundum powder and cotton wool to cause wound to the plants one week after transplanting. Solution of 0.6 M $K_2HPO_4$ was prepared by dissolving 10.45 g of $K_2HPO_4$ in 100 mL of sterile distilled water (SDW) while potassium phosphate buffer (Inoculation buffer) was prepared by mixing 80.2 mL of 0.6 M

$K_2HPO_4$ solution with 19.8 mL of 0.6 M $KH_2PO_4$ solution, this was diluted to a final volume of 1000 mL to obtain 0.06 M potassium phosphate buffer. Buffer pH was adjusted to 7.4 with HCl and autoclaved (Sambrook and Russell, 2001**).** The buffer was used to prepare virus inoculum for sap inoculation (Miller and Jansen, 2003**).** Sap-inoculation experiments were conducted mechanically and each treatment comprised of 9 plants for each ecotype giving a total number of 27 inoculated plants. Plants inoculated with buffer alone served as control. The inoculated plants were further observed for symptom development for at least one week before the data collection.

**Cultural Practices**

Diseased-free vine of about 30cm long was used for transplanting. The transplanting was carried out in a plastic pot containing a good well drained soil mixture. One vine was transplanted in each pot. Weeds were controlled by hand pulling subsequently; weeding was done regularly depending on the weed emergence **(**Davis, and Renner, 2007**).** Irrigation was done using Watering Can twice a week.

**Data Collection**

**Disease incidence**

Disease incidence was calculated according to the method developed by **(**Sseruwagi *et al.,* 2004)

$$\text{Disease Incidence (\%)} = \frac{\text{Number of plant with SPLCD}}{\text{Number of plant (control)}} \times 100$$

**Disease severity**

The severity status was assessed based on the severity scale of 1-5 developed by **(**Sseruwagi *et al.,* 2004)

**Where;**

1- Healthy/Symptomless
2-Mild
3-Severe
4-Very Severe
5-Extremly Severe

**Data Analysis**

Data obtained on incidence, symptom severity, mean whitefly population and sprouting ability were subjected to Analysis of variance (ANOVA) while mean was separated using Least Significance Difference (LSD) at 5% level of significance ($P \leq 0.05$).

**RESULTS AND DISCUSSION**

**Disease incidence (%) on sweet potato ecotypes after inoculation *with Sweet potato leaf curl virus***

All the three ecotypes screened were susceptible to SPLCV because they were infected when inoculated with the virus. There was significant difference ($P \leq 0.05$) among the three ecotypes screened for disease incidence due to SPLCV after inoculation (Table 1). Dangote ecotype recorded the highest disease incidence (77.78%) at two weeks after inoculation while, Dangoronyo and Danmadakali ecotypes obtained the lower and same mean disease incidence. Moreover, at 4 WAI, the results showed that Dangote ecotype obtained the higher mean disease incidence with (88.89%) followed by Dangoronyo (77.79 %) while Danmadakali recorded the lower disease incidence of (56.67%). At (3 WAI) Dangote recorded the highest mean disease incidence (100.00%) followed by Dangoronyo (77.80 %) and Danmadakali was ranked third (77.79 %). This is in line with the reports of Hedge *et al.* (2012) Who reported that, symptoms may appear seasonally and often disappear with time. The higher disease incidence observed on Dangote could be attributed to the susceptibility of the land races. This is in conformity with the findings of ICTVdB Management, (2006) that reported that various Ipomoea species were found to be susceptible to SPLCV in their studies.

**Table 1: Disease incidence (%) on sweet potato ecotypes after inoculation with *Sweet potato leaf curl virus* during the 2020/2021 dry season.**

| Ecotypes | Disease incidence (%) | | |
|---|---|---|---|
| | **2 WAI** | **4 WAI** | **6 WAI** |
| Dangote | 77.78[a] | 88.89[a] | 100.00[a] |
| Dangoronyo | 44.44[b] | 77.79[b] | 77.80[b] |
| Danmadakali | 44.44[b] | 56.67[c] | 77.79[b] |
| Control | 00.00 | 00.00 | 00.00 |
| **Sig.** | * | * | * |
| **LSD (P≤0.05)** | **38.45** | **64.76** | **31.37** |

**Mean values with the same letter(s) within a column are not significantly different at (P≤0.05). WAI= Weeks After Inoculation**

**Disease severity on sweet potato ecotypes after inoculation with *Sweet potato leaf curl virus***

The results in Table 2 showed the disease severity (%) on three potato ecotypes after inoculation with SPLCV. The results showed that there was no significant (P≤0.05)) difference among the potato ecotypes except at 6 WAI. At 6 WAI, Dangote had the highest disease severity (2.88 %) followed by Danmadakali (2.66 %) while the lowest disease severity of (2.33%) was recorded on Dangoronya.

**Table 2: Disease severity (%) on sweet potato ecotypes after inoculation with *Sweet potato leaf curl virus* during the 2020/2021 dry season**

| Ecotypes | Disease severity | | |
|---|---|---|---|
| | **2 WAI** | **4 WAI** | **6 WAI** |
| Dangote | 2.0 | 2.66 | 2.88[a] |
| Dangoronyo | 2.1 | 1.89 | 2.33[b] |
| Danmadakali | 1.67 | 2.22 | 2.66[ab] |
| Control | 00.00 | 0.00 | 0.00 |
| **Sig.** | **NS** | **NS** | * |
| **LSD 0.05** | **0.799** | **1.139** | **0.480** |

**Mean values with the same letter(s) within a column are not significantly different at (P≤0.05). WAI= Weeks After Inoculation**

**CONCLUSION**

The current research findings revealed that, all the ecotypes tested were susceptible to SPLCV infection, except for the Danmadakali ecotype which had some degree of resistance to SPLCV. Therefore, it could be concluded that, Danmadakali ecotype is recommended for the farmers for a better production in the study area coupled with the field sanitation and good agronomic practices which serves as strategies in battling the vector responsible for the transmission of SPLCV.

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# GROWTH AND YIELD RESPONSE OF COWPEA (*Vigna unguiculata* (L.) Walp) UNDER DIFFERENT WEEDING REGIME AND SPACING

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## ABSTRACT
Cowpea (*Vigna unguiculata)* is one of the oldest crops known to man, and it's produced in a variety of climate zones, most notably in Sub-Saharan Africa's arid savanna regions. A field trial was conducted in 2019 cropping season at the Teaching and Research Farm of the Federal University of Technology, Gidan Kwano campus to investigate the key period for weed interference and spacing on cowpea for optimum yield. The treatments T1= cowpea + spacing (30cm) no weeding, T2= cowpea + spacing(30cm) + weedy for 3 weeks, T3= cowpea + spacing (30cm) + weedy for 6 weeks, T4= cowpea + spacing (30cm) + weedy for 9 weeks, T5= cowpea + spacing (30cm) + weedy for 12 weeks, T6= cowpea + spacing (30cm) + weed free 0-12 weeks, T7= cowpea + spacing (35cm) + no weeding, T8= cowpea + spacing(35cm) + weedy for 3 weeks, T9= cowpea + spacing (35cm) + weedy for 6 weeks, T10= cowpea + spacing (35cm) + weedy for 9 weeks, T11= cowpea + spacing (35cm) + weedy for 12 weeks, T12= cowpea + spacing (35cm) + weed free 0-12 weeks. The treatments were laid out in a Randomized Complete Block Design (RCBD) replicated three times. There are twelve treatments including weeding and weed-free, with two spacing of 30cm and 35cm intra-row and 75cm inter-row. plot size of 3m x 4m. The treatments were separated by 1.0 m inter-plot and each replication was separated by discard of two ridges. The data collected on various parameters were subjected to analysis of variance (ANOVA) using statistical package (SAS, 2008) and means were separated using Duncan multiple range test (DMRT) at 5% level of probability. The result obtained showed that treatments with 30 cm spacing and weed free 0–12 weeks plot and 35 cm spacing weed free 0–12 weeks' plot have a great potential for better cowpea growth and higher yield.
**Keywords**: Cowpea, Weeding Regime, Spacing and Yield

## INTRODUCTION
The cowpea (*Vigna unguiculata*) was domesticated in Africa, most likely in Ethiopia's northwestern corner (Larry *et al*., 2015). Cowpea (*Vigna unguiculata*) is one of the oldest crops known to man, more than 5.59 million tons of dried cowpeas are produced on 12.61 million ha worldwide, with sub Saharan Africa producing nearly 5.3 million tons with West Africa producing over 84% of the production (FAOSTAT, 2017). It is produced in a variety of climate zones, most notably in Sub-Saharan Africa's arid savanna regions (Singh *et al*., 2016). It is one of the most preferred crops and a valuable component in the farming systems of the majority of resource poor rural households in sub-Saharan Africa for its various attribute. It is also known as southern pea, black eye pea, Crowder pea, lubia, niebe, coupe or frijole. About 6.5 million metric tons of cowpea is being produced annually on about 14.5 million hectares worldwide (Boukar *et al*., 2018). Weeds are a big stumbling block to crop development around the world. The yield losses caused by weeds alone in cowpea production can range from 25% to 76 percent, depending on the cultivar and area (Gupta *et al*., 2016). Weed difficulties in cowpea production

include decreased crop yield, inefficient land use, greater production costs due to pest and plant disease treatment, lower crop quality, water management issues, and ineffective labor utilization (Singh *et al*., 2016). The influence of crop row spacing required to achieve optimum yield in cowpea is still poorly understood. Plant spacing is one of the important factors of crop production, because appropriate spacing of crops makes for efficient use of space and reduction of competition among plants with the same cultural requirements. Closer crop spacing suppresses weed growth and increases crop yield, when compared to wider spacing. However, information on the use of proper spacing in controlling weed growth and enhancing cowpea performance is limited (Osipitan *et al*., 2013). In cowpea, hoe weeding is the most used physical weed management method. According to reports, two timely hand weeding within the first 30 to 40 days after emergence are required to reduce weed competition in cowpea (Osipitan *et al*., 2013). This reseach was carried out to know the best time weed before competition and best space to give the best ground cover to shade out the weed and reduce the growth.

## MATERIALS AND METHODS

A field trial was conducted in 2019 cropping season at the Teaching and Research Farm of the Federal University of Technology, Gidan Kwano Campus Minna, Niger State, located in the Southern Guinea Savannah Agro-ecological Zone of Nigeria. The treatments T1= cowpea + spacing (30cm) no weeding, T2= cowpea + spacing(30cm) + weedy for 3 weeks, T3= cowpea + spacing (30cm) + weedy for 6 weeks, T4= cowpea + spacing (30cm) + weedy for 9 weeks, T5= cowpea + spacing (30cm) + weedy for 12 weeks, T6= cowpea + spacing (30cm) + weed free 0-12 weeks, T7= cowpea + spacing (35cm) + no weeding, T8= cowpea + spacing(35cm) + weedy for 3 weeks, T9= cowpea + spacing (35cm) + weedy for 6 weeks, T10= cowpea + spacing (35cm) + weedy for 9 weeks, T11= cowpea + spacing (35cm) + weedy for 12 weeks, T12= cowpea + spacing (35cm) + weed free 0-12 weeks. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. There were twelve treatments including weeding and weed-free, with two spacing of 30cm and 35cm intra-row and 75cm inter-row. plot size of 3m x 4m. The treatments were separated by 1.0m inter-plot and each replication was separated by discard of two ridges. Cowpea seeds were manually sowed at two seeds per hole, at 30 cm or 35 cm intra row spacing, according to treatments.

Thinning was done at two weeks after sowing, to one seed per hill. Manual weeding with a hoe was done according to treatments planned. Lambda-cyhalothrin 2.5%EC was applied at the rate of 10ml mixed with 10 litres of water and sprayed using knapsack at 3 WAS liquid Fertilizer was applied at the rate of 28.0% Nitrogen, 11% (P2O5) and 14.2% (K2O),0.08% Mixed with 10litres of water per 10ml of the fertilizer was applied by spraying using knapsack (5 cm away from the plant stand) at 3 WAS. Cowpea pods were hand collected and sun dried from each treatment plot. When 90% of the pods in the plots had changed from green to straw. Data were collected on Weed fresh weight, Weed dry weight, Plant height, Number of days to 50% flowering, and Grain yield. Samples of fresh weed were taken from a 50cm quadrant thrown in each net plot prior to each weeding operation at 2, 4 and 6 WAS. The weed samples were weighed to obtain the fresh weight, oven dried at 700c to a constant weight and weighed to obtain dry matter content (grams per m-3). Plant height of randomly selecting and tagged five plants each plot was measured using measuring tape from the ground levels to the apex of the flag leaf at.2, 4, and 6 weeks following seeding, Number of days to flowering by visual observation of cowpea was recorded from the date of seeding until when 50% of the cowpea plants had flower, then calculated. Number of pod per plant was manually counted and recorded from each treatment Cowpea grain yield from each plot after shelling and winnowing were weighed with a meter balance and expressed in gram (g). The data collected were subjected to analysis of variance (ANOVA) using statistical package (SAS, 2008) and means was partitioned using Duncan multiple range test (DMRT) at 5% level of probability

## RESULTS

### Effect of different weeding regime and spacing on weed fresh and dry weight

Treatment with cowpea spacing(30cm) and weedy ( weed infested) for 9 weeks has the heaviest weed fresh weight (71.80g) compared to Treatment with cowpea spacing(30cm) and weed free 0-12 weeks which had the lightest weed fresh weight (10.40g) at 2 WAS (Table 1) Similarly, Treatment with cowpea spacing (35cm) and weedy for 12 weeks had heaviest weed fresh weight (86.16g) compared to the lightest weed fresh weight recorded on Treatment with cowpea spacing (30cm) and weed free 0-12 weeks (14.60g). Treatments at 6 WAS showed similar trend with Treatments at 2 WAS (Table 1). Weed dry weight at 2WAS shows treatment with cowpea spacing (35cm) and weedy for 6 weeks had the highest weed dry weight (42.77g) while treatment with cowpea spacing (35cm) and weed free 0-12 gave the lowest weed dry eight (4.88g), Similar results was seen at 4 and 6 WAS (Table 1). Effect of growth and yield response of cowpea under different weeding regime and spacing on Plant height and Number of days to 50% flowering.

