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General Information about Journal of Agriculture and Agricultural Technology

Background:

The Journal of Agriculture and Agricultural Technology, Minna, was established in the early 90s with Prof T.Z. Adama as the pioneer Editor-in-Chief. It is housed within the School of Agriculture and Agricultural Technology of the Federal University of Technology, Minna, Nigeria. The journal has been a prominent platform for disseminating research and knowledge in the field of agriculture and related technologies.

Philosophy:

The journal operates with the philosophy of advancing agricultural research and technology through the publication of original works and review articles. It aims to foster innovation, promote sustainable agricultural practices, and contribute to the growth of the agricultural sector. By providing a scholarly space for researchers and experts, the journal plays a vital role in the academic and practical development of agriculture and related areas.

Management:

Under various visionary leadership and editorial teams, the Journal of Agriculture and Agricultural Technology, Minna, has maintained a commitment to quality and excellence. The management is dedicated to upholding rigorous editorial standards, ensuring the publication of high-impact research, and facilitating a dynamic platform for collaboration and knowledge exchange within the agricultural community.

Future Prospects:

The journal has demonstrated remarkable growth over the years, evolving from an annual publication to a biannual one. Looking forward, there are ambitious plans to transition to a quarterly publication schedule. This strategic move reflects the journal's commitment to keeping pace with the rapid advancements in agricultural research and technology and providing a more frequent outlet for the dissemination of groundbreaking findings.

The Journal of Agriculture and Agricultural Technology, Minna, aspires to expand its readership and impact, reaching an even larger community at a faster rate. By doing so, it aims to contribute significantly to the global discourse on innovative solutions to the challenges facing agriculture and related areas. The future prospects include leveraging technology to enhance accessibility, collaborating with international researchers, and maintaining a steadfast commitment to excellence in agricultural research dissemination.

The journal has a rich history, a clear philosophical foundation, effective management, and ambitious plans for the future. Its evolution from an annual to a quarterly publication is a reflects its adaptability and commitment to advancing agricultural knowledge and technology.

EDITORIAL

Release of Volume 13 - Journal of Agriculture and Agricultural Technology (JAAT)

The Editorial Board is delighted to unveil Volume 13 of our esteemed Journal, marking another milestone in our commitment to scholarly excellence. As we look ahead, we anticipate the release of more issues and a special edition in 2024, promising a year of enriched academic discourse and valuable insights.

We are glad to share that our online-first approach is now a permanent feature, ensuring our esteemed readership has swift access to cutting-edge research. Furthermore, we are happy to state that many of our past editions are now online. All hard copies will be made available immediately after the online version has been released. All these are aimed towards a more extensive reach and impact within the academic community.

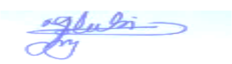
Deepest gratitude is extended to all dedicated members of the Board for their unwavering commitment in bringing forth this edition despite the numerous work load and challenges faced in 2023/2024. The collective effort and perseverance have truly made this achievement possible. Our sincere appreciation goes out to our diligent reviewers who dedicated their time, effort and resources to ensure timely and rigorous review of submitted articles. We value your contribution in upholding scholarly standards. As we navigate a global audience, we encourage our reviewers to adopt a more critical stance by continuously improving the quality and timeliness of their reviews.

We extend our profound appreciation to the Board of School of Agriculture and Agriculture Technology, Federal University of Technology, Minna, Nigeria as well as the entire University Community, for the honour bestowed upon us to serve as Editorial Board members. We recognize the significance of this trust and assure you that we will continue to do our best.

Lastly, we express our gratitude to everyone involved in making Volume 13 a reality. We are eager to continue our journey of academic exploration and look forward to the valuable contributions that will shape the future editions of the Journal.

Warm regards,

Editor-in-Chief



Prof. O.J. Alabi

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EFFECT OF *MORINGA OLEIFERA* LEAF POWDER AS SUBSTITUTE FOR LYSINE ON STORAGE QUALITY PROPERTIES OF BROILER BREAST MEAT

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ABSTRACT

This experiment explores the effect of Moringa oleifera leaf powder (MOLP) as a natural substitute for synthetic lysine supplementation in broiler diets on storage quality properties of broiler breast meat. The study used 250-day-old Cobb-500 broiler chickens in a completely randomized design, with five treatment groups receiving different proportions of synthetic lysine and MOLP during the starter and finisher phases. The meat quality properties evaluated were pH, water holding capacity, cooking yield, and thawing loss (TL). The results showed that MOLP significantly (p≤0.05) impacted meat quality properties as values recorded for each quality property followed a specific trend. The minimum values (5.35) recorded for pH were in Month1 and Month 2 at T4 (25% lysine and 75% MOLP) and T3 (50% lysine and 50% MOLP), respectively, while the maximum value (6.82) was recorded at Month 6 in chickens fed T5 (0% lysine and 100% MOLP). The dietary treatment also affected water holding capacity, with Month 1 showing the lowest value (2.46 %) in chickens fed diet T4, while Month 6 revealed the value (6.86 %) in chickens fed diet 2. The effect of dietary treatment on cooking yield and loss did not take a specific/straight trend as the cooking yield was highest at Month 2 (69.27 %) and *lowest at Month 5 (42.96) in T2 and T4, respectively. The cooking loss was also recorded at 49.73 % in Month 6 in Diet T1 and 31.05 % in Month 1 in Diet T5. The thawing loss followed a steady trend and increased in value from month 1 to 6, with the lowest value being recorded at Month 1 (1.02 %) in chickens fed diet T3, while the highest value was recorded in Month 6 (8.5 %) in chickens fed diet T1. The effect of MOLP as a substitute for lysine on storage duration impacted all the meat quality properties evaluated.*

Keywords: Broiler chickens, Lysine, Meat quality and *Moringa oleifera*,

INTRODUCTION

Broiler meat, as an affordable and good source of protein, is rich in low amounts of collagen, trace vitamins, mainly thiamin, vitamin B6, and pantothenic acid. It is a good source of iron, zinc, and copper, and has a low-fat content, making it a better decision for consumers (Naji *et al.,* 2013). These nutritional attributes, which are often overlooked, make broiler meat an important component of our meals (Arshad *et al.*, 2016) and, hence, the rising demand for a higher meat yield in the global broiler industry (Rehman *et al.*, 2018).

The poultry industry is an essential sector in Nigeria, contributing significantly to the country's economy and providing a valuable source of animal protein for its population (Heise *et al.*, 2015). Meanwhile, as the demand for poultry products grows in Nigeria and worldwide, it becomes imperative to explore sustainable and eco-friendly practices that can improve productivity while addressing environmental and welfare concerns (Anabaraonye *et al.*, 2021). Poultry scientists are poised to apply organic feed supplements, which may portend therapies to improve the well-being and performance of chickens (Mahfuz *et al.*, 2018a). Therefore, poultry studies are tailored toward finding possible organic feed materials that will be both ecologically adaptive and healthy for human consumption (Pourhossein *et al.,* 2015; Mahfuz *et al.*, 2018b). These make finding alternatives to synthetic additives like lysine using plant sources such as *Moringa* as a natural alternative to synthetic lysine supplementation in broiler diets while considering its potential in addressing environmental and sustainability concerns and as well as improving animal welfare and the nutritional value of the poultry products (Kaderides *et al.,* 2021).

Moringa oleifera, a tropical plant renowned for its nutritive and medicinal properties, has gained considerable attention as a potential natural alternative to synthetic lysine supplementation in broiler diets (Mahfuz and Piao, 2019). *Moringa oleifera* leaf is rich in essential amino acids, vitamins, minerals, and bioactive compounds, making it a promising resource to address the nutrient requirements of broiler chickens (Taufek *et al.,* 2022). Therefore, this experiment was undertaken to study the effect of MOLP as an alternative to lysine on the storage quality properties of broiler breast meat.

MATERIALS AND METHODS

Location of the experi

ment: The study was carried out at the Department of Animal Production Teaching and Research Farm, FUT Minna, Niger State, Nigeria. The area lies in southern Guinea's savannah belt of Nigeria, with rainfall ranging from 1100 to 1600 mm per annum and an average temperature of 29 °C.

The Moringa *oleifera* Leaf Powder and its Chemical Evaluation: The fresh *Moringa oleifera* leaf was air dried in an open-air space under a shade that prevented direct sunlight radiation to avoid losing its green colouration. The dried leaf was pulverised afterwards using a conventional grinding machine. Following the description of AOAC (2020), the *Moringa oleifera* leaf powder was analysed for proximate composition (crude protein, fat, fibre, ash, moisture, and carbohydrate), anti-nutrients (alkaloid, saponin, oxalate, tannins, cyanide and phytates) and phenolics.