Plant heights at 4 WAS showed Treatment with cowpea spacing (30cm) and weed-free for 12 weeks had the highest height plant height (37.76 cm) while Treatment with cowpea spacing (30cm) and weedy recorded the lowest plant height (27.13cm) (Table 2). Similar trend was recorded at 6 WAS. In days to 50% flowering, cowpea spacing (30cm) and weedy for 12 weeks had the longest number of day to flowering (56.66) compared to the shortest seen in Treatment with cowpea spacing (30cm and 35cm) and weed free 0-12 weeks (42.66, 43.00 respectively) (Table 2).

### Effect of growth and yield response of cowpea under different weeding regime and spacing on grain yield

Treatment with cowpea and spacing (30cm and 35cm) with weed free 0-12 weeks produced the highest grain yield (861.61g and 898.88g respectively) compared to the lowest yield seen in treatment with cowpea and spacing (35cm) with no weeding (weed infested) (200.11g) (Table 3)

## DISCUSSION

The reduced weed fresh weight found in treatments with cowpea (30cm) spacing and weed free 0-12 weeks could be due to the treatments' ability to reduce weed population on the field. This is in accordance with Parasuraman (2000), who stated that hand weeding at 30 DAS resulted in significant reduction in weed population and weed dry matter and increase in crop yield in rain-fed cowpea. The taller plant height observed in treatments with cowpea (30cm and 35cm) spacing and weed free 0-12 weeks could be due to reduction of weed-crop competition which translated to taller plant height, this is in agreement with the finding of Ofunsun-Anim and Limani (2007), reported that provided weeds were subsequently removed, infestation for the first 3WAS did not have adverse effects on the growth and yield of crops.

The increased grain yield observed in treatment with cowpea (30cm and 35cm) spacing and weed free 0-12 weeks could be due to lower weed weight, taller plant heights all of which contributed to achieving a better yield due to the treatment's ability to reduce the detrimental effect of weed competition on the plant, according to Adigun et al (2014), extended competition between crops and weeds can result in poorer yields.

**CONCLUSION**

Plant height, 50% days to flowering and yield components of cowpea cultivated under various weeding regimes exhibited substantial variation in the results of this experiment. Treatments with 30cmand 35cm spacing and weed free 0–12 weeks' plots have great potential for good growth and higher yield.

**RECOMMENDATION**

For better yield and yield increase, treatments with 30cmand 35cm spacing and weed free 0 - 12 weeks could be used by farmers

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Table 1: Effect of weeding regime and spacing on weed fresh weight and weed dry weight.

| | weed fresh weight (g) | | | weed dry weight (g) | | |
|---|---|---|---|---|---|---|
| Treatment | 2WAS | 4WAS | 6WAS | 2WAS | 4WAS | 6WAS |
| T1-C+P1W0 | 60.71ab | 69.52ab | 96.29a | 31.63ab | 37.05b | 28.38d |
| T2-C+P1W3 | 50.78ab | 72.02a | 47.45b | 24.90ab | 36.39b | 21.20e |
| T3-C+P1W6 | 45.18b | 66.25ab | 98.76a | 20.07b | 32.29b | 27.43d |
| T4-C+P1W9 | 71.80a | 65.39ab | 118.42a | 35.54ab | 29.07b | 7.65g |
| T5-C+P1W12 | 65.28ab | 71.98a | 98.92a | 31.42ab | 35.00b | 42.29c |
| T6-C+P1Wo-W12 | 10.40c | 14.60c | 11.00c | 6.00c | 8.11c | 2.60h |
| T7-C+P2Wo | 59.87ab | 58.26ab | 125.37a | 21.10b | 29.09b | 21.11e |
| T8-C+P2W3 | 50.93ab | 39.40b | 43.21b | 26.42ab | 19.88bc | 14.53f |
| T9-C+P2W6 | 62.12ab | 77.11a | 108.84a | 42.77a | 40.06b | 5.75gh |
| T10-C+P2W9 | 60.46ab | 65.15ab | 100.02a | 31.41ab | 33.19b | 50.14b |
| T11-C+P2W12 | 67.31a | 86.16a | 108.19a | 31.41ab | 62.29a | 56.76a |
| T12-C+P2Wo-12 | 14.80c | 18.13c | 15.00c | 4.88c | 4.63c | 3.24h |
| S.E | 4.21 | 5.10 | 7.60 | 2.59 | 3.22 | 3.11 |

Means having the same letter in a column are not significantly different at P<0.05 level of probability.
Wo =No weeding (weed infested), P1= 30cm spacing, C=cowpea, Wo-12=weeding from week0-week12, P=35cm spacing, WAS = weeks after sowing.

Table 2: Effect of weeding regime and spacing on Days to 50% flowering and plant height per plot

| | Days to 50% flowering | Plant height (cm) | | |
|---|---|---|---|---|
| Treatment | | 2WAS | 4WAS | 6WAS |
| T1-C+P1Wo | 55.33a | 19.93a | 27.13c | 35.60d |
| T2-C+P1W3 | 48.33b | 20.50a | 32.66ab | 58.67a |
| T3-C+P1W6 | 52.33ab | 20.73a | 31.83bc | 43.00 |
| T4-C+P1W9 | 56.00a | 19.30a | 33.76ab | 43.68bc |
| T5-C+P1W12 | 56.66a | 20.90a | 34.50ab | 41.20cd |

| | | | | |
|---|---|---|---|---|
| T6-C+P1Wo-W12 | 42.66c | 20.60a | 37.76a | 63.92a |
| T7-C+P2Wo | 51.00ab | 20.66a | 34.43ab | 41.52cd |
| T8-C+P2W3 | 51.33ab | 20.10a | 33.30ab | 50.66b |
| T9-C+P2W6 | 50.66ab | 19.90a | 33.46ab | 45.77bc |
| T10-C+P2W9 | 55.00a | 19.98a | 32.00ab | 44.63bc |
| T11-C+P2W12 | 56.35a | 19.1a | 34.33ab | 39.40cd |
| T12-C+P2Wo-12 | 43.00c | 20.80a | 35.50ab | 64.30a |
| S.E | 0.89 | NS | 0.56 | 1.65 |

Means having the same letter in a column are not significantly different at P<0.05 level of probability.
Wo =No weeding (weed infested), P1= 30cm spacing, C=cowpea, Wo-12=weeding from week0-week12, P=35cm spacing, WAS = weeks after sowing.

Table 3: Effect of weeding regime and spacing on grain yield

| TREATMENT | Grain yield (g) |
|---|---|
| T1-C+P1W0 | 242.74ef |
| T2-C+P1W3 | 553.16b |
| T3-C+P1W6 | 418.90c |
| T4-C+P1W9 | 378.25c |
| T5-C+P1W12 | 280.61de |
| T6-C+P1Wo-W12 | 861.61a |
| T7-C+P2Wo | 200.11f |
| T8-C+P2W3 | 580.74b |
| T9-C+P2W6 | 403.01c |
| T10-C+P2W9 | 306.89d |
| T11-C+P2W12 | 273.51de |
| T12-C+P2Wo-12 | 898.88a |
| SE | 37.75 |

Means having the same letter in a column are not significantly different at P<0.05 level of probability.
Wo =No weeding (weed infested), P1= 30cm spacing, C=cowpea, Wo-12=weeding from week0-week12, P=35cm spacing, WAS = weeks after sowing.

# PROPELLER PERFORMANCE AND DOWNWASH CHARACTERISTICS OF AGRICULTURAL DRONES

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## ABSTRACT
Agricultural drones, especially multi-rotors, have revolutionized precision agriculture by providing efficient solutions for crop monitoring, pesticide application, and data collection. However, most research has focused on outdoor environments, leaving a knowledge gap regarding their performance in controlled indoor settings. This study aims to analyze the radial speeds of a 16L agricultural hexacopter in the field under varying payloads (0-16 kg) and forward speeds (2-6 m/s), and then test the downwash characteristics under laboratory conditions. Results indicate that radial speed increases with both payload and speed, highlighting the need for optimizing payload to improve drone performance and stability. Downwash distribution, a critical factor for uniform pesticide and fertilizer application, is also influenced by these variables. The downwash is concentrated near the propellers, with a near-zero downwash region directly below the UAS, providing insights into optimal spraying distances. These findings are essential for the design and programming of agricultural drones, offering guidance on achieving more efficient material distribution while minimizing oversaturation and under-coverage in field applications. The results contribute to improving the overall stability, efficiency, and performance of agricultural drones, advancing the development of reliable technologies for sustainable agricultural practices.
**Keywords:** Agricultural drones, downwash distribution, payload optimization, precision agriculture, UAS stability.

## INTRODUCTION
Agricultural drones, particularly multi-rotors, have emerged as transformative tools in modern precision agriculture, offering innovative solutions for monitoring crop health, applying pesticides and fertilizers, and collecting field data efficiently (Zhang & Kovacs, 2012; Torres-Sánchez et al., 2018; Gulak, 2024). Despite their growing adoption, most research has focused on outdoor applications, leaving a knowledge gap regarding their performance and optimization in enclosed environments such as laboratories. Controlled indoor testing provides a unique opportunity to evaluate critical performance metrics, including propeller speed and downwash distribution, without the variability introduced by outdoor conditions.

Programming drones for safe and precise operation indoors is a significant challenge. Indoor environments demand finer control due to constrained maneuverability, the absence of GPS navigation, and airflow disturbances from confined spaces (Pérez et al., 2019; Sandamini et al., 2023). These challenges are especially pronounced for heavier agricultural drones like the 16L hexacopter, where instability could lead to safety risks (Salamí et al., 2014; Velusamy et al., 2022; Alhafnawi et al., 2023). Gathering data on propeller radial speeds under various payloads and forward speeds enables better motor response calibration, ensuring stable flight. Such

insights are essential for programming drones to adapt effectively to varying operational demands in precision agriculture (Borges, 2015; Scanavino, 2021).
A key focus of this research is analyzing the average downwash distribution of the hexacopter, which is crucial for ensuring uniform application of agrochemicals. Downwash, the airflow generated by propellers, affects how pesticides or fertilizers are delivered to crops (Potts, 1959; Ismail et al., 2020; Shouji et al., 2021; Li, & Wu, 2024). Uneven distribution can lead to crop damage from overdosing or ineffective treatment due to underdosing (Courshee, 1967; Asogwa, & Dongo, 2009; Taseer, & Han, 2024). By studying downwash distribution under different payload and speed conditions in a controlled environment, this research provides valuable insights for optimizing drone performance and coverage uniformity, directly benefiting field applications (Nahiyoon et al., 2024; Byers et al., 2024).

This study aimed to develop a methodology for evaluating the propeller radial speeds and downwash distribution of a 16L agricultural hexacopter under varying payloads and forward speeds in a laboratory setting. By addressing these challenges, this research seeks to enhance the stability, efficiency, and overall performance of agricultural drones. The findings will contribute to the development of more reliable and effective drone technologies for precision agriculture, advancing sustainable practices and providing a framework for future research in drone-based agricultural systems (Puri et al., 2017; Singh, & Sharma, 2022).

## MATERIALS AND METHODS

### Test Site

The tests were performed both in the field and in the laboratory. The drone propeller parameters were tested outdoors at the Universiti Putra Malaysia Southern campus testing field, adjacent to the gymnasium. This level of grassland measures approximately 50x50 meters, with grass pile buffers at both ends. The drone's downwash study was conducted at the Indoor Drone Testing Lab within the Faculty of Engineering at Universiti Putra Malaysia (UPM). This semi-enclosed facility measures 24x10x5 meters and was equipped with an overhead rail track that guides and moves the height-adjustable Unmanned Aerial System (UAS). The UAS hanger can be lowered from a height of 3.5 meters using additional 1-meter frames. The rail track spans 23 meters and was 4.5 meters above the ground. The centrally located test area measures 6x6 meters and can be raised in 0.5-meter increments, up to a maximum of 3.5 meters above the ground.