Table 1: Proximate Compositions of *Moringa oleifera* Leaf Powder (MOLP)

Protein (%)	28.33
Ether Extract (%)	3.40
Fibre (%)	16.70
Ash (%)	4.80
Moisture (%)	5.00
Nitrogen Free Extract (NFE) (%)	42.05

Table 2: Phytochemical Composition of *Moringa oleifera* Leaf Powder (MOLP)

Alkaloids (g/100g)	4.95
Saponins (g/100g)	6.44
Oxalates (g/100g)	12.56
Tannins (g/100g)	8.80
Cyanides (g/100g)	0.04
Phytates (g/100g)	2.95
Phenolics Composition	
Phenolic acids (g/100g)	41.35
Flavonoids (g/100g)	12.22

Sources of the Experimental Birds and MOLP: A total of 250-one-day-old Cobb-500 broiler chickens were used for the experiment. They were obtained from Olam Hatchery, Kaduna, Nigeria. *Moringa oleifera* leaf was obtained at villages around the university community.

Experimental Design and Feeding Management: The birds (Chickens) were cared for under deep litter and were divided into five (5) diet groups designated as T1, T2, T3, T4, and T5 using a completely randomized design experimental design. Each treatment had five replicates of ten (10) chicks each. The group T1 constituted birds fed 100 % synthetic lysine and 0 % MOLP, T2 constituted birds fed 75 % synthetic lysine and 25 % MOLP, T3 constituted birds fed 50 % synthetic lysine and 50 % MOLP, T4 constituted birds fed 25 % synthetic lysine and 75 % MOLP, while T5 constituted birds administered 0 % synthetic lysine and 100 % MOLP.

While adopting the method of Cargil *et al.* (2007), the birds were orally administered vaccines through drinking water. Lasota vaccine at days seven and twenty-one and Gumboro vaccine at days fourteen and twenty-eight. Experimental starter and finisher diets (Tables 1 and 2) and water were provided *ad libitum.* After the feeding trial, two birds of average weight from each replicate were selected for meat quality analysis. The selected chickens were deprived of feed for twelve hours (6:00 PM to 10:00 AM the following day), after which the chickens' live weight was taken. This was preceded by slaughtering, using a kitchen knife to cut the jugular vein for proper bleeding. The individual slaughter weight was taken, and the slaughtered bird was submerged in warm water (60 seconds) for a few seconds for easy manual feather plucking. The plucked weight was recorded, and evisceration ensued. The dressed weight of each carcass was recorded. The dressed carcass was cut into parts (breast, thigh, drumstick, wings, back, and neck) and visceral (liver, heart, gizzard, abdominal fat, Intestine, and lungs). The breast meat samples from each replicate were separately packed in a polyethene bag and stored at 5 degrees Celsius for 6 Months. The meat quality properties were assessed at one-month intervals during the six-month storage period.

Assessment of meat quality characteristics: The following parameters were measured to evaluate the quality of breast meat. pH, Water Holding Capacity (WHC), Thawing Loss (TL), Cooking yield (CY) and Cooking Loss (CL).

pH

The breast muscle samples' pH was measured using a pH meter (pH spear, model 35634-40, Eurotech Instruments, Malaysia). This was done by making an incision with a kitchen knife into the breast meat and placing the probe into the incised point while the displayed value on the pH meter screen was recorded. This was carried out for six (6) months.

Water Holding Capacity

While adopting the methodology of Kaufman *et al.* (1992), a 5g sample of breast meat was placed under two filter papers and pressed under a screw jack to get rid of the inherent liquid. WHC was calculated thus;

$$WHC(\%) = \frac{InitialWeight - Finalweight}{Initialweight} \times 100$$

Thawing Loss

Fifty grams of the breast (pectoral) muscle sample was packed in a polythene bag and frozen under 4 ^{o}C for 24 hours. After that, the sample was submerged in a water basin, which was changed twice every 30 minutes. The thawing loss was assessed following the description of Northchut *et al.* (1994) by calculating the differences between initial and final weight and expressing it as the percentage of the initial weight.

Table 3: Starter Diets of Broiler Chickens Fed Diets Containing *Moringa oleifera*Leaf Powder (MOLP) as Substitute for Synthetic Lysine (SL)

Ingredients (kg)	T1	T2	T3	T4	T5
Maize	50.57	50.38	49.48	47.87	46.97
Maize Offal	11.00	11.00	11.00	11.00	11.00
Groundnut Cake	32.43	30.95	30.17	30.11	29.34
Fish meal	3.00	3.00	3.00	3.00	3.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25
Vitamin Premix	0.25	0.25	0.25	0.25	0.25
SL	0.25	0.19	0.13	0.06	0.00
MOLP	0.00	1.74	3.47	5.21	6.94
Methionine	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analyses					
Crude Protein%	23.00	23.00	23.00	23.00	23.00
Metabolizable Energy (Kcal/kg)	2855.62	2860.50	2857.71	2847.73	2845.06

T1: 100% SL, 0% MOLP, T2: 75% SL, 25% MOLP, T3: 50% SL, 50% MOLP, T4: 25% SL, 75% MOLP, T5: 0% SL, 100% MOLP, SL: Synthetic Lysine, MOLP: *Moringa oleifera* leaf powder

Cooking Yield

The assessment of cooking yield of the breast meat sample was determined using the method of Bethany *et al.* (2012). A 20 g breast meat sample was taken for boiling. The breast meat sample was placed in a glass container of 20 ml of water and the water bath was preheated for five minutes at 100 degrees Celsius. The glass container was then placed in the water bath and cooking was done at 75 ^{o}C for thirty minutes. The sample was retrieved from the water bath, allowed to cool to room temperature, and cleaned off of excess liquid. the new weight of the sample was recorded. The cooking yield was calculated thus;

$$Cookingyield(\%) = \frac{Cookedmeatweight(g)}{Initialmeatweight(g)} \times \frac{100}{1}$$

Table 4: Finisher Diets of Broiler Chickens Fed Diets Containing *Moringa oleifera* Leaf Powder (MOLP) as Substitute for Synthetic Lysine (SL)

Ingredients (kg)	T1	T2	T3	T4	T5
Maize	64.27	64.08	63.16	61.57	60.67
Maize Offal	5.00	5.00	5.00	5.00	5.00
Groundnut Cake	24.73	23.25	22.49	22.41	21.64
Fish meal	3.00	3.00	3.00	3.00	3.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25
Vitamin Premix	0.25	0.25	0.25	0.25	0.25
SL	0.25	0.19	0.13	0.06	0.00
MOLP	0.00	1.74	3.47	5.21	6.94
Methionine	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analyses					
Crude Protein%	20.00	20.00	20.00	20.00	20.00
Metabolizable Energy (Kcal/kg)	3009.56	3014.44	3011.44	3001.67	2999.00

T1: 100% SL, 0% MOLP, T2: 75% SL, 25% MOLP, T3: 50% SL, 50% MOLP, T4: 25% SL, 75% MOLP, T5: 0% SL, 100% MOLP, SL: Synthetic Lysine, MOLP: *Moringa oleifera* leaf powder

Data Analysis

Using the statistical software SPSS V.23.0.0, a widely accepted tool for data analysis in scientific research, the recorded experimental data were subjected to a one-way analysis of variance (ANOVA). Means were separated at P≤0.05) probability level using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effect of *Moringa oleifera*Leaf Powder on pH of Stored Broiler Chickens' Meat

The effect of MOLP on storage quality significantly influenced the meat pH at various inclusion levels from the second month to the sixth month (Table 5). No significant (P>0.05) differences in pH within the first month across the Treatment groups of MOLP. These differences in pH from the second to the sixth month did not follow a specific trend, indicating that MOLP inclusion in broiler chicken diets did not affect the pH of broiler chicken meat within the first month of storage. The minimum pH of stored broiler chicken meat recorded is similar to the value reported by Soeparno (2009), whereas the maximum value (6.80) recorded is in variance with that (6.50) reported by Soeparno (2009).

Similarly, the water-holding capacity of broiler chicken meat administered various inclusions of MOLP (Table 6) did not vary across the treatment groups within the first two months of storage of the meat. The result of water holding capacity of broiler chicken meat differed significantly ($P \leq 0.05$) across the MOLP treatment group from the third to the sixth month, even though these differences did not follow any specific pattern, just as observed in the result of the broiler chicken meat pH seen earlier. The findings align with previous research, indicating that the treatment choice can also influence the meat's water retention ability (Cheng and Sun, 2008), as the mean values ranged from 2.46 in the first month in T4 to 6.86 in the 6th Month in T2. This is also similar to the report of Muthukumar *et al.* (2012) that the addition of *Moringa oleifera* leaf extracts increased the WHC of goat meat and raw pork patties, as is now seen in broiler chicken meat, especially from the third to the sixth month in the present study (Table 6).

The result of the cooking yield of broiler chicken meat presented in Table 7 shows significant ($P \leq 0.05$ differences in cooking yield across the treatment group of MOLP from the first month up until the sixth month. The result within the first three months of storage indicated that the cooking yield variation across the MOLP treatment group followed the same trend. While differences in the cooking yield of meat of chickens administered MOLP existed, there was no specific pattern of variation from the fourth to the sixth month across the treatment groups (Table 7). This indicates that treatment can certainly influence the cooking yield of the meat. Comparing these findings with previous studies, it is important to note that there is limited research specifically investigating the effect of *Moringa oleifera* on the storage quality of broiler meat. However, studies have been conducted examining the individual effects of *Moringa oleifera* treatment and storage duration on meat quality parameters. These previous studies investigating *Moringa oleifera* as a treatment for broiler meat quality have reported varying results. Some studies have suggested that *Moringa oleifera* supplementation can positively impact meat quality characteristics, such as tenderness and juiciness. These effects may be attributed to the bioactive compounds present in *Moringa oleifera*, including antioxidants and anti-inflammatory agents. However, it is worth noting that the specific impacts of *Moringa oleifera* treatment on carcass yield have not been extensively explored in the existing literature. The results of this study, therefore, provide valuable insights into the potential benefits of Moringa oleifera supplementation on the quality of broiler chicken meat.

The result of Thawing Loss presented in Table 8 shows a significant difference between the treatment groups as measured from the first to sixth months. Treatment 2 had the highest Thawing loss in 2nd Month. Generally, the results did not follow a particular pattern. This is also in variance with the findings by Lawrie (1998) that diet does not seem to affect drip loss, and Comale *et al.* (2011) reported that the use of the phytotherapeutic compound in the diets does not globally influence drip and cooking losses. The significant differences in thawing loss across the treatment groups suggest that the inclusion of Moringa oleifera Leaf Powder in broiler chicken diets can influence the thawing loss of the meat, potentially affecting its overall quality and nutritional value.

Table 5: Effect of *Moringa oleifera* Leaf Powder on pH of Stored Broiler Chickens' Meat

TRT	T1	T2	T3	T4	T5	SEM	LOS
1ST Month	5.40	5.40	5.40	5.35	5.35	0.01	NS
2ND Month	5.60^{a}	5.50^{ab}	5.35^{b}	5.55^{a}	5.65^{a}	0.03	*
3RD Month	5.80^{ab}	5.75^{b}	5.45^{d}	5.65^{c}	5.85^{a}	0.04	*
4TH Month	6.10^{cd}	6.15^{c}	6.05^{d}	6.25^{b}	6.40^{a}	0.03	*
5TH Month	6.15^{d}	6.40^{c}	6.35^{c}	6.50^{b}	6.65^{a}	0.05	*
6TH Month	6.80^{a}	6.55^{b}	6.55^{b}	6.75^{a}	6.80^{a}	0.03	*

^{abcd}: Means with varying superscripts and on the same row are significantly (P≤0.05) different. Trt: Treatment, T1: 100% Synthetic lysine, 0% *Moringa oleifera* leaf powder, T2: 75% Synthetic lysine, 25% *Moringa oleifera* leaf powder, T3: 50% Synthetic lysine, 50% *Moringa oleifera* leaf powder, T4: 25% Synthetic lysine, 75% *Moringa oleifera* leaf powder, T5: 0% Synthetic lysine, 100% *Moringa oleifera* leaf powder, SEM: Standard Error of Mean, LOS: Level of significance

Table 6: Effect of *Moringa oleifera* Leaf Powder on Water Holding Capacity of Stored Broiler Chickens' Meat

TRT	T1	T2	T3	T4	T5	SEM	LOS
1ST Month	2.52	2.75	2.51	2.46	2.48	0.08	NS
2ND Month	2.70	2.89	3.08	3.11	2.68	0.07	NS
3RD Month	2.85^{b}	3.38^{a}	3.21^{a}	3.42^{a}	3.23^{a}	0.07	*
4TH Month	3.86^{c}	4.00^{bc}	3.22^{d}	4.32^{a}	4.18^{ab}	0.10	*
5TH Month	5.05^{b}	6.33^{a}	5.11^{b}	4.72^{b}	5.36^{b}	0.16	*
6TH Month	6.02^{cd}	6.86^{a}	5.81^{d}	6.56^{ab}	6.32b^{c}	0.11	*

^{abcd}: Means with varying superscripts and on the same row are significantly (P≤0.05) different. Trt: Treatment, T1: 100% Synthetic lysine, 0% *Moringa oleifera* leaf powder, T2: 75% Synthetic lysine, 25% *Moringa oleifera* leaf powder, T3: 50% Synthetic lysine, 50% *Moringa oleifera* leaf powder, T4: 25% Synthetic lysine, 75% *Moringa oleifera* leaf powder, T5: 0% Synthetic lysine, 100% *Moringa oleifera* leaf powder, SEM: Standard Error of Mean, LOS: Level of significance

Table 7: Effect of *Moringa oleifera* Leaf Powder on Cooking Yield of Stored Broiler Chickens' Meat

TRT	T1	T2	T3	T4	T5	SEM	LOS
1ST Month	66.72^{b}	68.23^{a}	64.26^{c}	54.17^{e}	59.48^{d}	1.38	*
2ND Month	67.85^{b}	69.27^{a}	66.40^{c}	57.61^{e}	64.21^{d}	1.10	*
3RD Month	61.13^{b}	63.23^{a}	60.66^{b}	52.52^{c}	58.02^{d}	1.01	*
4TH Month	60.06^{ab}	59.31^{b}	60.27^{a}	49.66^{d}	52.23^{c}	1.20	*
5TH Month	54.66^{a}	51.20^{b}	54.67^{a}	42.96^{c}	43.12^{c}	1.44	*
6TH Month	56.00^{a}	50.63^{c}	54.99^{ab}	45.86^{d}	54.31^{b}	1.01	*

^{abcd}: Means with varying superscripts and on the same row are significantly (P≤0.05) different. Trt: Treatment, T1: 100% Synthetic lysine, 0% *Moringa oleifera* leaf powder, T2: 75% Synthetic lysine, 25% *Moringa oleifera* leaf powder, T3: 50% Synthetic lysine, 50% *Moringa oleifera* leaf powder, T4: 25% Synthetic lysine, 75% *Moringa oleifera* leaf powder, T5: 0% Synthetic lysine, 100% *Moringa oleifera* leaf powder, SEM: Standard Error of Mean, LOS: Level of significance

Table 8: Effect of *Moringa oleifera* leaf powder on thawing loss of stored broiler chickens' meat

TRT	T1	T2	T3	T4	T5	SEM	LOS
1ST Month	1.30^{ab}	1.37^{a}	1.02^{b}	1.06^{ab}	1.15^{ab}	0.05	*
2ND Month	2.00^{a}	1.86^{b}	1.33^{cd}	1.42^{c}	1.31^{d}	0.08	*
3RD Month	2.18^{a}	2.13^{a}	1.16^{c}	2.16^{a}	1.95^{b}	0.10	*
4TH Month	3.02^{c}	3.41^{b}	1.28^{e}	3.77^{a}	2.69^{d}	0.23	*
5TH Month	5.33^{c}	5.02^{d}	4.33^{e}	6.23^{b}	6.33^{a}	0.20	*
6TH Month	8.51^{a}	8.29^{a}	5.79^{c}	7.24^{b}	8.19^{a}	0.28	*

^{abcd}: Means with varying superscripts and on the same row are significantly ($P \leq 0.05$) different. Trt: Treatment, T1: 100% Synthetic lysine, 0% *Moringa oleifera* leaf powder, T2: 75% Synthetic lysine, 25% *Moringa oleifera* leaf powder, T3: 50% Synthetic lysine, 50% *Moringa oleifera* leaf powder, T4: 25% Synthetic lysine, 75% *Moringa oleifera* leaf powder, T5: 0% Synthetic lysine, 100% *Moringa oleifera* leaf powder, SEM: Standard Error of Mean, LOS: Level of significance

CONCLUSION

This study indicates that including *Moringa oleifera* leaf powder (MOLP) significantly influenced broiler meat quality. While cooking yield did not show a consistent pattern of increase, other quality properties such as pH, WHC, CL, and TL were notably influenced over the months of storage, providing valuable insights into the effects of MOLP inclusion. It is clear from the study that *Moringa oleifera* treatment and storage duration significantly influenced broiler meat's cooking yield. These findings underscore the need for further investigation into the specific impacts of *Moringa oleifera* treatment on cooking yield, a promising area for future research.