### Downwash Pressure Generator - The UAS

The Oryctes 16L agricultural drone (Poladrone Solutions Sdn Bhd, Cyberjaya, Selangor) was used for downwash testing. Its key features are listed in Table 1. It was a 16 kg payload capacity hexacopter designed for spraying. Figure 1 shows the drone and the comparative positions of the propellers and wheelbase. The six propellers are evenly spaced, the wheelbase is the diameter, and the drone's center is where the arms meet. The wheelbase stretches 1600 mm, propellers have a 780 mm diameter, and the arm angle is 60°.

### Downwash Pressure Sensor System

A pressure sensor system was used to measure UAS downwash based on Bernoulli's principle. It includes 16 PT60 pitot tube airspeed sensors, a CD74HC4067 multiplexer, an Arduino Nano, a DS3231 RTC clock module, an SD card module, and a power source. Each PT60 pitot tube has ports for dynamic and static pressure. The MPXV7002DP module converts airflow into voltage variations, processed by the Arduino to calculate velocity or differential pressure. The Arduino reads data from up to 16 channels via the multiplexer, converts it to pressure using a calibration formula, and logs it to the SD card with timestamps from the RTC. The sensors, spaced 0.2 m apart, are mounted on a metallic bar with a control box for SD card access. This setup is suitable for continuous data logging in environmental monitoring or process control, as shown in Figure 2.

**Table 1:** Drone specifications for downwash pressure analysis

| Item No. | Parameters | Value |
|---|---|---|
| 1 | Drone model ID | ORY001 |
| 2 | Extended dimension | 2364.6 x 2144.6 x 556 mm |
| 3 | Maximum tank capacity | 16 L |
| 4 | Max take-off weight | 35.5 kg |
| | ***Propulsion System-ESC/Motor*** | |
| 5 | Load/Rotor | 5-7 kg |
| 6 | Max. Thrust | 15.3 kg/rotor |
| 7 | Stator Size | 81*20 mm |
| 8 | KV value or rating | 100 KV |
| | ***Propulsion System-Foldable Propellers*** | |
| 9 | Propeller model no | R3390 |
| | Diameter x thread pitch | 29 x 11 inches |
| 10 | Weight (per propeller) | 180 g |
| 11 | Material | Plastic |


**Figure 1:** The Oryctes 16L drone, its propeller layout and sizing

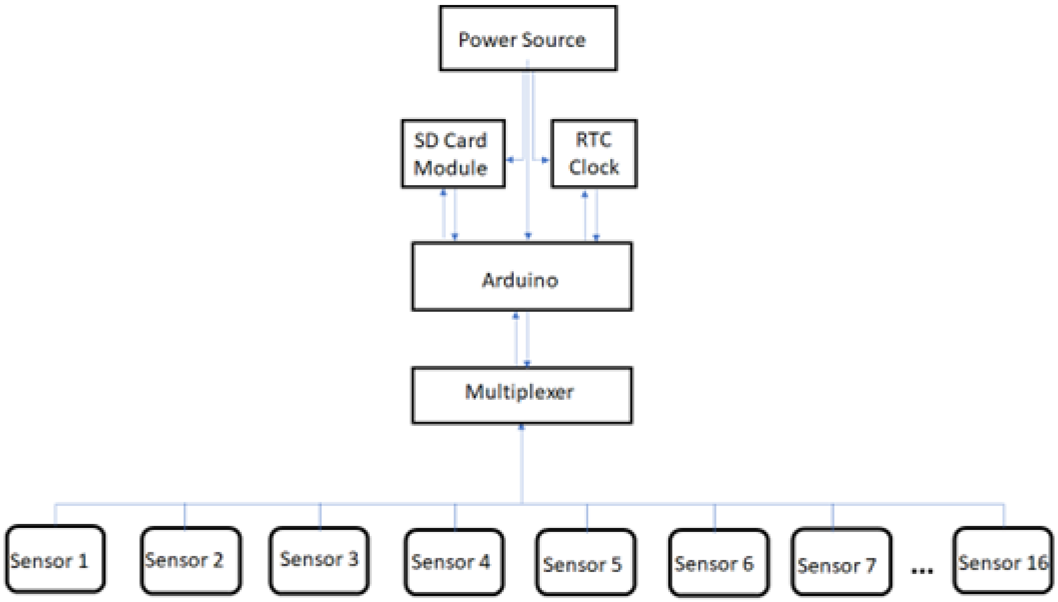


**Figure 2:** Schematic of the pressure sensor system

**Determination of Propeller Speed based on Forward Speed and Payload**

This test was instrumental in coding the UAS for indoor use and testing. The test was conducted in the field where Payload (0, 4, 8, 12, and 16 kg) and Forward speed (2, 4, and 6 m/s) were used to determine the radial speed of each propeller while on flight mission. Each test involves take off and landing of the UAS over a field length of 100m, at a travel height of 3 m. Data were computed and collated using a Python program. Each test was replicated thrice.

**Determination of Downwash Formation in Static UAS Conditions**

A grid point distribution method, illustrated in Figure 3, was employed to collect downwash data within a 0.2 x 0.2 m matrix across a test area of 3 x 4 meters, resulting in 336 measurement points. Due to sensor limitations, the downwash sensor system was repositioned stepwise after each localized data collection. The UAS operated for approximately 180 seconds, with downwash data recorded using the developed pressure sensor system. The test was conducted at a drone height of 3.5 meters above the ground, with a fixed payload of 8 kg and a speed of 2 m/s. Pressure data was collected 1.0 meters above the ground to simulate the average height of rice plants and similar crops.

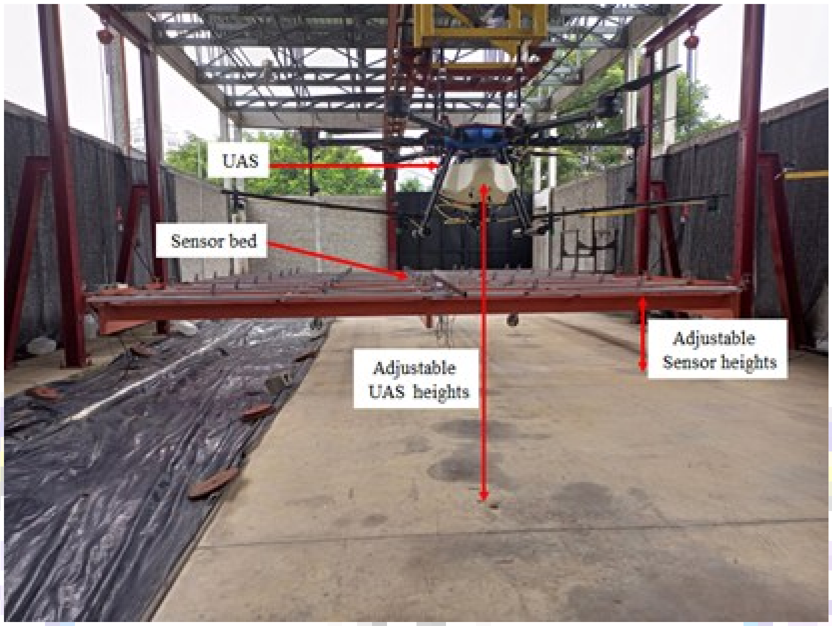


**Figure 3:** Setup of test facility

**Analysis of Collected Data**

Propeller and pressure sensor data were collected based on sensor IDs, time intervals, and line locations. Outliers were removed, and averages were calculated. Data analysis, including descriptive statistics, normality tests, ANOVA, and regression, was performed using Microsoft Excel, SigmaPlot 14.0, and Origin software, enabling the creation of graphs and a 3D heatmap.

**RESULTS AND DISCUSSION**

Radial Speed Analysis of Propellers Under Varying Payloads and Speeds

Table 2 shows the radial speeds (rpm) of six propellers (M1 to M6) under different payloads (0–16 kg) and speeds (2, 4, and 6 m/s). Radial speed increases with both payload and speed, indicating higher rotational demands for maintaining lift. For example, M1's speed rises from 1477 rpm at 0 kg and 2 m/s to 1642 rpm at 16 kg and 2 m/s. Propellers M2 and M4 consistently have higher mean speeds, while standard deviation analysis reveals variability in speed consistency. Notably, M1 at 16 kg and 6 m/s shows greater fluctuations (±13.69 rpm), indicating potential performance differences.

ANOVA results (Table 3) confirm that payload significantly affects the average radial speed ($p < 0.0001$), while forward speed does not ($p = 0.559$). Forward speed is influenced by the variation between the fore and rear propellers' radial speeds in rpm. The larger the variation, the greater the forward speed and pitch. The non-significant interaction between payload and speed ($p = 0.691$) simplifies programming, as payload adjustments do not require simultaneous speed considerations. These findings emphasize optimizing payload for efficient drone performance and stability. These findings align with prior research. Rutherford et al. (1991) demonstrated that heavier payloads demand higher rotational speeds. Similarly, Brindejonc et al. (2007) found that pitch increases in tandem with propeller radial speed. Yeo (2019) and Yeo & Johnson (2007) observed that achieving optimal rotor speed is essential for efficient high-speed cruise flight, reinforcing the need for precise control of rotational dynamics to maximize performance.

**Table 2.** Radial Speed of Propellers at Various Payloads and Speeds

| Payload (kg) | Speed (m/s) | N | Radial Speed of Propeller (rpm) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | M1 | M2 | M3 | M4 | M5 | M6 |
| 0 | 2 | 60 | 1478+59.24 | 1419+68.49 | 1465+68.87 | 1421+113.0 | 1359+108.5 | 1510+92.67 |
| | 4 | 60 | 1471+8.62 | 1526+7.47 | 1430+8.98 | 1559+7.18 | 1486+8.20 | 1512+7.28 |
| | 6 | 60 | 1464+7.03 | 1531+7.49 | 1418+8.21 | 1567+5.89 | 1490+6.96 | 1507+7.05 |
| 4 | 2 | 60 | 1538+9.00 | 1586+5.77 | 1494+12.79 | 1623+6.40 | 1551+5.92 | 1574+7.35 |
| | 4 | 60 | 1516+7.56 | 1586+5.38 | 1468+11.15 | 1624+6.56 | 1542+8.26 | 1561+9.21 |
| | 6 | 60 | 1519+12.03 | 1574+7.66 | 1466+11.87 | 1618+7.45 | 1539+9.34 | 1556+9.75 |
| 8 | 2 | 60 | 1563+8.90 | 1606+7.56 | 1529+8.58 | 1636+8.31 | 1581+8.06 | 1589+7.68 |
| | 4 | 60 | 1565+10.40 | 1614+6.40 | 1517+10.08 | 1655+6.59 | 1578+8.50 | 1602+7.96 |
| | 6 | 60 | 1565+6.75 | 1624+7.17 | 1516+9.80 | 1664+8.26 | 1586+9.56 | 1604+9.14 |
| 12 | 2 | 60 | 1623+10.80 | 1685+8.13 | 1591+13.14 | 1713+9.24 | 1658+10.76 | 1651+11.79 |
| | 4 | 60 | 1630+11.97 | 1678+12.90 | 1582+15.06 | 1719+15.91 | 1648+18.65 | 1661+12.72 |
| | 6 | 60 | 1593+13.04 | 1681+10.08 | 1545+16.20 | 1719+12.05 | 1637+13.72 | 1639+13.74 |
| 16 | 2 | 60 | 1642+10.50 | 1682+8.87 | 1617+18.03 | 1704+15.28 | 1656+11.83 | 1668+10.90 |
| | 4 | 60 | 1657+8.38 | 1699+7.14 | 1619+20.44 | 1732+16.56 | 1666+14.92 | 1690+13.47 |
| | 6 | 60 | 1648+13.69 | 1721+10.04 | 1595+26.88 | 1765+20.98 | 1680+17.90 | 1691+16.93 |

**Table 3.** ANOVA for the Speed and Payload on Radial speed

| SoV | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Payload | 4 | 435,844.29 | 108,961.07 | 46.7 | 0.0001** |
| Speed | 2 | 2,736.69 | 1,368.34 | 0.59 | 0.559$^{NS}$ |
| Payload x Speed | 8 | 13,057.64 | 1,632.21 | 0.7 | 0.691$^{NS}$ |
| Error | 75 | 174,991.83 | 2,333.22 | | |
| Toral | 89 | 626,630.45 | | | |

**= Highly significant, $^{NS}$=not significant

**Downwash Formation in Static UAS Conditions**

Hovering involves maintaining a fixed position in the air during UAS operations. Figure 4 illustrates the downwash generated from a height of 3.5 meters. Pressure measurements range from -10 to 50 Pa, with most airflow concentrated within a 2-meter radius. The results show that downwash formation occurs within the UAS's physical spread, with pressure concentrated near the propellers and dissipating outward. A region of nearly zero downwash exists directly below the mid-section of the UAS, referred to by Tang et al. (2023) as the "negative velocity channel." This stable downwash area aligns with the concept of an optimal spraying distance, crucial for determining appropriate crop-to-system intervals during operations like spraying, as noted by Zhu et al. (2022). This pattern of downwash distribution is critical for agricultural applications such as pesticide spraying or fertilizer application. The uniformity and intensity of the pressure can affect the coverage and penetration of materials (Lochan et al., 2024). The observed central peak indicates the potential for oversaturation directly beneath the drone, while lower pressures at the edges suggest the possibility of under-coverage. These insights can inform the optimization of drone height and speed for even and efficient material distribution.