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NUTRITIONAL, THERMAL, PHYSICAL, AND ENGINEERING PROPERTIES OF BAMBARA GROUNDNUTS (Vigna subterranean (L) VERDC.) SEEDS CULTIVATED IN NIGERIA

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ABSTRACT

Bambara groundnut is an underutilized African legume that has the potential to contribute to improved food and nutrition security while providing solutions for environmental sustainability and equity in food availability and affordability. This research aimed to determine the thermal, physical, and engineering resources properties of three varieties of Bambara groundnut seeds grown in Nigeria. The study was a factorial experiment in a completely randomized design. The thermal, physical, and engineering properties of the red, cream, and multi-coloured varieties of Bambara groundnut seeds were determined at moisture contents of 6.00 %, 7.00 %, and 9.94 %. The values for the mean thermal conductivity, specific heat capacity, latent heat, and thermal diffusivity were 0.24 ± 0.02 Wm-1K-1, 1.62 ± 0.11 KJ Kg-1K-1, 20.10 ± 1.20 KJKg-1 and 0.12 ± 0.01×10-7 m2s-1 for the red variety; 0.25 ± 0.01Wm-1K-1, 1.65 ± 0.11 KJ Kg-1K-1, 23.45 ± 0.01 KJKg-1 and 0.11 ± 0.01×10-7 m2s-1for cream variety and 0.24 ± 0.01 Wm-1K-1, 1.62 ± 0.12 KJ Kg-1K-1, 32.96 ± 0.01KJKg-1 and 0.12 ± 0.01 × 10-7 m2s-1. The mean values for bulk density, true density, and porosity were 0.75 ± 0.02 kgm-3, 1.25 ± 0.02 kgm-3 and 40.27 ± 1.29 % for the red variety 0.77 ± 0.01 kgm-3, 1.37 ± 0.01 kgm-3 and 43.91 ± 0.75 % for the cream and 0.70 ± 0.05 kgm-3, 1.23 ± 0.16 kgm-3 and 42.45 ± 11.70 % for the multi-coloured variety. The mean angle of repose and coefficient of static friction over stainless steel, glass, formica, and plywood surfaces were 25.31 ± 1.89o, 0.22 ± 0.02, 0.23 ± 0.35, 0.28 ± 0.05, and 0.28 ± 0.05 for the red, 20.11 ± 1.40o, 0.14 ± 0.02, 0.17 ± 0.03, 0.16 ± 0.01 and 0.18 ± 0.02 for the cream and 22.02 ± 1.36o, 0.21 ± 0.01, 0.18 ± 0.03, 0.20 ± 0.16 and 0.20 ± 0.02 for the multi-coloured variety. This implies that these values are in the normal distribution of properties in heat transfer. These implications are that the transport properties of food during *processing and preservation are based on these parameters. They are, therefore, of utmost importance in predicting heat and mass transfer rates during preservation and optimal design of processing equipment. The physical properties of food and agricultural materials, such as mass, size, shape, surface area, volume, aspect ratio, sphericity, true density, bulk density, porosity, and angle of repose, are the attributes that are relevant to the design and development of harvesting, handling, processing and storage equipment for the specified material. There was no significant (P>0.05) difference between the values of the coefficient of static friction for the red and multi-coloured varieties on stainless steel and glass surfaces. It can be concluded that all varieties of Bambara groundnut grain in Nigeria can withstand processing and preservative stress.*

Keywords: Bambara, Equipment, Engineering Handling Physical

INTRODUCTION

Bambara groundnut is reported to have been widely cultivated in tropical areas of the world since the seventeenth century. Outside sub-Saharan Africa, Bambara groundnut is now enormously distributed and cultivated in Asia, some regions of Northern Australia, and Southern and Central America and Oceania (Baudoin and Mergeai, 2001). It is cultivated throughout Africa (Atiku *et al.*, 2004; Oluwole *et al.*, 2007). It is known to have its origin in the Sahelian area of present West Africa, in the Bambara area, a district occupying the Upper Niger close to Timbuktu, which is now majorly located in Central Mali (Nwanna *et al.*, 2005). Nigeria is considered a major producer of Bambara groundnut in Africa (Ibrahim and Ogunwusi, 2016). Bambara groundnut is an important leguminous crop that has a similar composition to cowpea (Oyeyinka *et al*., 2018). It is an important source of affordable protein in diets, especially in regions where animal protein is comparatively expensive (Mubaiwa *et al*., 2018).

Bambara groundnut is an underutilized African legume that has the potential to contribute to improved food and nutrition security while providing solutions for environmental sustainability and equity in food availability and affordability (Tan *et al*., 2020). Bambara groundnut is a sustainable, low-cost source of complex carbohydrates and plant-based protein. It is low in unsaturated fatty acids and rich in essential minerals. Despite its impressive nutritional and agro-ecological profile, the potential of Bambara groundnut to improve the global food system is undermined by several factors, including resource limitation, knowledge gap, social stigma, and lack of policy incentives (Tan *et al*., 2020). Consumers have always continued to demand food products with high nutritional value and extra health benefits (Mpho, 2020). On average, Bambara seed comprises approximately 19 % protein, 63 % carbohydrate, and 6.5 % fat. The fatty acid composition is mainly linoleic, linolenic, and palmitic (Minka and Bruneteau, 2000; Bamishaiye *et al*., 2011). Bambara groundnut has a higher quantity of lysine than all other legumes, and the seed possesses higher amounts of methionine than all other grain legumes (Addo and Oyeleke, 1986). Bambara groundnuts are a good source of starch that may be potentially used for various industrial applications (Oyeyinka *et al.*, 2019). Bambara starch was modified with lipids for improved functionality (Oyeyinka *et al*., 2016b, c). The use of Bambara starch in complexation with lipids and biofilm application is special in many ways. Bambara starch has an amylose content of 20 % to 35 % (Sirivongpaisal, 2008; Oyeyinka *et al*., 2015), which is higher than that of corn and potato starches (Oyeyinka *et al*., 2016).

According to Burubai and Amber (2014), physical properties of food and agricultural materials such as mass, size, shape, surface area, volume, aspect ratio, sphericity, true density, bulk density, porosity, and angle of repose are the attributes that are relevant to the design and development of harvesting, handling, processing, and storage equipment for the specified material. The mass, size, and shape are essential for sorting, grading, and separation operations (Zare *et al*., 2013; Chandrasekar and Viswanathan, 1999). The static coefficient of friction of seed against the various surfaces is also necessary for designing conveying, transporting, and storing structures (Taser*et al*., 2005). Many researchers have studied agricultural products' thermal, physical, and engineering properties. They have reported thermal, physical, and mechanical properties of roots, seeds, nuts, kernels and fruits such as sweet potato (Obomeghei and Ebabhamiegbebho, 2020), corn seed (Babic *et al*., 2013), flaxseed (Singh *et al*., 2012), arigo seeds (Davies, 2010), lentil seeds (Bagherpour *et al*., 2010), soybeans (Davies and El-Oken, 2009), groundnuts (Davies, 2009), chia seeds (Ixtaina *et al*.,2008), rice (Correa *et al*., 2007), watermelon seeds (Razavi and Milani, 2006), maize (Bart-Plange *et al*., 2005), raw and parboiled paddy (Reddy and Chakraverty, 2004), and hemp seeds (Sacilik *et al*., 2003). Despite these efforts, very little has been done on Bambara groundnut seeds' thermal, physical, and engineering properties. Baryeh (2001) studied the physical properties of Ghanian bambara groundnuts; Mpotokwane *et al*. (2008) studied the physical properties of Bambara groundnuts from Botswana, while Abioye (2016) studied some moisture-dependent physical and thermal properties of Bambara groundnut. According to Mariani *et al*. (2008), interest in the transport properties of foods (thermal conductivity, heat capacity, density, mass and thermal diffusivity, and heat and mass transfer coefficient) appear due to the importance of predicting heat and mass transfer rates during processing, preservation and optimal design of processing equipment. Therefore, the objective of this study was to determine the thermal, physical, and engineering properties of three varieties of Bambara groundnut (red, cream, and multi-coloured) seeds grown in Nigeria.

MATERIALS AND METHODS

Materials

Matured and dried Bambara groundnut seeds were purchased in Uchi Market, Auchi, Nigeria

Experimental Design

The study was carried out as a factorial experiment in a completely randomized design.

Methods

Proximate Composition

The proximate analyses of the dried Bambara groundnut were conducted according to the methods described in AOAC (2010).

Determination of Thermal Properties

Thermal conductivity

The thermal conductivity (K) of food materials is related to the composition of the material and was estimated using the method described by Sweat (1986) as:

K = 0.25 mc + 0.155 mp + 0.16 mf + 0.135 ma + 0.58 mm.