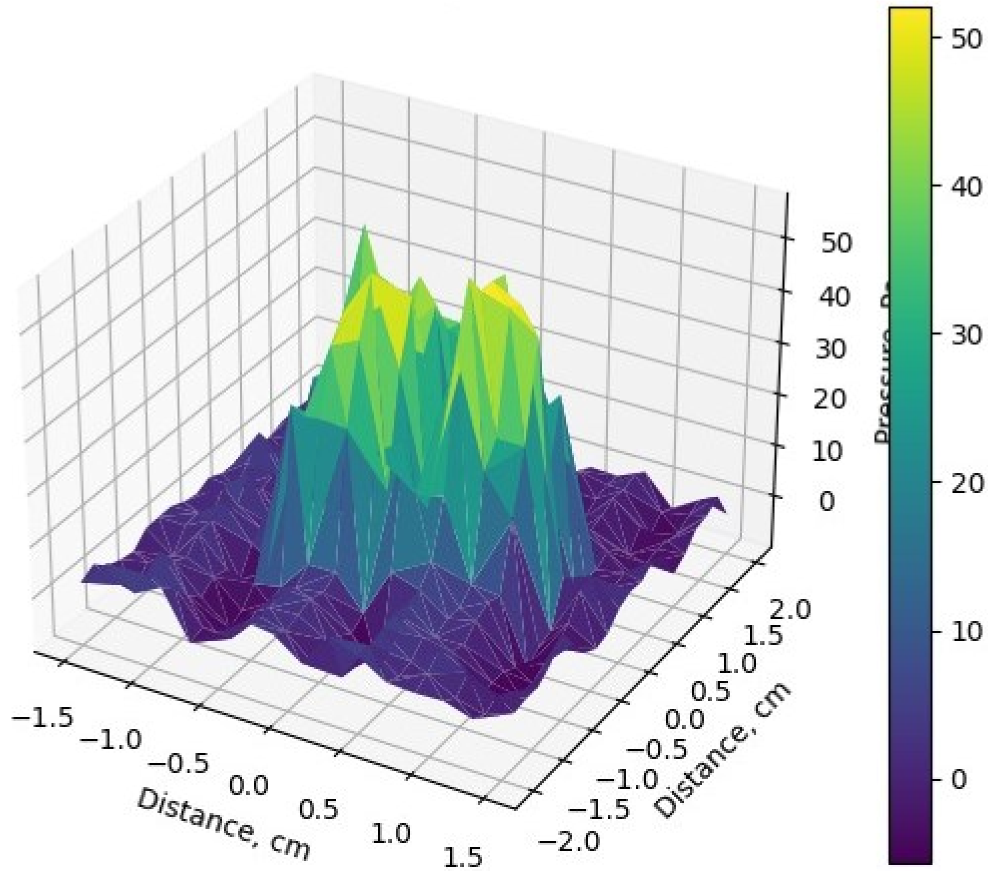


**Figure 4.** 3D plot of downwash pressure from a UAS hovering at a height of 3.5m

## CONCLUSION

The analysis of radial speeds for six propellers (M1 to M6) under varying payloads and speeds reveals that radial speed increases with both factors, indicating higher rotational demands for maintaining lift. This emphasizes the need to optimize payload for efficient drone performance, with a simplified programming approach since adjustments to one factor do not affect the other. The study also highlights the importance of downwash distribution, with pressure concentrated near the propellers and a near-zero downwash area beneath the UAS. This stable downwash region is crucial for optimizing spraying distances and minimizing oversaturation in agricultural applications like pesticide and fertilizer distribution. The findings contribute to improving UAS design and operational efficiency, with practical implications for stability, material distribution, and performance in precision agriculture.

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# GROWTH AND AESTHETIC CHARACTERISTIC OF QUEEN OF THE NIGHT (*Mussaenda philipica*) AND BOUGAINVILLEA *(Bougainvillea spectabolus)* AS INFLUENCED BY DIPPING DURATION IN HORMONE

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## ABSTRACT

A field experiment was carried out at the Horticultural Nursery of the Department of Crop Production, Federal University of Technology Minna, Niger State situated in the Southern Guinea savannah of Nigeria on a Latitude 6º30'E and Longitude 9º40'N during the rainy season of 2023. The treatments were two different types of ornamentals (Mussaenda philipica and Bougainvillea spectabilis) and varying dipping durations of (0, 10, 20, and 30 minutes) in Indole-3-butyric acid (IBA) thus making it a 2 x 4 factorial experiment fitted into a completely randomised design (CRD) with three replications. Data were collected on the number of leaves, plant height, leaf area, and number of flowers, data collected was subjected to analysis of variance (ANOVA) using Genstat 12.0 version, and treatment means were separated using least significant difference (LSD) at 5 % level of probability. Results obtained showed that growth hormone had a significant ($p \leq 0.05$) effect on the number of leaves, plant height, leaf area, and number of flowers with the queen of the night having higher growth performance than bougainvillea (18.9, 16.21 cm, 9.69 cm2, and 5.7) and (14.2, 12.06 cm, 6.51 cm2, and 3.8), for the two ornamentals respectively. Dipping duration was significant for the parameters measured throughout the research period with cuttings dipped for 30 minutes having the highest (18.5, 20.35 cm,7.95 cm2, and 6.1) growth performance irrespective of the type of ornamental plant used during the period of the research work. This was closely followed by cuttings dipped for 20 minutes (16.4, 6.68 cm2 and 17.68 cm, 6.1), respectively for the number of leaves, plant height, leaf area, and number of flowers. It could be therefore concluded that the use of hormones stimulates the growth of the two ornamentals and the 30-minute dipping duration of the cuttings in the hormone holds promises to enhance the optimum growth and prompt propagation of the ornamentals

**Keywords**: Mussaenda phillipica, Bougainvillea spectabilis, Indole-3-butyric acid (IBA), dipping durations

## INTRODUCTION

Flowers are not only admired for their beauty but also hold a special place in horticulture, as they are key components of gardens, landscapes, and indoor ornamental displays. Among the wide variety of flowering plants, the Queen of the Night (Mussaenda philipica) and Bougainvillea (Bougainvillea spectabilis) stand out as popular choices for their striking blooms and hardiness.

These two plants have long been favorites among gardeners and horticulturists due to their attractive, colorful flowers and relatively low maintenance requirements (Abdolbaset et al., 2011).
Mussaenda philipica is a succulent ornamental plant grown for attractive and fragrant flowers. It is the foremost cultivated species within the genus Mussaenda, meaning "on the leaf" belonging to the family Rubiaceae (Stevens, 2019). It is a night-blooming ornamental; the plant has received several other popular names such as Night-blooming cereus and Queen of the Night. The plant grows well under full sun or light (Purak, 2013). The stems are erect, branched, or climbing, primary stems are cylindrical and flattened laterally (Else et al., 2011). *Mussaenda philipica* is the commonly cultivated species planted in gardens, and yards grown in hanging baskets. It is used in traditional medicine, and the mucilaginous flowers are often eaten in vegetable soup by some tribes (Lim, 2014).

The genus Bougainvillea is a popular group throughout the world. It belongs to the family Nyctaginaceae and, according to the "The Plant contains approximately 18 species (GRIN, 2010), Only four species (*B. buttiana*, *B. glabra*, *B. spectabilis*, and *B. peruviana*) are commercially exploited (Kobayashi et al., 2017). However, there are also more than 100 cultivars and three hybrids. Bougainvillea is a popular ornamental, mostly valued for its multi-coloured bracts, it can be used in the garden as a shrub, climber, and pot plant or as a specimen plant. Recent studies have discovered that Bougainvillea potentially has anti-inflammatory, anticancer, antioxidant, antimicrobial, and antihyperglycemic properties (Chauhan et al., 2016; Abarca and Petricevlch, 2018; Ogunwande et al., 2019; Abarca and Petricevlch, 2019; Rauf et al., 2019). This plant group has attracted widespread attention in horticulture, the pharmaceutical industry, and environmental research (Bautista et al., 2020).

Plant hormones are involved in various processes including plant growth and development, cell division, cell elongation and differentiation, and apical dominance (Davies, 2013). The root development and nutrient absorption and transportation by roots are directly related to the endogenous hormone levels (Wang et al., 2015). Auxins are a class of phytohormones that control numerous processes of plant growth and development, they are known primarily for their ability to induce cell elongation, stimulate cell division, vascular differentiation, and root initiation. Indole-3-butyric acid (IBA) is a kind of auxin that exists naturally in various species of plants and tissues (Epstein & Ludwig-Müller, 2010) IBA exerts different effects on plant growth and development, regulating responses of plants against biotic and abiotic stresses (Tognetti et al., 2010), or increasing plant yield, but it is primarily implicated in adventitious root formation and widely used commercially for the induction of adventitious roots (EPA, 2010, Ludwig-Muller, 2011; Normanly et al., 2017). Despite the popularity of Queen of the Night (*Mussaenda philipica*) and Bougainvillea as ornamental plants, they are difficult to root and therefore need a growth hormone (indole-3-butyric acid) to enhance the growth and root formation of *Mussaenda philipica* and Bougainvillea

## MATERIALS AND METHODS

This experiment was carried out at the beginning of October, 2023 in the Horticultural Nursery of Crop Production Department School of Agriculture and Agricultural Technology, Federal University of Technology Minna, Niger state on Latitude6º30'E and Longitude 9º40'N. The following materials were used for the research work: *Mussaenda philipica* plant, Bougainville, Indole-3-butyric acid, Beaker, Scateur, Wooden pole for shading, Measuring tape and rule, Polyethylene container, Topsoil, Rope for screening. The cuttings of the plant material were collected from established parent plants at Eva's garden beside union bank Tunga, Minna Niger State. The growth hormone was purchased from Standard Allied Chemical Limited Ibadan Oyo State. Routine activities carried out include weeding, handpicking, and watering.

**Treatments and Experimental Design**

The treatments were two different types of ornamentals (*Mussaenda philipica* and *Bougainvillea spectabilis*) and varying dipping durations of (0, 10, 20, and 30 minutes) in Indole-3-butyric acid (IBA) thus making it a 2 x 4 factorial experiment fitted into a completely randomised design (CRD) with three replications.

Data were collected on the number of leaves, leaf area, plant height, and number of flowers. Data collected were subjected to analysis of variance (ANOVA) using Genstat 12.0 version and treatment means were separated using least significant difference (LSD) at a 5 % level of probability.

## RESULTS

The effect of growth hormones and dipping duration on the propagation success of Queen of the Night and bougainvillea, on the number of leaves is shown in Table 1. The use of hormones had a significant effect on the number of leaves as the queen of the night had significantly higher numbers of leaves compared to bougainvillea cuttings although cuttings that were dipped for 30 minutes in indole-3-butyric acid produced a higher number of leaves than those other duration of dipping and the control. The leaf area of Queen of the Night recorded the broadest leaf area and was significantly different from the leaf of bougainvillea (Table 2). Queen of the Night recorded the highest leaf area for cuttings dipped in IBA for 30 minutes, closely followed by cuttings dipped for 20 minutes, and cuttings that were dipped for 0 minutes (control) recorded the least for both ornamental cuttings.

The number of flowers produced by Queen of the Night was significantly higher than those produced by Bougainvillea throughout the period of the research work. The number of flowers produced by the control cuttings was significantly lower than other durations of dipping this was the trend observed in the growth parameter. The effect of growth hormone and concentration significantly influence the height of bougainvillea and Queen of the Night (Table 4). Queen of the Night cuttings had significantly taller seedlings than bougainvillea cuttings throughout the research period. Cuttings dipped for 30-minute duration of dipping were the tallest, closely followed by those dipped for 20 minutes and cuttings dipped for 10 minutes had the least height.

## DISCUSSION

The study investigated the influence of growth hormones, particularly indole-3-butyric acid, and dipping duration on the growth and aesthetic characteristics of bougainvillea and Queen of the /Night ornamentals. The results revealed that hormones improved the growth pattern of the two ornamentals although the growth response exhibited by Queen of the Night was more vigorous than those of bougainvilleas. These findings were in line with the work of Stevens, 2019 who opined that despite the difficulty experienced in propagating the two ornamentals, Queen of the was prompt in response to hormone treatment and thus exhibited good growth. Also, the duration of dipping the cuttings into the hormone plays an important role in the root formation and growth of the ornamentals. The results from the research corroborate the work of Bautista et al. (2020)

who reported that the more time the cutting used in submerging the cutting into the hormone, the better their growth and aesthetic performance.