Where mc = mass of carbohydrate, mp = mass of protein, mf = mass of fat, ma = mass of ash, and mm = mass of moisture in the food material.

Specific heat capacity

The specific heat capacity of the seeds was estimated using the method of Miles *et al*. (1983):

Cp = mwcw + mscs (KJ Kg-1K-1) and

Cp= 1.424 mc + 1.549 mp + 1.675 mf + 0.837 ma + 4.187 mm (Singh and Heldman, 1993).

Where Cp = specific heat capacity, mw = mass fraction of water, cw = specific heat capacity of water (4.18 KJ Kg-1k-1), ms = mass fraction of solids, and cs = specific heat capacity of solids (1.46 KJ Kg-1K-1).

Latent heat of fusion

The method of Lamb (1976) was used to estimate the latent heat of fusion as:

L = 335 mw (KJ Kg-1).

Where mw = mass fraction of water.

Thermal diffusivity

The thermal diffusivity was estimated as described by Lewis (1987) as:

$\alpha = K/\rho Cp$

where α = thermal diffusivity, K = thermal conductivity, ρ = density, Cp = specific heat capacity.

Determination of Physical Properties

Seed Size

Twenty seeds were selected randomly from each batch of the Bambara groundnut varieties. The seed sizes, in terms of the major diameter (L), intermediate diameter (W), and minor diameter (T) of the seed, were measured using a Vernier calliper (Kennedy Tools) reading to 0.01 mm. Determination was replicated twenty times. The average diameter was estimated using the three axial dimensions' arithmetic mean and geometric means. The arithmetic mean diameter, Da, equivalent diameter, Dp, and geometric mean diameter, Dg in mm of seed were estimated using the methods of Galedar *et al*. (2008); Mohsenin (1986) and Bahnasawy (2007), respectively as:

$D_a = \frac{(L+W+T)}{3}$

$D_g = (LWT)^{1/3}$

$D_p = [L\ \frac{(W+T)2}{4}]^{1/3}$

Where Da is the arithmetic mean diameter (mm), Dg is the geometric mean diameter (mm), Dp is the equivalent diameter (mm), L is the length (mm), W is the width (mm), and T is the thickness (mm).

Sphericity

The sphericity (Sp), defined as the ratio of the surface area of the sphere having the same volume as that of the seed to the surface area of the seed, was estimated by the method of Mohsenin (1978) as:

$$S_p = \frac{(LWT)1/3}{L}$$

Surface Area

The surface area (S) was estimated using the formula:

$$S = \pi D_g^2$$

Coefficient of Contact Surface

The coefficient of contact surface (C.C.S) was calculated according to the method of Abd Alla *et al*. (1995) as:

$$\text{C.C.S.} = \frac{Af - At}{Af} \times 100$$

Where;

A_f: Flat area surface = $\frac{\pi}{4}$ (LW)

A_t: Transverse area surface = $\frac{\pi}{4}$ (WT)

Aspect Ratio

The aspect ratio (R_a) was estimated using the method of Omobouwajo *et al*. (2000).

$$R_a = [\frac{W}{L}]\ 100$$

Where: R_a = aspect ratio, W = width, L = Length

Flakiness ratio (Rf) was determined by the method of Ebrahimzadeh *et al*. (2013) as:

$$(Rf) = \frac{T}{W}$$

Where: T = Thickness, W = width

1000 Seed Mass

The mass of 1000 seeds was determined by using an electronic balance to an accuracy of 0.001 g. The measurement was replicated five times for 1000 seeds selected at random (Mohsenin, 1978).

Unit Volume

The unit volume of 100 individual seeds was estimated from the values of length (L), width (W), and thickness (T) using the method of Mohsenin (1986):

$$V = \frac{\pi}{6}(LWT)$$

Gravimetric Properties

True Density

The true density of the seed was determined using the toluene displacement technique. Toluene was used instead of water because it is not easily absorbed by agricultural produce. The volume of toluene displaced was found by immersing a weighed quantity of tiger nuts in toluene (Singh and Goswami, 1996). Determinations were done inside a fume cupboard since toluene is known to be carcinogenic.

$$\rho_t = {}^{m}/_{v} \quad (4)$$

Where: m is the mass of the seed in kg and v is the volume of the seed in m^3

Bulk Density

The average bulk density of the seeds was determined by packing weighed nuts into a 250 mL measuring cylinder as described by Heidarbeigi *et al.* (2013). The packed seeds were gently tapped to allow them to settle. The volume of the measuring cylinder occupied by the seeds was recorded. The bulk density was calculated in g/mL using the formula:
Bulk density (Pb) = Weight of material packed / bulk volume

Porosity

Porosity (E) was computed as a percentage of the true and bulk densities using the equation below, as described by Varnamkhasti *et al.* (2007):

$$E = 1 - \frac{\rho b}{\rho t} \times 100$$

Where ρb = bulk density, ρt = true density

Engineering Properties

Angle of Repose

The dynamic angle of repose (emptying angle) was determined using the method of Amin *et al.* (2004) and Sessiz *et al.* (2007) as adopted by Idowu and Owolarafe (2015). A regular PVC (Polyvinyl Chloride) cylinder of dimensions 100 mm diameter and 150 mm height was used to determine the angle of repose. The cylinder was placed on the surface filled with the sample and then raised until it formed a cone of seeds. This was replicated ten times. The angle of repose was then calculated using the equation below:

$$\Theta = \tan^{-1}\left[\frac{2H}{D}\right]$$

Where Θ = Angle of repose, H = Height of the pile, D = Diameter of the pile

Coefficient of Static Friction

The static coefficients of friction (μ) were determined for each structural material, namely formica, plywood, stainless steel, and glass. The static coefficient of friction was determined using an inclined plane (Suthar and Das, 1996). The friction surface, which is part of a special construction, was made to replace it with the required friction surface. The special construction was hinged at one end to lift it gradually at the unhinged end using a pulley device, as described by Bart-Plange and Baryeh (2003). The angle at which the material just began to slide down was recorded as the static angle of friction between the material and the friction surface. Several other investigators who used this method include Baryeh (2001, 2002), Joshi *et al*. (1993), Dutta*et al*. (1988), and Suthar and Das (1996). The coefficient of static friction was calculated as:

$\mu = \tan \beta$

Where μ = coefficient of friction and

β = angle of inclination in degrees

Data Analysis

The data obtained were statistically analysed using Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 23. The means were compared and separated using Duncan's Multiple Range Test (DMRT) and LSD at $p \leq 0.05$.

RESULTS AND DISCUSSION

Proximate Composition

The results of the proximate analysis of the dried and ground Bambara groundnut seeds are presented in Table 1. The protein, fat, fibre, ash, and carbohydrate reported by Abu El-Gasim and Abdalla (2007) for an unspecified variety of dry raw Bambara groundnut seed were 22.70, 5.00, 3.72, 3.76 and 65.00 %, respectively. These values are similar to those obtained in this study except for crude fibre, which is far lower than the obtained value.

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Table 1. Proximate Composition of Dried Bambara Groundnut Seeds g/ 100g

Parameter	Red	Cream	Multi-coloured
Protein	21.50 ± 0.27^{a}	21.30 ± 0.27^{ab}	19.71 ± 0.15^{b}
Fat	4.17 ± 0.21^{b}	5.67 ± 0.42^{a}	7.43 ± 0.12^{a}
Fiber	11.33 ± 0.58^{a}	10.67 ± 0.58^{a}	6.54 ± 0.17^{b}
Ash	2.00 ± 0.00^{b}	1.67 ± 0.58^{b}	3.56 ± 0.15^{a}
Moisture	6.00 ± 1.00^{b}	7.00 ± 1.00^{b}	9.84 ± 0.10^{a}
Carbohydrate	55.00 ± 1.01^{a}	53.69 ± 1.44^{b}	52.92 ± 1.10^{b}

Values with the same superscript along rows do not differ significantly at $P \geq 0.05 \pm SD$

Mubaiwa *et al*. (2018) reported lower values of protein (15.6 – 19.6 %), higher values of fat (7.00 – 8.60 %), and similar values of ash (2.5 – 3.2 %) for red and black varieties of Bambara groundnut seeds of different processing methods. The values Adebowale *et al*. (2013) reported for cream-coloured Bambara groundnut were protein, 18.4 %; fat, 7.7 %; fibre, 3.0 %; ash, 2.7 %; moisture, 10.1 %; and carbohydrate, 60.6 %.