**Table 1: Effect of growth hormone and dipping duration on number of leaves (cm) of Bougainvillea and Queen of the Night**

| | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 4 | 6 | 8 | 10 |
| **Flower type** | | | | |
| Bougainvillea | 1 | 7.4 | 10.8 | 14.2 |
| Queen of the night | 3.7 | 10.5 | 14.4 | 18.9 |
| LSD ($p \leq 0.05$) | 1.02 | 1.04 | 0.95 | 1.03 |
| **Hormone (IBA) Dipping Duration (minutes)** | | | | |
| 0 | 0.5 | 2.7 | 4.5 | 9.7 |
| 10 | 1.5 | 3.5 | 8.6 | 14.2 |
| 20 | 2.7 | 5.3 | 9.2 | 16.4 |
| 30 | 3.5 | 8.5 | 12.25 | 18.5 |
| **LSD ($p \leq 0.05$)** | 1.06 | 1.01 | 1.03 | 0.85 |
| **Interaction (FT X DD)** | * | * | * | * |

LSD; Least significant difference.
IBA = Indole-3-butyric acid

**Table 2: Effect of growth hormone and dipping duration on leaf area ($cm^2$) of Bougainvillea and Queen of the night**

| | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 4 | 6 | 8 | 10 |
| **Flower type** | | | | |
| Bougainvillea | 4.41 | 4.91 | 5.12 | 6.51 |
| Queen of the night | 5.17 | 6.8 | 8.58 | 9.69 |
| **LSD ($p \leq 0.05$)** | 0.82 | 0.44 | 1.21 | 0.47 |
| **Hormone (IBA) Dipping Duration (minutes)** | | | | |
| 0 | 2.08 | 3.15 | 4.32 | 4.93 |
| 10 | 3.12 | 4.1 | 4.38 | 5.31 |
| 20 | 4.1 | 4.8 | 5.27 | 6.68 |
| 30 | 5.15 | 5.92 | 6.45 | 7.95 |
| **LSD ($p \leq 0.05$)** | 1.02 | 0.68 | 1.11 | 0.74 |
| **Interaction (FT X DD)** | * | * | * | * |

**Table 3: Effect of growth hormone and dipping duration on Number of flower of Bougainvillea and Queen of the Night**

| | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 4 | 6 | 8 | 10 |
| **Flower type** | | | | |
| Bougainvillea | 1 | 1.6 | 2.8 | 3.8 |
| Queen of the night | 1 | 2.6 | 3.4 | 5.7 |
| **LSD ($p \leq 0.05$)** | 0.4 | 0.9 | 1.4 | 1.2 |
| **Hormone (IBA) Dipping Duration (minutes)** | | | | |
| 0 | 0.5 | 1.2 | 2.3 | 2.9 |
| 10 | 0.9 | 1.7 | 2.6 | 3.5 |
| 20 | 1.1 | 2.9 | 3.5 | 4.9 |
| 30 | 1.8 | 3.8 | 4.5 | 6.1 |
| **LSD ($p \leq 0.05$)** | 0.7 | 1.1 | 1.2 | 1.3 |
| **Interaction (FT X DD)** | * | * | * | * |

LSD; Least significant difference; IBA = Indole-3-butyric acid

**Table 4: Effect of growth hormone and dipping duration on Plant height (cm) of Bougainvillea and Queen of the Night**

| | Weeks After Planting (WAP) | | | |
|---|---|---|---|---|
| | 4 | 6 | 8 | 10 |
| **Flower type** | | | | |
| Bougainvillea | 8.84 | 10.11 | 10.85 | 12.06 |
| Queen of the night | 10.4 | 12.15 | 14.64 | 16.21 |
| **LSD ($p \leq 0.05$)** | 1.21 | 0.25 | 0.33 | 0.18 |
| **Hormone (IBA) Dipping Duration (minutes)** | | | | |
| 0 | 10.35 | 11.51 | 12.9 | 14.93 |
| 10 | 12.31 | 13.4 | 15.2 | 16.5 |
| 20 | 13.51 | 15.52 | 15.82 | 17.26 |
| 30 | 16.35 | 17.6 | 18.31 | 20.35 |
| **LSD ($p \leq 0.05$)** | 0.44 | 0.41 | 0.52 | 1.13 |
| **Interaction (FT X DD)** | * | * | * | * |

LSD; Least significant difference.

IBA = Indole-3-butyric acid

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# RESPONSE OF MAIZE (*Zea mays* L.) TO NICOSULFURON RATES AND WEEDING REGIMES IN SUDAN SAVANNAH OF NIGERIA

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## ABSTRACT

Field trial was conducted during the dry season of 2021/2022 at the Teaching and Research Farm of Kebbi State University of Science and Technology Jega, (lat. 12° $11^N$, long. 04° $16^E$; 262m above sea level) located in the Sudan Savannah Agroecological zone of Nigeria. The research aimed at determining the appropriate Nicosulfuron rate for maize production. The experiment consisted of three rates of Nicosulfuron at (0.5, 0.75 and 0.85 kg a.i. $ha^1$, hoe weeding at 3 and 6 Weeks After Sowing (WAS), and a weedy check as control). The treatments were laid out in Randomized Complete Block Design (RCBD) and replicated three times. The gross and net plot sizes were 12 $m^2$ and 6 $m^2$. Weed cover score and weed dry weight were significantly decreased by the weed control treatment compared with weedy check plots. The treatments with Nicosulfuron at 0.85 kg a.i. $ha^1$ and hoe weeding at 3 and 6 WAS had significantly higher values for crop vigour, plant height, number of leaves per plant, leaf area and days to 50% tasseling and silking. Yield parameters such as cob weight per plant, cob length, 100grain weight and grain yield per hectare were also significantly increased in plots treated with Nicosulfuron at 0.85 kg a.i. $ha^1$ and those weeded twice at 3 and 6 WAS. Based on the result obtained from this trial, it can be concluded that Nicosulfuron at 0.85 kg a.i. $ha^1$ and two hoe weeding at 3 and 6 WAS resulted in effective weed control and the highest grain yield of maize.

**Keywords:** Nicosulfuron, Maize, Weed, Length, Plan, cob,

## INTRODUCTION

Maize (*Zea mays* L.) is one of the most significant cereal crops cultivated globally and plays a crucial role in the diet of millions, especially in Nigeria. It serves as a key food source and provides raw materials for agro-based industries, particularly in animal feed production (Iken & Amusa, 2004; Abdulraham & Kolawole, 2006). Additionally, maize is utilized in the production of alcohol, starch, and pharmaceuticals, and is increasingly used for biofuel production (Acharya & Young, 2008; Ranum *et al*., 2014). The crop is cultivated across various agroecological zones in Nigeria, including the forest, derived savannah, and guinea savannah regions (Olaniyan, 2015).

Despite its economic and nutritional importance, maize production faces significant threats from weed interference, which remains one of the leading causes of yield reduction. Globally, weeds can cause maize yield losses of over 40-60% (Ayana, 2023). In Nigeria, these losses can range between 40% to 100%, depending on factors like crop type, weed species, and weed density (Ozkan *et al*., 2023). For instance, spear grass (Imperata cylindrica) alone can reduce maize and soybean yields by over 50%, and its impact on cassava can exceed 90% (Chikoye *et al*., 2001).

Weeds compete with crops for essential resources such as water, light, and nutrients, causing both quantitative and qualitative losses (Ayana, 2023; Ozkan *et al.*, 2023; Hamada, 2023). This competition not only affects crop growth but also reduces the quality of agricultural outputs, contaminates crop seeds, and interferes with tillage and harvesting operations, ultimately leading to higher labor costs (Hamada, 2023; Horvath *et al.*, 2023). In fact, weed-related damage in maize fields can sometimes outweigh the impact of pests and diseases (Horvath *et al*., 2023).

The challenge of managing weeds is particularly pronounced in developing countries, where weed competition can lead to food losses of up to 25% of potential production (Koch, 1992). Manual weeding, although effective, is highly labor-intensive, often accounting for 30-70% of total labor inputs in traditional farming systems (Gomez & Gomez, 2020). As Porwal (2002) observed, severe weed infestations, especially during the early stages of crop growth, can result in yield reductions of up to 40%. Manual hoe weeding, while commonly practiced, is not only costly and time-consuming but also physically demanding, particularly on heavy soils.

Addressing these challenges requires the implementation of efficient weed management strategies to optimize maize production. Recent studies emphasize the need for integrated approaches, combining chemical herbicides and manual weeding, to enhance crop productivity while reducing labor costs (Griehar *et al.*, 2004; Horvath *et al*., 2023). This research focuses on evaluating the effectiveness of varying rates of Nicosulfuron herbicide and manual weeding at critical growth stages in the Sudan Savannah agroecological zone of Nigeria.

## MATERIALS AND METHODS

### Experimental Site

Field trial was conducted at the University Teaching and Research Farm during 2021/2022 dry season. Teaching and Research Farm of Kebbi State University of Science and Technology Jega, (lat. 12° $11^{N}$, long. 04° $16^{E}$; 262m above sea level) located in the Sudan Savannah Agroecological zone of Nigeria. The area has a long dry season that is characterized by cool dry air (harmattan) that prevails from November to Febuary, and hot dry air extending from March to May. The treatment consisted of three rates of Nicosulfuron at (0.5, 0.7 and 0.85 kg a.i. $ha^{1}$, hoe weeding at 3 and 6 WAS, and a weedy check as control). The treatments were laid out in Randomized Complete Block Design (RCBD) with four replications. The gross plot size consisted of 4 ridges each measured 4m long and 3 m wide (4m x $3m=12m^2$). While the two inner ridges 4m x 1.5m ($6m^2$) constituted the net plot. The experimental area was harrowed to a fine tilth and ridged 75 cm apart. The land was then marked into plots and replications. Border spaces of 0.5m between the plots and two ridges between replicates was also marked. The seeds were sown manually at the rate of two seeds per hole at a depth of 3 cm and a spacing of 75 cm x 25 cm. The emerged seedlings were later thinned down to one plant per stand at two weeks after sowing. The post emergence herbicide (Nicosulfuron) was applied at 3 weeks after sowing (WAS) on treatment basis. Hoe weeding was carried out at 3 and 6 WAS only for the hoe weeded treatment. Harvesting was done by removing the ear manually when the plants have attained physiological maturity as the cobs turn yellowish-brown and grains have hardened. Data on Weed cover score, weed dry weight, plant height; number of leaves were taken at intervals. Number of days to 50% tasseling and silking, seeds per row, cob weight, 100seed weight and grain yield were also taken and recorded.

Weed Cover Score: The weed cover score is assessed visually by estimating the percentage of ground covered by weeds within a plot. This is done via quadrat placed at different sections of the plot to aid in consistent scoring.
This score helps quantify the extent of weed infestation, indicating the effectiveness of weed control treatments.

Weed Dry Weight: Weeds are collected from a designated sample area within each plot. The collected weeds are cut at ground level, dried in an oven at 70°C for 48 hours to remove moisture, and then weighed using a digital scale.
Measuring weed dry weight provides a precise estimate of weed biomass, which reflects the level of competition weeds impose on crops.

Plant Height: Plant height is measured using a long ruler. The measurement is taken from the soil surface to the highest point of the plant (the tip of the tallest leaf). Measurements are recorded at specific intervals, such as 4, 8, and 12 weeks after sowing (WAS).
Plant height serves as an indicator of growth vigour and can help assess the impact of different treatments on crop performance.

Number of Leaves: The number of fully expanded leaves on each plant is counted manually. This is done at specific growth stages, such as 4, 8, or 12 WAS. The counting is performed on a representative sample of plants within each plot.
Counting the number of leaves helps determine plant health and photosynthetic potential, which can be affected by weed competition or other agronomic treatments.

Number of Days to 50% Tasseling and Silking: This is a measure of the time it takes for 50% of the plants in a plot to reach the tasseling and silking stages.
Tasseling: This is recorded when 50% of the plants have fully emerged tassels.
Silking: This is recorded when 50% of the plants have visible silks at the ear tip.
Regular observations are made every day after sowing until the criteria are met.
These measurements are indicators of the crop's reproductive maturity and can be influenced by environmental factors and treatments.

Seeds per Row: After harvesting the maize cobs, representative samples of cobs were selected from each plot. The number of seeds (kernels) in a single row on each cob is counted manually. This is done on several cobs per plot to get an average value.
Counting seeds per row helps determine the effectiveness of treatments on pollination and grain filling, which ultimately impacts yield.

Cob Weight: Cobs are harvested when they reach physiological maturity (when the husks turn yellow-brown and kernels are hard). The cobs are weighed using a digital scale.
Measurements were taken for each sample of cobs from each plot.
Cob weight is a direct indicator of productivity and reflects the impact of different agronomic treatments on maize yield.

100-Seed Weight: After shelling the maize cobs, 100 seeds are randomly selected from the harvested grain of each plot. The seeds are dried to a constant moisture level (usually around 12-14%) and weighed using a digital scale.
The 100-seed weight is used to assess seed size and quality, which are important for market value and overall grain yield.

Grain Yield (t/ha): After harvesting, all the ears from a plot are threshed to separate the grains. The grains are weighed, and moisture content is measured. Grain yield per hectare is calculated Grain yield is the ultimate measure of the effectiveness of treatments on crop productivity and is a key metric for evaluating agricultural practices.

Data collected were subjected to analysis of variance as described by (Snedecor and Cochran, 1967) using SAS software (version 9.6, released 2013). The treatment means were compared using least significant difference LSD at 5% level of probability.

**RESULTS**

At 8 and 12 WAS (Table 1) maize plants treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$ and hoe weeding at 3 & 6 WAS showed taller significant plants compared to other treatments. The weedy check plots consistently exhibited the shortest plants throughout the study period, particularly at 12 WAS. The number of leaves was significantly higher in plots treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$and those that underwent hoe weeding at 3 & 6 WAS, especially at 8 and 12 WAS. In contrast, the weedy check consistently recorded the lowest number of leaves at all sampling periods. The largest leaf area was recorded in plots treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$and those that underwent hoe weeding at 3 & 6 WAS, particularly at 12 WAS. In contrast, the weedy check plots had significantly smaller leaf areas. The highest crop vigour scores were noted in plots treated with hoe weeding at 3 & 6 WAS and Nicosulfuron at 0.85 kg a.i. $ha^{-1}$, especially at 8 and 12 WAS. The lowest vigour scores were found in the weedy check plots. The results show that the highest weed dry weight was recorded in the weedy check plots, particularly at 12 weeks after sowing (WAS), with values as high as 661.83 $gm^2$. In contrast, the lowest weed dry weight was observed with Nicosulfuron applied at 0.85 kg a.i. $ha^{-1}$and the 3 & 6week hoe weeding treatment. The weed cover score followed a similar trend, with the highest scores in the weedy check plots and the lowest in plots treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$and that hoe weeded at 3 & 6 WAS. The results in Table 4 indicate that the weedy check reached tasseling and silking much earlier than the treated plots. Conversely, plots treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$and hoe weeded plots took longer to reach 50% tasseling and silking. The highest grain yield (2.78 t $ha^{-1}$) was achieved in plots treated with Nicosulfuron at 0.85 kg a.i. $ha^{-1}$, followed by the hoe weeded plots (2.59 t $ha^{-1}$). The weedy check yielded the lowest (0.19 t $ha^{-1}$).

**Table 1:** Influence of weed control on plant height (cm) and number of leaves of maize during 2021/2022 dry season at Jega.

| **Weed Control** | | **Plant Height** | | | **Number of Leaves** | |
|---|---|---|---|---|---|---|
| **Nicosulfuron (kg a.i ha$^{1}$)** | **4WAS** | **8WAS** | **12WAS** | **4WAS** | **8WAS** | **12WAS** |
| 0.5 | 25.66$^{a}$ | 53.42$^{b}$ | 95.64$^{b}$ | 5.40$^{a}$ | 7.07$^{b}$ | 11.87$^{a}$ |
| 0.70 | 26.25$^{a}$ | 58.75$^{b}$ | 98.92$^{b}$ | 5.45$^{a}$ | 7.00$^{b}$ | 12.07$^{a}$ |
| 0.85 | 22.01$^{a}$ | 78.05$^{a}$ | 116.36$^{a}$ | 6.82$^{a}$ | 10.13$^{a}$ | 11.75$^{a}$ |
| Hoe weeding at 3&6WAS | 25.50$^{a}$ | 69.29$^{a}$ | 109.61$^{a}$ | 6.57$^{a}$ | 9.45$^{a}$ | 9.98$^{a}$ |
| Weedy check | 21.13$^{a}$ | 16.90$^{c}$ | 15.98$^{c}$ | 3.00$^{b}$ | 3.75$^{c}$ | 5.25$^{b}$ |
| **LSD** | **6.81** | **7.01** | **9.52** | **1.22** | **2.13** | **2.28** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**). **WAS**= week after sowing, **t ha$^{1}$**= tone per hectare. **Kg**= kilogram, **a.i**=active ingredient.

**Table 2:** Influence of weed control treatments on leaf area (cm$^{2}$) and crop vigor score of maize during 2021/2022 dry season at Jega.

| **Weed Control** | | **Leaf Area** | | | **Crop Vigour** | |
|---|---|---|---|---|---|---|
| **Nicosulfuron ( kg a.i ha$^{1}$)** | **4WAS** | **8WAS** | **12WAS** | **4WAS** | **8WAS** | **12WAS** |
| 0.5 | 80.05$^{b}$ | 174.70$^{b}$ | 351.70$^{b}$ | 3.65$^{a}$ | 6.25$^{b}$ | 5.47$^{a}$ |
| 0.70 | 95.25$^{b}$ | 122.73$^{b}$ | 359.40$^{b}$ | 3.30$^{a}$ | 7.42$^{a}$ | 6.10$^{a}$ |
| 0.85 | 120.55$^{a}$ | 344.05$^{a}$ | 668.70$^{a}$ | 3.80$^{a}$ | 7.57$^{a}$ | 6.12$^{a}$ |
| Hoe weeding at 3&6WAS | 112.20$^{a}$ | 313.60$^{a}$ | 651.00$^{a}$ | 3.20$^{a}$ | 7.65$^{a}$ | 6.15$^{a}$ |
| Weedy check | 33.10$^{c}$ | 58.00$^{c}$ | 37.00$^{c}$ | 3.75$^{a}$ | 3.00$^{c}$ | 2.75$^{b}$ |
| **LSD** | **11.7** | **44.75** | **76.97** | **2.56** | **1.18** | **1.21** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**). **WAS**= week after sowing, **t ha$^{1}$**= tone per hectare. **Kg**=kilogram, **a.i**=active ingredient.

**Table 3:** Influence of weed control treatments on weed dry weight and weed cover score of maize during 2021/2022 dry season at Jega.

| **Weed Control** | | **Weed Dry Weight(gm$^{2}$)** | | | **Weed Cover** | |
|---|---|---|---|---|---|---|
| **Nicosulfuron ( kg a.i ha$^{1}$)** | **4WAS** | **8WAS** | **12WAS** | **4WAS** | **8WAS** | **12WAS** |
| 0.5 | 79.45$^{a}$ | 80.10$^{b}$ | 98.00$^{b}$ | 3.12$^{a}$ | 4.47$^{b}$ | 5.90$^{b}$ |
| 0.70 | 67.55$^{a}$ | 76.83$^{b}$ | 83.28$^{c}$ | 2.67$^{b}$ | 4.20$^{b}$ | 5.05$^{b}$ |
| 0.85 | 67.58$^{a}$ | 71.70$^{b}$ | 58.93$^{e}$ | 2.12$^{b}$ | 3.07$^{c}$ | 3.80$^{c}$ |
| Hoe weeding at 3&6WAS | 66.70$^{a}$ | 72.80$^{b}$ | 61.35$^{d}$ | 4.25$^{a}$ | 3.62$^{b}$ | 3.47$^{c}$ |
| Weedy check | 136.25$^{b}$ | 562.68$^{a}$ | 661.83$^{a}$ | 4.77$^{a}$ | 7.27$^{a}$ | 8.05$^{a}$ |
| **LSD** | **6.42** | **7.92** | **13.18** | **1.69** | **1.49** | **1.53** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**). **WAS**= week after sowing, **t ha$^{1}$**= tone per hectare. **Kg**=kilogram, **a.i**=active ingredient.

**Table 4:** Influence of weed control treatments on days to 50% tasseling and silking, number of seed per row cob weight, 100 grain weight and grain yield of maize during 2021/2022 dry season at Jega.

| Weed Control | Days to 50% Tasseling | Days to 50%Silking | Seed/Row | Weight of cob | 100 grain weight | Yield (t ha$^{1}$) |
|---|---|---|---|---|---|---|
| **Nicosulfuron( kg a.i ha$^{1}$)** | | | | | | |
| 0.5 | 53.50$^{b}$ | 66.50$^{a}$ | 26.20$^{c}$ | 60.37$^{b}$ | 19.25$^{b}$ | 1.67$^{d}$ |
| 0.70 | 54.00$^{b}$ | 67.25$^{a}$ | 31.75$^{b}$ | 64.77$^{b}$ | 20.22$^{b}$ | 2.22$^{c}$ |
| 0.85 | 55.50$^{b}$ | 67.25$^{a}$ | 37.95$^{a}$ | 79.21$^{a}$ | 25.00$^{a}$ | 2.78a |
| Hoe weeding at3&6WAS | 59.75$^{a}$ | 72.75$^{a}$ | 33.75$^{b}$ | 69.53$^{a}$ | 22.82$^{a}$ | 2.59$^{a}$ |
| Weedy check | 42.00$^{c}$ | 43.00$^{b}$ | 11.55$^{d}$ | 23.38$^{c}$ | 10.77$^{c}$ | 0.19$^{e}$ |
| **LSD** | **3.44** | **5.30** | **4.08** | **9.63** | **3.15** | **0.33** |

Means followed by unlike letter(s) within a column in each treatment group are significantly different at 5% probability level using least significant different (**LSD**). **WAS**= week after sowing, **t ha$^{1}$**= tone per hectare. **Kg**=kilogram, **a.i**=active ingredient.

## DISCUSSION

The increased plant height in treated plots is likely due to reduced weed competition for essential resources such as light, nutrients, and water. The effectiveness of the 0.85 kg a.i. ha$^{-1}$ Nicosulfuron treatment and hoe weeding is evident, as they allowed maize plants to utilize available resources more effectively. The stunted growth observed in the weedy check plots is attributed to intense competition with weeds, which restricted the maize plants' access to necessary growth factors. This aligns with findings by Griehar *et al*. (2004), who reported that effective weed control promotes better crop growth by minimizing competition. The increase in the number of leaves in treated plots indicates better vegetative growth due to reduced competition from weeds. Enhanced leaf development is crucial for photosynthesis, which drives overall plant health and yield. These results align with findings by Porwal (2003), who noted that effective weed management leads to improved leaf growth, which can directly contribute to higher crop productivity. The increase in leaf area in treated plots suggests that effective weed control allows for better leaf expansion, which is vital for maximizing light interception and photosynthesis. This is essential for enhancing dry matter accumulation and overall crop productivity. Reduced leaf area in weedy plots indicates that weed competition limits the plant's ability to expand its foliage, reducing photosynthetic efficiency. These results are consistent with studies by Coble *et al.* (1978), which highlight the importance of weed management in optimizing crop growth. Higher crop vigour scores indicate healthier plants with better overall growth, which can be attributed to reduced weed competition. Vigorous crops tend to be more resilient and productive, as they can utilize resources more efficiently.

The weedy check's poor vigour scores are indicative of reduced growth potential due to competition for nutrients, water, and light. This observation supports findings by Jordan *et al.* (1987), who demonstrated that effective weed control results in healthier, more vigorous crops. The significant reduction in weed dry weight in the treated plots suggests that the application of Nicosulfuron, especially at 0.85 kg a.i. $ha^{-1}$, was effective in suppressing weed growth. The effectiveness of hoe weeding at 3 and 6 WAS was comparable, indicating that both chemical and manual weeding methods are efficient in reducing weed biomass. The untreated control (weedy check) showed the highest weed dry weight due to the absence of weed control measures, leading to unrestrained weed growth and competition. These findings align with studies such as Griehar *et al*. (2004), which reported that efficient weed control significantly reduces weed biomass, thereby minimizing competition for nutrients, water, and light. Lower weed cover scores in treated plots indicate that both Nicosulfuron and manual hoe weeding were effective in reducing weed cover over time. This is crucial for reducing competition during the critical growth stages of maize. The effectiveness of Nicosulfuron at 0.85 kg a.i. $ha^{-1}$aligns with findings by Porwal (2003), who observed that higher herbicide rates provide better weed suppression. The use of hoe weeding also significantly reduced weed cover, which is beneficial in environments where herbicide use is limited or not preferred.

Delayed tasseling and silking in treated plots may be due to reduced competition from weeds, allowing the maize plants to develop more vigorously. In contrast, increased competition in the weedy check may have induced earlier, stress induced flowering. Similar results were noted by Coble *et al*. (1978), where effective weed management delayed flowering by allowing crops to utilize available resources more efficiently. The increased cob weight, grain weight, and yield in the treated plots indicate that effective weed management allows for better utilization of nutrients and water by the maize crop. This leads to improved photosynthesis, grain filling, and overall productivity. The superiority of the 0.85 kg a.i. $ha^{-1}$ Nicosulfuron treatment suggests that this herbicide rate effectively controlled weed competition, resulting in higher yields. This is consistent with findings by Jordan *et al*. (1987), who reported significant yield increases with optimized herbicide rates. Plots weeded at both 3 and 6 weeks also performed well, highlighting that manual weeding can be a viable option in smallholder farming systems where herbicide use may not be feasible.