Thermal Properties

The results of the thermal properties of Bambara groundnut seeds are presented in Table 2. The three varieties' thermal conductivities, specific heat capacities, and thermal diffusivities were not significantly (P>0.05) different. The latent heat for the red and cream varieties was not significantly different but significantly lower than that obtained for the multi-coloured variety. The thermal conductivities obtained in this experiment are similar to the value 0.26 reported by Abioye *et al*. (2016). The specific heat and thermal diffusivity values were lower than 1.75 KJKg-1K-1 and 0.19×10-7 m2s-1, respectively, as Abioye *et al*. (2016) reported.

Physical Properties

The means of the physical properties of the three varieties of Bambara groundnut studied are shown in Table 3. The mean length, width, thickness, arithmetic mean diameter, geometric mean diameter, equivalent diameter, sphericity, surface area, aspect ratio, and 1000 seed mass for the three varieties studied were not significantly different (P > 0.05). The value for the 1000 seed weight for the cream-coloured variety was found to be significantly higher than the other two varieties. Also, the value for the multi-coloured variety was significantly higher than that of the red variety.

Table 2. Thermal Properties of Dried Bambara Groundnut Seeds

Parameter	Red	Cream	Multi-coloured
Thermal conductivity $Wm^{-1}K^{-1}$	0.24 ± 0.02^a	0.25 ± 0.01^a	0.24 ± 0.01^a
Specific heat capacity $KJ\ Kg^{-1}K^{-1}$	1.62 ± 0.11^a	1.65 ± 0.11^a	1.62 ± 0.12^a
Latent heat of fussion $KJ\ Kg^{-1}$	20.10 ± 1.20^b	23.45 ± 0.01^b	32.96 ± 0.01^a
Thermal diffusivity $\times 10^{-7} m^2 s^{-1}$	0.12 ± 0.01^a	0.11 ± 0.01^a	0.12 ± 0.01^a

Values with the same superscript along rows do not differ significantly at $P \geq 0.05 \pm SD$

Table 3. Physical Properties of Dried Bambara Groundnut Seeds

Parameter	Red	Cream	Multi-coloured
Major diameter (L) mm	12.10 ± 0.21^a	11.12 ± 0.17^a	11.92 ± 0.18^a
Intermediate diameter (W) mm	9.40 ± 0.17^a	9.34 ± 0.17^a	9.93 ± 0.13^a
Minor diameter (T) mm	8.02 ± 0.13^a	8.81 ± 0.16^a	9.10 ± 0.09^a
Arithmetic Mean Diameter (D_a)	9.84 ± 0.14^a	9.76 ± 0.16^a	10.32 ± 0.13^a
Geometric Mean Diameter (D_g)	9.70 ± 0.14^a	9.71 ± 0.16^a	10.25 ± 0.12^a
Equivalent Diameter (D_e)	9.72 ± 0.14^a	9.71 ± 0.16^a	10.26 ± 0.38^a
Sphericity (%)	80.57 ± 10.44^a	87.37 ± 3.80^a	86.00 ± 4.08^a
Surface area mm^2	295.71 ± 5.87^a	296.32 ± 6.39^a	330.20 ± 6.78^a
Coefficient of contact surface	33.72 ± 0.15^a	20.77 ± 0.21^b	24.62 ± 0.17^b
Aspect ratio %	78.32 ± 13.31^a	83.76 ± 5.09^a	83.60 ± 4.62^a
Flakiness ratio	86.16 ± 10.48^b	95.19 ± 2.67^a	91.20 ± 6.56^a
1000 seed mass (g)	7691.48 ± 111.66^c	9470.12 ± 414.42^a	9225.49 ± 999.90^b
Unit volume (mm^3)	477.82 ± 0.23^a	479.29 ± 0.09^a	564.21 ± 0.20^a

Values with the same superscript along rows do not differ significantly at $P \geq 0.05 \pm SD$

Other researchers who reported similar values for length, width, and thickness include Abioye *et al*. (2016) with values of 12.10 mm, 10.71 mm, and 11.36 mm at about 11.23 % moisture content; Mpotokwane *et al*. (2008) with value range of 11.81 – 11.44 mm, 9.41 – 9.77 mm, 8.99 – 9.48 mm at about 8 % moisture and Baryeh (2001) with values of 10.50 mm, 9.0 mm and 8.6 mm at about 7 % moisture contents, respectively.

The values of the physical dimensions are essential considerations in the development of seed sizing, and grading machines are useful in their separation from undesirable materials (Ogunjimi *et al*., 2002) and decorticating equipment (Abioye *et al*., 2016). Geometric properties of seeds are important because they determine interactions between and among particles, as well as with the surrounding air (Abioye *et al*., 2016). According to de Figueiredo *et al*. (2011), the interactions influence almost all the engineering properties of grains that must be considered in designing and evaluating grain storage and handling systems. Mpotokwane *et al*. (2008) reported a value of 9.81 mm for geometric mean diameter, similar to the values obtained in this study.

The sphericity, surface area, and volume obtained in this study are similar to the values 85.8 %, 277 mm2, 462 mm3 and 88 %, 320 mm2, 450mm3 reported by Mpotokwane *et al*. (2008) and Baryeh (2001) respectively. Mpotokwane *et al*. (2008) reported a value of 84.6 % for aspect ratio, which agrees with the values obtained in this work. According to Gharibzahedi *et al*. (2010), sphericity is an expression of a solid shape relative to that of a sphere of the same volume, while the aspect ratio relates the width to the length of the seed, which is indicative of its tendency toward being spherical. The values of sphericity obtained in this experiment show that the seeds are nearly spherical and will roll easily rather than sliding on surfaces, especially in hoppers and dehulling equipment. According to Omobuwajo (1999), the surface area of agricultural produce is generally an index of its pattern of behaviour in a flowing fluid like air, as well as the ease of using pneumatic means to separate extraneous materials from the produce during cleaning. It is also important in heat and mass transfer processes such as drying and other thermal applications (Emurigbo *et al*., 2020).

Gravimetric Properties

The mean densities and porosity of the Bambara groundnut seeds are presented in Table 4. There were no significant differences among the varieties in terms of bulk density, true density, and porosity. The results of this experiment are in agreement with 0.78 and 0.77 reported for bulk density by Abioye *et al*. (2016) and Mpotokwane *et al*. (2008), respectively. The values for true density and porosity obtained in this study are similar to those of 1.28 kgm-3 and 40 % reported by Baryeh (2001). Information on density is useful for the design of hoppers and silos for grain handling and storage (Nalladulai *et al*., 2002) to estimate the weight of agricultural and food products that these containers will handle.

Table 4. The Gravimetric Properties of Bambara Groundnut Seeds

Parameter	Red	Cream	Multi-coloured
True density (kgm^{-3})	1.25 ± 0.02^a	1.37 ± 0.01^a	1.23 ± 0.16^a
Bulk density (kgm^{-3})	0.75 ± 0.02^a	0.77 ± 0.01^a	0.70 ± 0.05^a
Porosity (%)	40.27 ± 1.29^a	43.91 ± 0.75^a	42.45 ± 11.70^a

Values with the same superscript along rows do not differ significantly at $P \geq 0.05 \pm SD$

Engineering Properties

The mean angle of repose (emptying angle) and coefficient of static friction on Formica, glass, stainless steel, and plywood surfaces of the three varieties of Bambara groundnuts are shown in Table 5. The value of the emptying angle for the red variety was significantly ($P \leq 0.05$) higher than the values for the cream and multi-coloured varieties. There was no significant ($P > 0.05$) difference between the cream and multi-coloured varieties values.

Table 5. The Engineering Properties of Bambara Groundnut Seeds

Parameter	**Red**	**Cream**	**Multi-coloured**
Angle of repose	25.31 ± 1.89^a	20.11 ± 1.40^b	22.02 ± 1.36^b
Coefficient of static friction			
Stainless steel	0.22 ± 0.02^a	0.14 ± 0.02^b	0.21 ± 0.01^a
Glass	0.23 ± 0.35^a	0.17 ± 0.03^a	0.18 ± 0.03^a
Formica	0.28 ± 0.05^a	0.16 ± 0.01^b	0.20 ± 0.16^b
Plywood	0.28 ± 0.05^a	0.18 ± 0.02^b	0.20 ± 0.02^b

Values with the same superscript along rows do not differ significantly at $P \geq 0.05 \pm SD$

There were no significant (P>0.05) differences between the values of the coefficient of static friction for the red and multi-coloured varieties on stainless steel and glass surfaces. The value for the cream-coloured variety was significantly lower than those of the other two varieties. The values for the cream and multi-coloured varieties on formica and plywood surfaces are also not significantly different but were significantly lower than those for the red-coloured variety. Baryeh (2001) reported values of 20 and 0.45 for the angle of repose and coefficient of static friction, respectively, on plywood surfaces.

CONCLUSION

All three varieties studied had similar thermal conductivities, specific heat capacities, and thermal diffusivities. The latent heat for the multi-coloured variety was significantly higher than those of other varieties. The mean length, width, thickness, arithmetic mean diameter, geometric mean diameter, equivalent diameter, sphericity, surface area, aspect ratio, and 1000 seed mass for the three varieties studied were not significantly (P > 0.05) different. The values of sphericity obtained in this experiment show that the seeds are nearly spherical and will roll easily rather than slide on surfaces.

All three varieties had similar values of bulk density, true density, and porosity. The angle of repose and coefficient of static friction were low, but stainless steel and glass are recommended for constructing surfaces such as hoppers.

Declaration of Interest

This research has no competing interest

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EFFECT OF *Tetrapleura tetraptera* ON BLOOD PROFILES AND NUTRIENT DIGESTIBILITY COEFFICIENT OF BROILER CHICKENS

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ABSTRACT

This study was conducted out of the quest to promote fast growth and better performance in livestock and aimed at determining the effect of Tetrapleura tetraptera on blood profiles and nutrient digestibility coefficient of broiler chickens. One hundred and sixty day-old (Abor acre) strains of broiler chickens were used for the study. Two diets were formulated, one at the starter phase and the other at the finisher phase. The diets were divided into four portions and labelled T1, T2, T3, and T4. T1 (Control) had no Tetrapleura tetraptera fruit powder (TTFP), while T2, T3, and T4 contained 300, 400, and 500 g of TTP per 100 kg feed, respectively. The birds were allocated into four groups of 40, each containing four replicates of 10 birds. Treatment diets were randomly assigned in a completely randomized design, and the birds had access to feed and water ad libitum. The research lasted 56 days. All the data collected were statistically analyzed. The result of the haematological assay showed that the diets did not have any significant (P>0.05) influence on the birds. No significant (P>0.05) differences were observed in the values of serum biochemical parameters analyzed except cholesterol and triglyceride. Birds in T1 recorded the highest significant values for the two parameters compared to other treatments. The nutrient digestibility in all the parameters measured (crude protein, crude fibre, ether extract, and ash) indicated significant differences (P≤0.05) across treatments. However, birds in the in T4 group recorded higher digestibility values in all parameters accessed compared to other treatments. It was therefore concluded that Tetraptera tetraptera fruit powder could be incorporated into a broiler diet of up to 500 g as a feed additive to enhance its blood profiles and nutrient digestibility.

Keywords: Broiler chicken, Cholesterol, Serum protein, *Tetrapleura tetraptera*, and Triglyceride.

INTRODUCTION

Over the years, antibiotics have been widely employed as feed additives for enhanced livestock and poultry performance (Okon *et al.,* 2023a). Regrettably, their utilization has been associated with various adverse effects, encompassing microbial drug resistance, liver injury, teeth discolouration, and gastrointestinal disorders in both humans and animals (Jing*et al*., 2009; Isikwenu and Udomah, 2015; Essien *et al.,* 2023). The global ban on this product (Cardozo *et al*., 2004; Okon *et al*., 2023c) has prompted feed producers worldwide to adopt healthier, plant-based alternatives called phytobiotics, minimizing side effects. Phytobiotics include spices and herbs from plant origin. They can be incorporated into animal diets to boost their performance and improve the quality of their products, such as meat and eggs (Windisch *et al*., 2008; Okon*et al.,* 2022). These natural herbs and spices are readily available, cheaper, and have no side effects. They could come from leaves, bulbs, rhizomes, seeds, and fruit, and they have been used in animal diets with promising results. Examples of such known spices include *Xylopia aethiopica* (Solomon *et al*., 2022), *Monodora myristica* (Okon *et al*., 2023b), turmeric and clove (Ayodele *et al.,* 2021), *Ocimum gratissimum* (Essien and Udoh, 2021). However, these herbs and spices have been reported to contain an array of bioactive compounds such as *saponin, alkaloid, tannin, glycoside, phenols, and terpenoids which* could be responsible for their nutritional and pharmacological activities (Okwu, 2003; Essien *et al*., 2022).

Tetrapleura tetraptera, commonly known as Aridan, Uho in Igbo, and Uyayak in Efik and Ibibio, is a lowland forest plant in tropical Africa. The plant is highly sought because of its nutritional and medicinal properties. The tree grows to approximately 25 meters in height. The fruit is brownish, and the pod contains tiny hard seeds that measure up to 8mm long. It is used in many Nigerian cuisines because of its strong but pleasant aromatic fragrances (Orwa *et al*., 2009). Aladesanmi (2007) reported that the fruit could control and prevent many ailments, such as diabetes, arthritis, inflammation, hypertension, convulsion, Jaundice, rheumatism, and malaria. The proximate composition of *T. tetraptera* reveals its possession of crude protein (7.51 %), crude fibre (10.33 %), ether extract (4.11 %), ash (6.14 %), nitrogen-free extract (61.11 %), and a cocktail of minerals which include iron, calcium, magnesium potassium and zinc (Okwu, 2003; Essien, 2021). However, information on the value of *T. tetraptera* as a feed additive is limited; hence, this research was conducted to assess the effect of *T. tetraptera* on nutrient digestibility and blood profiles 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 Science, Akwa Ibom State University, Obio Akpa Campus, Nigeria. Obio Akpa lies between latitudes 5017 and 50171North of the equator and longitudes 70271 and 71581east with a temperature of 25oC annual rainfall ranging from 3500 to 5000mm and a relative humidity of between 60 and 90 % (SLUS-AK, 1994).

Sourcing and Processing of Tested Material

Tetrapleura tretraptera fruits used in this research were purchased from Abak market, Abak Local Government area of Ibom State. The fruit was sliced into small pieces to aid in the drying process, and it was left to sun-dry for seven days. Subsequently, the dried fruit was manually blended into a powder using a hand-operated blender (Corona 1016, Landersy Y. CIA, South Africa).

Proximate and Phytochemical Composition of *Tetrapleura tetraptera*

A sample of the ground *T. t**etraptera*** was subjected to proximate analysis for the determination of crude protein ether extract, crude fibre ash, and moisture using the guide provided by AOAC (1995), while the phytochemical assay was adapted from the studies of (Dosunmu, 1997; Ojewole and Adewunmi, 2004).

Experimental Diets

Two experimental diets were specifically formulated for the starter and finisher phases of the study. Each diet was divided into four portions and labelled T1, T2, T3, and T4. T1(control) had no *T. tetraptera* powder, while T2, T3, and T4 contained 300, 400, and 500 g of *T.* ***tetraptera*** powder per 100 kg feed, respectively. Table 1 represents the ingredients and nutrient composition of the experimental diets.

Management of Experimental Birds and Design

A total of one hundred and sixty (Abor acre) day-old chicks were used for the research. The birds were purchased from a reputable poultry distributor at Abak, Abak Local Government

Area of Akwa Ibom State. On arrival, the birds were weighed equally and divided into four groups of forty birds. Each group was randomly assigned to one of the treatment diets using a completely randomized design (CRD). Each group was further divided into four replicates of ten birds per replicate housed in a pen measuring 2 m × 2 m. The experiment followed standard brooding procedures, providing feed and water *ad libitum*. In the fifth week, the diet was switched to broiler finisher mash. Routine medication and vaccines were administered as scheduled. Biosecurity measures and other management practices were adhered to throughout the 56-day duration of the experiment.

Table 1: Gross Composition of Experimental Diet

Ingredient	Starter Phase	Finisher Phase
Yellow maize	50.00	55.00
Soya bean meal	25.00	20.00
Blood meal	3.00	3.00
Fish meal	3.00	3.00
Palm kernel cake	5.00	5.00
Wheat offal	9.00	9.00
Bone meal	4.00	4.00
Common salt	0.25	0.25
Premix	0.25	0.25
Lysine	0.25	0.25
Methionine	0.25	0.25
Total	100.00	100.00
Calculated chemical composition		
Crude protein	22.92	21.37
Ether extract	4.09	4.32
Crude fibre	3.15	3.96
Ash	3.57	5.25
NFE	66.27	65.10
ME (Kcal/kg	2879.85	2911.02

Blood Collection and Analysis

On the 56th day, 10 ml of blood samples were drawn from two birds per replicate through the wing vein into different bottles for haematological and serum biochemical indices. From the 10 ml collected, 5 ml was transferred into labelled and sterilized bottles containing ethylene diamine tetraacetic acid (EDTA) with anticoagulant for haematological assay. Haemoglobin concentration (Hb), red blood cell (RBC), and white blood cell (WBC) counts were determined by the Cyanmethemoglobin method as described by Coles (1986). Mean corpuscular volume (MCV), mean corpuscular Haemoglobin (MCH), and mean corpuscular Haemoglobin concentration (MCHC) were calculated according to the formula described by Sharma (1990) as shown below:

MCV (%) = PCV × 10/RBC

MCH (%) = HB × 10/RBC

MCHC (%) = HB × 100/PCV

The remaining 5ml of the blood sample was transferred into anticoagulant-free bottles and was used to determine blood biochemical components, which include total protein, albumin globulin, cholesterol, and triglyceride; serum enzymes aspartate aminotransferase (AST), Alanine amino transaminase (ALT) and alkaline phosphatase (ALP) using Cobas Mira Automatic Analyzer (Roche Diagnostic system, Basel Switzerland) with the aid of commercial kits (Lab Test Diagnostica Lagoa Santa, MG Brazil) samples reading were performed using spectrophotometer (Lasany single Beam visible spectrophotometer (L1 – 720), Lasany International Panchkula) with light wavelength adequate for each parameter.