**CONCLUSION**

This study demonstrated the significant impact of various weed control methods on maize growth and yield under the Sudan Savannah conditions of Nigeria. The findings highlight that Nicosulfuron at 0.85 kg a.i. $ha^{-1}$, as well as hoe weeding at 3 and 6 weeks after sowing (WAS), were the most effective treatments in reducing weed competition and enhancing maize productivity. Additionally, manual hoe weeding at both 3 and 6 WAS proved effective, especially in enhancing plant height, leaf area, and grain yield. The findings from this study indicate that a combined approach of chemical control using Nicosulfuron at 0.85 kg a.i. $ha^{-1}$ and timely manual hoe weeding can optimize maize yield in the Sudan Savannah agroecological zone of Nigeria. These weed management strategies not only improve maize growth parameters but also enhance grain yield, which is crucial for food security in this region. Future research should explore the longterm impacts of these weed control methods on soil health and the environment to ensure sustainable maize production.

## RECOMMENDATIONS

Farmers in similar agroecological zones should consider using Nicosulfuron at 0.85 kg a.i. $ha^{-1}$ or manual hoe weeding at 3 and 6 WAS to achieve optimal maize yield. A combination of chemical and manual weed control may offer an integrated weed management approach that balances effectiveness and environmental sustainability.

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# PRODUCTIVITY OF MAIZE *(ZEA MAYS* L.) AS INFLUENCED BY POULTRY DROPPING RATES IN SUDAN SAVANNA AGRO-ECOLOGICAL ZONE OF NIGERIA

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## ABSTRACT

Maize production in Nigeria is predominantly dependent on the utilisation of synthetic fertilisers. However, the persistent application of inorganic fertilisers without adequate soil replenishment has raised significant environmental concerns within the agricultural domain. It is in line with this challenge a field trial was conducted during 2020 rainy season at the Department of Crop Science Teaching and Research Farm, Kebbi State University of Science and Technology, Aliero, Nigeria. The research aimed at determining the most appropriate level of poultry dropping for the productivity of maize. The treatments consisted of four levels of poultry dropping:-(2.0, 4.0, 6.0 t/ha and 0.0 t/ha as control), arranged in a randomised complete block design with three replications. The study revealed that plots that received 6.0 t/ha of poultry droppings recorded taller plants, heavier shoots higher leaf area index, heavier seeds, and higher grain yield of maize compared with the other treatments. Based on the findings of this study, the application of 6 t/ha of poultry dropping can increase maize grain yield by 3.04 t/ha in this agroecology of Nigeria.

**Key words:** Maize, poultry dropping, tons, hectare, yield

## INTRODUCTION

Maize (*Zea mays* L.), is one of the world's most important cereal crops. It is an important cereal crop that is grown in Nigeria's rainforest and savanna ecological zones. Maize has potentials over any other grain crop. It is capable of producing a higher yield and is easier to cultivate. If properly managed, it can help Nigeria increase its food supply. According to [4], globally maize occupies a total cultivated land of 197 mega hectares with a yield of 1134 metric tons per year and a productivity of 5.75 tons per hectare. Each portion of the crop has monetary value: the seeds, shoot, head and kernel which can be synthesized to produce a large diversity of food and non-food products. Maize is consumed in developed nations as a second-cycle product in meat, eggs, and dairy products. The crop is eaten directly in third-world nations and is a staple nutrition for around 200 million people. Maize is a principal meal for an estimated 50% of the people in Africa's sub-Saharan region. It is high in carbohydrates, protein, iron, vitamin B, and minerals. In advanced countries, it is an important source of many industrial products such as corn sugar, corn oil, corn flour, starch, syrup, brewer's grit, salad, soap-making, lubrication and alcohol [6]. Unfortunately, despite its high yield potential, Nigeria's average yield remains low (1.5–2.5t/ ha) due to lack of adequate fertilizer application, drought, pests, diseases, or weed interference [7]. Farmers are hesitant to use inorganic fertilisers because of their rising costs, so they are looking for alternatives. Inorganic fertilisers, once again, tend to degrade agricultural soils quickly. The shortage and high cost of inorganic fertiliser has hampered the provision of adequate mineral nutrients to crops, necessitating the use of an alternate source of nutrients, such as poultry manure.

Poultry manure is the most useful of all the manures produced by livestock if treated appropriately. It's been utilised as a soil amendment and a source of plant nutrients. Poultry manure contains nearly all of the needed plant nutrients. When added to soil, it also provides a great supply of organic matter, replenishing some of the organic matter that has been reduced by numerous agricultural activities [8]. As a result, poultry droppings provide all of the vital elements that a typical farmer would require for maize production. The possibility of boosting maize yield and soil fertility by improving soil fertility and nutrient availability to the crop could be an alternate approach for increasing maize yield and soil fertility through poultry manure application. The objective of this study was to assess the effect of rates of poultry manure on maize growth and yield.

## MATERIALS AND METHODS

During the 2020 wet season, research was undertaken at the University Teaching and Research Farm Jega (Latitude 12° 18.64'N, longitude 04°29.85', elevation 262 m) in Nigeria Sudan Savannah Agro-ecological zone. The experiment included four treatments of poultry droppings at different rates (0.0, 2.0, 4.0, and 6.0 t/ha). With three replications, the experiment was set up in a Randomized complete block design (RCBD). The plot consists of four ridges, each measuring 4m long and 3m wide (12m$^2$). The net plot was made up of the two inner ridges, which were 4m x 1.5m (6m$^2$) in size. The SAMMAZ-17 maize variety was used in this experiment. The experimental area was ridged 75 cm a part 0.5 m border space between plots and two ridges between replicates were left among the plots. The seeds were manually sown at a spacing of 75 cm x 25 cm. Weeding with a hoe was done at 3 and 6 weeks after sowing (WAS). The ear was manually harvested at physiological maturity, when the cobs turn yellowish-brown and the grains have hardened. To obtain clean grain, the cobs were sundried, weighed, and then threshed and winnowed. Data on plant height, leaves per plant, days to 50% tasselling and silking, cobs per plant, cob weight, length, test weight, and grain yield were all collected. The statistical analysis system (SAS) software, ([9] was used to analysed the data using the analysis of variance as stated by [10]. The least significant difference (LSD) was used to compare the treatment means that are significant at (0.05%).

## RESULTS

The (Table 1) result shows the chemical composition of poultry manure used during the trial Nitrogen (N) was present 2.04g kg-$^1$ and available Phosphorus (P) were found moderate with 1.28mg/kg, Potassium (K) is also present at 1.22 cmol (+)kg$^{-1}$ and Magnesium (Mg) were low with 0.01 cmol(+) respectively. Details of physical and chemical properties of the soil at the experimental site shown in the (Table 2). The result showed that the experimental site was clay loam with low content of total nitrogen, organic carbon, exchangeable cation and slightly acidic. The effect of poultry dropping rate on plant height was not significant at 4 WAS. But poultry droppings applied at 6.0 t/ha produced taller plants compared to the other treatments, such that shorter plants were recorded in the plots without the poultry droppings (0.0 t/ha) at 8 and 12 WAS, respectively (Table 3). Similarly, the effect of treatments on the number of leaves were significantly different at 8 and 12 WAS only (Table 3). Plots with poultry dropping applied at 6.0 t/ha recorded the production of more leaves per plant that was significantly different with the others treatment plots (Table 3). Significantly longer days to 50% tasselling and silking, heavier cob and longer cobs were recorded in the plot that received 6.0 t/h of poultry droppings compared to the plots given 4.0, 2.0 and 0.0 t/ha poultry droppings, respectively (Table 4). In Table 5, the results showed that poultry dropping applied at a rate of 6.0 t/ha produced significantly more rows per cob, more seeds per row which was similar to 4.0 t/ha only, and heavier grains and higher grain yield than the other rates and the control.

## DISCUSSION

Based on the findings of this research the result shows that nitrogen is found higher in poultry dropping, and the soil of the study area is characterized as sandy loam. Similarly, results of this study showed that the addition of poultry droppings increased maize growth significantly. The production of better growth parameters in terms of taller plants and more leaves in plots treated with 6.0 t/ha of poultry droppings may be related to increased soil fertility and soil microbial activity. This increased chlorophyll content, which might have stimulated the photosynthetic activity, which translated to the improvement. This result is in agreement with the findings of ([11], [12]), who reported a significant increase in plant height with an increase in doses of organic manure in maize. The delay in attainment of 50% tasselling and silking in the 6.0t/ha poultry dropping applied plots could be attributed to the improvement in nutrients and water holding capacity, which might have resulted in moisture and nutrient availability that sustained the vegetative growth of the maize plant throughout the growing period. The shoot dry weight of maize was also higher in the poultry droppings at 6.0t/ha compared to other treatments. This was due to an increased moisture content in the soil coupled with the availability of primary nutrients in the soil as a result of the application of poultry manure. This boosted the photosynthate production during photosynthesis, which translated to increasing the dry matter and maize growth. The results follow the findings of ([13],[14],[15]), who reported an increase in total dry matter accumulation of maize as result of the supply of nutrients by the organic fertilizer. Maize yield and yield attributes were significantly enhanced when poultry dropping was applied in a 6.0t/ha plot. The superior grain weight, row per cob, cob length grain weight and grain yield obtained in plots that received 6.0t/ha was as a result of a balanced supply of mineral nutrients from the poultry dropping during the plant's growing phase. This result is consistent with the findings of ( [16],[17],[18], [19], [20] and [21] ) who found the highest maize grain production due to enhanced cob and grain weight from combining organic and inorganic fertilizers compared to control.

## CONCLUSION

Based on the findings of this study, the application of 6 t/ha of poultry dropping can enhance increase maize grain yield by 3.04 t/ha in this agroecology of Nigeria.

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Table 1: Chemical composition of poultry manure used

| Chemical composition | Values |
|---|---|
| Nitrogen (N) | 2.04 |
| Phosphorus (P) | 1.28 |
| Potassium (K) | 1.22 |
| Calcium (Ca) | 0.48 |
| Magnesium (Mg) | 0.01 |

Analysed in the soil science department Kebbi State University of Science and Technology, Aliero

**Table 2:** Properties of soil of the experimental site at a depth of 0-30 cm on maize in 2022 rainy season

| Composition | (%) |
|---|---|
| **Particle Size Analysis** | |
| Sand | 58.00 |
| Silt | 30.40 |
| Clay | 11.60 |
| Textural Class | Sandy Loam |
| **Chemical Analysis** | |
| pH $H_2O$ 1.2.5 | 6.58 |
| Organic Carbon (%) | 0.42 |
| Available Nitrogen (kg/ha) | 268 |
| Available Phosphorus (Kg/ha) | 25 |
| Available Potassium (kg/ha) | 295 |
| EC ($dSm^{-1}$) | 0.22 |

Analysed in the Soil Science Department, Kebbi State University of Science and Technology, Aliero

Table **3**: Influence of poultry dropping rates on plant height and number of leaves of maize at Aliero

| | **Plant height (cm)** | | | **Number of leaves** | | |
|---|---|---|---|---|---|---|
| **Poultry manure (t/ha)** | **4WAS** | **8WAS** | **12WAS** | **4WAS** | **8WAS** | **12WAS** |
| 0.0 | 29.65 | $66.35^{d}$ | $105.55^{d}$ | 8.00 | $9.00^{c}$ | $11.40^{b}$ |
| 2.0 | 39.00 | $84.60^{c}$ | $146.85^{c}$ | 9.60 | $10.10^{c}$ | $11.75^{b}$ |
| 4.0 | 39.10 | $108.45^{b}$ | $160.25^{b}$ | 8.70 | $12.75^{b}$ | $12.35^{b}$ |
| 6.0 | 36.10 | $139.53^{a}$ | $177.0^{a}$ | 8.50 | $13.90^{a}$ | $14.80^{a}$ |
| LSD (0.05) | 7.58 | 12.024 | 15.843 | 0.87 | 0.92 | 0.90 |

Means with subscript letters (a, b, c) varied significantly at (0.5%), WAS= week after sowing, LSD= least significant different, t/ha= tones per hectare, cm=centimetre, g=gram

**Table 4**: Influence of poultry manure rates on days to 50% tasselling and silking, weight of cob per plant and cob length of maize at Aliero

| PoultryManure (t/ha) | Days to 50% tasseling | Days to 50% silking | Weight of cob (g) | Cob length (cm) |
|---|---|---|---|---|
| 0.0 | $47.50^{d}$ | $58.00^{d}$ | $61.38^{d}$ | $8.80^{c}$ |
| 2.0 | $67.75^{c}$ | $71.25^{c}$ | $75.21^{c}$ | $11.50^{b}$ |
| 4.0 | $70.75^{b}$ | $74.50^{b}$ | $87.82^{b}$ | $13.05^{b}$ |
| 6.0 | $73.50^{a}$ | $78.25^{a}$ | $101.73^{a}$ | $15.70^{a}$ |
| **LSD (0.05)** | **1.53** | **1.60** | **7.60** | **2.52** |

Means with subscript letters (a, b, c) varied significantly at (0.5%), WAS= week after sowing, LSD= least significant different, t/ha= tones per hectare, cm=centimetre, g=gram

**Table 5**: Influence of poultry manure rates on rows per cob, seeds per rows, test weight and grain yield of maize at Aliero

| Poultry manure (t/ha) | Row/cob | Seeds/row | Test weight(g) | Grain yield (t/ha) |
|---|---|---|---|---|
| 0.0 | 6.60$^{d}$ | 11.50$^{c}$ | 15.63$^{d}$ | 0.80$^{d}$ |
| 2.0 | 11.45$^{c}$ | 18.00$^{b}$ | 20.18$^{c}$ | 1.70$^{c}$ |
| 4.0 | 13.00$^{b}$ | 22.30$^{a}$ | 24.75$^{b}$ | 2.52$^{b}$ |
| 6.0 | 14.80$^{a}$ | 25.55$^{a}$ | 29.90$^{a}$ | 3.04$^{a}$ |
| LSD (0.05) | 1.05 | 4.47 | 4.29 | 0.45 |

Means with subscript letters (a, b, c) varied significantly at (0.5%), WAS= week after sowing, LSD= least significant different, t/ha= tones per hectare, cm=centimetre, g=gram

# EFFECTS OF POULTRY MANURE ON THE NUTRIENT ELEMENT ABSORBTION AND PROXIMATE COMPOSITION OF GARDEN EGGS (*Solanum melongena* L.)

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## ABSTRACT

Field experiment was conducted in 2023 to investigate the effect of variety and poultry manure on the nutrient element absorption and proximate composition of garden egg (*Solanum melongena*) in Lapai, southern guinea savanna, Nigeria, at the Teaching and Research Farm of Ibrahim Badamasi Babangida University, Lapai. The experiment consisted of two varieties; Local and improve (Easter white) and Four levels of poultry manure (0, 10, 20 and 30t/ha and NPK 15:15:15). The treatments were factorially combined and fitted into a Randomized Complete Block Design (RCBD). The data collected were leaf and fruit samples for laboratory investigation. The leaf samples were collected at 4 and 8 weeks after transplanting while the fruit samples were collected at 8 weeks after transplanting. Data collected were subjected to analysis of variance and means were separated using least significant different. The results showed that poultry manure significantly enhanced nitrogen and phosphorus uptake of the leaf. Poultry manure also significantly increase percentage content of crude fibre, crude fat, crude protein and carbohydrate compared to other treatments

**Key words:** poultry manure, leaves, fruits, proximate, Garden egg

## INTRODUCTION

Garden egg (*Solanum melongena*) is a widely cultivated vegetable crop in many parts of the world, rich in essential nutrients and antioxidants. To enhance its productivity and nutritional quality, farmers often rely on fertilizers. However, the use of inorganic fertilizers has raised concerns about environmental degradation, soil health, and human health risks. Organic alternatives, such as poultry manure, have gained attention for their potential to promote sustainable agriculture. Previous studies have shown that organic amendments can improve soil fertility, increase crop yields, and enhance nutrient uptake (Ogunwale *et al*., 2017; Singh *et al*., 2018). Poultry manure, in particular, is rich in nitrogen, phosphorus, and potassium, making it a valuable fertilizer source (Adekiya *et al*., 2016). In contrast, inorganic fertilizers provide essential nutrients but may lead to soil degradation and environmental pollution (Liu *et al*., 2019).

The application of organic manure significantly enhances the nutrient element absorption of vegetables. Organic manure, rich in essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), improves soil fertility and structure, allowing vegetables to absorb these nutrients more efficiently (Adekiya *et al*., 2016). Studies have shown that organic manure increases the uptake of N, P, and K in vegetables like tomatoes (Ogunwale *et al*., 2017), spinach (Singh *et al*., 2018), and lettuce (Liu *et al*., 2020). Additionally, organic manure promotes the absorption of micronutrients like calcium (Ca), magnesium (Mg), and iron (Fe), essential for vegetable growth and human nutrition (Kumar *et al*., 2019). The improved nutrient uptake resulting from organic manure application leads to enhanced vegetable yields, quality, and nutritional value.

Application of organic manure also significantly influences the proximate composition of vegetables, enhancing their nutritional value. Studies have shown that organic manure increases the protein content in vegetables like spinach (Singh *et al*., 2018), tomatoes (Ogunwale *et al*., 2017), and carrots (Kumar *et al*., 2019). Organic manure also improves the fiber content, moisture retention, and ash content in vegetables, contributing to their overall nutritional quality (Liu *et al*., 2020). Furthermore, organic manure reduces the fat content and increases the mineral content, including calcium, potassium, and iron, in vegetables (Adekiya *et al*., 2016). The enhanced proximate composition resulting from organic manure application makes vegetables more nutritious and beneficial for human consumption. Therefore, the objective of this study was to compare the effects of poultry manure and inorganic fertilizer on nutrient element absorption and proximate composition of two varieties of garden egg.

## MATERIALS AND METHODS

Field experiment was conducted at the Teaching and Research Farm of Ibrahim Badamasi Babangida University, Lapai during the 2023 rainy season. The experiment consisted of two factors namely Variety [local and improved (Easter white) varieties] and Four levels of poultry manure [0, 10, 20 and 30 t/ha and inorganic fertilizer (NPK 15:15:15)]. Soil samples were collected across the experimental field and bulk together into composite. The bulk soil samples were air dried, grounded and sieved through 2 mm sieved for soil physicochemical analysis in the laboratory using standard procedures. The poultry manure sample was also collected for nutrient content composition analysis and later it was incorporated into the experimental field two weeks before transplanting of the seedlings. Leaf samples were collected at 4 and 8 weeks after transplanting (WAT) for nitrogen, phosphorus and potassium nutrient element uptake analysis while fruits samples were collected at 8 WAT for proximate composition. The samples (leaves and fruits) were dried in the shade and later ground into powder form for proximate composition in the laboratory analysis. Data collected were subjected to analysis of variance and means were separated using least significant different.

## RESULTS AND DISCUSSION

Table 1 shows the results of the laboratory analysis of soil and poultry manure samples collected before the commencement of the experiment in the field. The textural class of the soil in the experimental site was Sandy loamy with pH 6.48 in the water and 5.40 in CaCl. The chemical analysis of the soil is based on the rating of Esu (1991) which shows that organic matter (0.35), Total Nitrogen (0.54), Available P (0.08) and Available K were low. Analysis also indicates that elements in the exchangeable base such as $Na^+$ was low, with medium levels of $K^+$ and Ca+ and high level of Mg+. the low status of chemical properties of the soil could be attributed to continues cropping of the experimental site which must been responsible of loses of nutrients. Similar result was reported by Garba Garba *et al*. (2023) who reported low organic carbon, Total nitrogen, available P including low $Mg^+$ in the experimental field.

**Table 1: Physical and chemical properties of soil and poultry manure**

| Physical Properties | Soil | Poultry |
|---|---|---|
| Sand (%) | 73.3 | - |
| Silt (%) | 18.1 | - |
| Clay (%) | 10.6 | - |
| Textural Class | Sandy loam | - |
| **Chemical properties** | | |
| pH in water | 6.48 | 6.30 |
| pH in $CaCl_2$ | 5.40 | - |
| Organic carbon (g/kg) | 0.35 | 25.29 |
| Organic matter (g/kg) | 20.64 | 74.71 |
| Total N(%) | 0.54 | 0.95 |
| Available P (mg/kg) | 0.08 | 0.25 |
| Available K (Cmol/kg) | 0.56 | 2.33 |
| **Exchangeable Base** | | |
| Na+ | 0.46 | 2.12 |
| $K^+$ | 0.29 | 2.33 |
| $Mg^+$ | 1.28 | 0.42 |
| $Ca^+$ | 2.38 | 1.36 |
| CEC | 3.84 | - |

**The effects of variety and poultry manure on the nutrient element absorption by the garden egg leaves**

The effect of variety and poultry manure on the absorption of Nitrogen, Phosphorus, and Potassium in garden eggs is presented in Table 2. The result shows that garden egg varieties were not significantly ($p<0.05$) influenced by the absorption of nitrogen, phosphorus, and potassium elements. The effect of poultry manure on the absorption of nitrogen and phosphorus differed significantly at both 4 and 8 WAT. Poultry manure applied 30 t/ha consistently influenced the highest absorption of nitrogen, phosphorus and potassium at 4 and 8 WAT, but were statistically similar with the result obtained at 20kg/ha of poultry manure except at 4 WAT. Nutrient composition of potassium at 4 and 8 WAT recorded statistically similar results when applied with 0 t/ha and NPK: 15:15:15 including phosphorus at 4 WAT. Application of poultry manure at the rates of 0 t/ha, NPK 15:15:15 at 4 and 8 WAS respectfully including phosphorus at 8 WAT recorded the lowest nutrient composition in this study, but lower than the compositions of obtained from phosphorus at 4 and 8 WAT under the application of 0 t/ha and 10 t/ha. The high content of nitrogen, phosphorus and potassium found in the leaves of egg plant as a result of the application of high poultry manure (20 to 30 t/ha) might be connected to gradual but steady release of nutrients by organic manure. This finding agree with work of Ogunwale *et al*. (2017), Singh *et al*. (2018) and Liu *et al*. (2020) who reported increase in the uptake of N, P and K in tomato, spinach and lettuce respectfully.

**Table 2: Effect of variety and poultry manure on the absorption of Nitrogen, Phosphorus, and Potassium by garden egg leaves**

| | NITROGEN | | PHOSPHORUS | | POTASSIUM | |
|---|---|---|---|---|---|---|
| **Treatments** | 4 WAT | 8 WAT | 4 WAT | 8 WAT | 4 WAT | 8 WAT |
| **VARIETY** | | | | | | |
| Local | 1.55a | 0.86a | 0.98a | 0.78a | 0.71a | 0.54a |
| Improved (Easter white) | 1.49a | 0.76a | 0.99a | 0.78a | 0.69a | 0.49a |
| **POULTRY MANURE** | | | | | | |
| 0 t/ha | 1.05c | 0.63c | 0.08b | 0.67b | 0.50a | 0.39a |
| 10 t/ha | 1.31b | 1.04b | 0.07b | 0.60b | 0.49a | 0.37a |
| 20 t/ha | 1.52a | 1.26a | 0.08b | 0.78a | 0.56a | 0.32a |
| 30 t/ha | 1.58a | 1.35a | 1.01a | 0.89a | 0.60a | 0.39a |
| NPK 15:15:15 | 1.12bc | 0.50c | 0.90a | 0.12c | 0.57a | 0.33a |

Values carrying the same letter(s) in the same column are not significantly different at 5% probability level ($P<0.05$) according to the Least Significant Difference (LSD). WAT: Weeks after transplanting.

**The effect of variety and poultry manure application on the percentage proximate composition of garden egg fruit**

Table 3 shows the effect of variety and poultry manure on the percentage proximate composition of garden egg fruits. The local and improved varieties did not differ significantly on the fruit content of the parameters measured except with ash content where the local variety significantly has a higher content of ash compared to the improved variety. The effect of poultry manure on the percentage proximate composition of garden egg fruit was significant on all parameters measured except the energy value. Application of 20 and 30 t/ha of poultry manure resulted in significantly lowest percentage moisture content (dry weight basis) compared to other treatments. Control and check (inorganic fertilizer) significantly had the lowest ash content compared to others. The consistently high percentage content of crude fibre, crude fat, crude protein, carbohydrate, and energy value as result of application of poultry manure might be due to the gradual and steady release of nutrients. Application of organic manure has been reported to significantly influence the proximate composition of vegetables thereby enhancing their nutritional values (Singh et al., 2018, Ogunwale *et al*., 2017, and Kumar et al., 2019)

Table 3: Effect of variety and poultry manure on the percentage proximate composition of garden egg fruits at 8 weeks after transplanting

**Table 3: Effects of variety and poultry manure on the percentage proximate composition of garden egg fruits at 8 WAT.**

| Treatments | Moisture content (DWB) | Ash | Crude fibre | Crude fat | Crude protein | CHO | Energy value |
|---|---|---|---|---|---|---|---|
| **VARIETY** | | | | | | | |
| Local | 4.17 | 4.08a | 24.38 | 1.05 | 2.90 | 63.42 | 274.71 |
| Improved (Easter white) | 4.33 | 2.71b | 21.56 | 1.05 | 2.93 | 63.42 | 251.55 |
| **POULTRY MANURE** | | | | | | | |
| 0 t/ha | 4.60a | 2.40c | 22.22b | 0.88b | 0.83c | 57.37b | 263.14a |
| 10 t/ha | 4.17a | 3.57a | 20.73c | 1.07b | 1.98b | 67.49a | 252.30a |
| 20 t/ha | 3.47b | 4.72a | 24.18a | 0.95b | 1.54b | 60.59ab | 246.68a |
| 30 t/ha | 3.47b | 4.26a | 21.63 | 1.23a | 4.35a | 65.26a | 287.75a |
| NPK 15:15:15 | 4.56a | 2.46 | 26.11a | 1.32a | 3.39a | 60.98ab | 265.76 |

Values carrying the same letter(s) in the same column are not significantly different at 5% probability level (P<0.05) according to the Least Significant Difference (LSD)

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