Nutrient Digestibility Coefficient

A nutrient digestibility trial was conducted on the 49th day of the experiment. Two birds per replicate were randomly selected and housed separately in individual metabolic cages for seven days. A known quantity of feed was given to the birds. Polyethylene was placed under the cage for easy collection of faeces. The birds were allowed to acclimatize for three days before their excreta were collected. Faeces collected per bird per day were oven-dried at 85 0C until a constant weight was obtained. The faeces were bulked according to treatment and taken to the laboratory for proximate composition analysis.

$$\text{Nutrient digestibility coefficient} = \frac{\text{Nutrient in feed consumed} - \text{Nutrient in faeces voided} \times 100}{\text{Nutrients in feed consumed}}$$

Data Analysis

Data collected from various parameters measured were subjected to a one-way analysis of variance according to Steel and Torrie (1980). The analysis of variance indicated significant treatment effects, and the means were compared using Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

The proximate and phytochemical composition of *Tetrapleura tetraptera*is is presented in Table 2. The protein, fat, fibre, and ash values were comparable to values (7.80 %, 4.45 %, 18.56 %, and 9.42 %), respectively, as reported by Olubunmi (2013) except for Nitrogen-free extract and dry matter, which was comparable to N'zibo *et al*. (2019). The plant also contains phytochemicals, including tannin, saponin, flavonoid, alkaloid, and phenol. Phenols were the highest constituents, followed by flavonoids, tannins, saponins, and alkaloids. Studies have detected these phytochemicals as medicinal, antioxidant, anti-inflammatory, and antimicrobial properties (Yadav and Agarwala, 2011). The values reported in this study were comparable to those reported by Adusei *et al*. (2019) but lower than those reported by Igwe and Akabuike (2016). These values may be influenced by the soil characteristics and climatic conditions where the plant was cultivated, genetics, and analytical procedure variation (Okon *et al*., 2022). The results of the haematological parameters determined in this research are presented in Table 3. The results revealed that the diet did not significantly(P>0.05) affect all the haematological parameters analyzed. Numerous studies have outlined typical haematological parameters in avian species. Mitruka and Rawnsley (1977) and Campbell (2013) documented the following normal ranges for haematological measures in broiler chickens: Packed cell volume (35.9-41.0 %), haemoglobin (11.60-13.68 g/dl), red blood cell (2.21-4.84 × 106 /ml), white blood cell (4.07-4.32 × 103 /ml), mean corpuscular volume (81.60-89.10 FI), mean corpuscular haemoglobin (27.20-28.90pg) and mean corpuscular haemoglobin concentration (32.41-33.37 %). The values observed in this study aligned to a great extent with the normal ranges previously reported by the same author.

The diet did not negatively influence the birds' red blood cell (RBC). The red blood cell values obtained in this research did not vary between the experimental diet and the control, indicating that including *T. tetraptera* powder did not alter its normal functions. No significant increase (P>0.05) was observed in the value of packed cell volume (PCV) and Haemoglobin count (Hb) of the birds across treatment. Blood haematological parameters help evaluate the animal's physiological state (Etim *et al*., 2013). Ekpo and Okon (2023) reported that RBC, Hb, and PCV are sensitive to dietary type and quality.

Also, Adejumo (2004) indicated that there was a correlation between PCV, Hb, and the quality of the diet. Packed cell volume (PCV) is known as an index for blood toxicity. Its abnormal level could suggest the presence of toxic factors in the diet (Oyawoye and Ogunkunle, 1998). Low PCV usually portrays iron deficiency. The result showed the absence of toxic substances, an adequate level of iron in the feed, and the ability of the birds to perform normal erythropoietin activity.

The white blood cells (WBC) of the birds were not significantly (P>0.05) influenced by the diet. White blood cells play a major role in fighting against disease-causing micro-organisms in the body, such as bacteria, fungi, and viruses (Britannia, 2020). Therefore, the non-significance in values of the birds could suggest an enhanced immune system. The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin count (MCHC) of the birds were not affected by the diet. These parameters are used to measure or evaluate anaemic conditions in humans and animals. However, all the haematological parameters analyzed fell within the normal range reported by Abdulazeez*et al*. (2016). The results of the serum biochemical composition of the birds are presented in Table 4. The diets across treatments did not significantly (P>0.05) affect serum total protein, albumin, and globulin. Total protein measures the amount of protein in the blood and its balance in amino acid levels or profile. Albumin is produced in the liver, and it helps to prevent the blood from leaking out of blood vessels, while globulin binds with haemoglobin to transport iron in the blood. High levels of globulin indicate liver damage, chronic infection, and kidney dysfunction, while a low level of albumin depicts poor health conditions in animals. This result revealed the absence of disease conditions in the experimental birds and adequate protein levels in the feed. Total protein, albumin, and globulin values reported in this study fell within the normal ranges (2.50-5.50 g/dl; 2.10-3.45 g/dl; 2.13-3.02 g/dl) reported by Howlett (2000), Mitruka and Rawnsley (1977), and Adeyemo and Sani (2013), respectively.

The liver enzymes aspartate aminotransferase (AST), Alanine transaminase (ALT), and alkaline phosphatase (ALP), though present in negligible concentrations, are important as they help in the determination of the proper functioning of the liver of animals. These enzymes were not affected by the diet. The values reported in this study were within the normal range reported by Meluzzo *et al*. (1992), suggesting that the liver of the birds functioned optimally. The liver is the centre of all bodily metabolic activities and is subject to chemical and biological damage (Aikpitanyi and Egweh, 2020). These damages are made obvious by the levels of these enzymes. Increased levels of these enzymes are associated with liver damage, which could result from toxic substances in feed. Therefore, the similarities in values between the control and the rest of the group indicate normal or proper functioning of the enzymes and could suggest an absence of toxic substances in the feed. The result of this study agrees with the findings of Emadi and Kermanshali (2007), who reported non-significant AST, ALP, and ALT values in broilers fed turmeric powder.

Significant (P≤0.05) variations were observed in the value of cholesterol and triglyceride. Triglycerides are synthesized in the liver from fatty acids, protein, and glucose when they are above the body's current needs and then stored in adipose tissues (Esubonteng, 2011). Values reported in this study fell within the normal range (87 – 192 mg/dl) reported by Meluzzi *et al.* (1992). Birds in T4 had the lowest cholesterol and triglyceride values. Their values decreased significantly with an increase in the test ingredient or feed additive level. The lower values obtained for the two parameters could suggest the antioxidant effect of *T. tetraptera*. The spice has been reported to possess antioxidant properties which inhibit lipid peroxidation. The results align with other researchers' reports on other spices and herbs (Ekpo and Okon, 2022; Okon *et al*., 2023c). Studies by Ekine *et al*. (2020) and Ayodele *et al*. (2016) recorded significant decreases in triglyceride and cholesterol values of broilers fed ginger, black pepper, turmeric, and clove. These findings confirmed the antilipidemic and hypolipidemic properties of *the Tetrapleura tetraptera* fruit.

Table 2: Proximate and Phytochemical Composition of *Tetrapleura tetraptera*

Parameter	TTFP
Crude protein	7.51
Crude fibre	10.13
Ether extract	4.11
Ash	6.14
NFE	61.11
Dry matter	89.0
Anti-nutrient (mg/100g)	
Tannin	1.82
Saponin	1.63
Flavonoid	2.57
Alkaloid	1.30
Phenol	3.21

TTFP = *Tetrapleura tetraptera fruit powder*

Table 3: Haematological Indices of Broiler Chickens fed *Tetrapleura tetraptera* Fruit Powder

Parameter	T_1 (0 gTTFP)	T_2 (300 gTTFP)	T_3 (400 gTTFP)	T_4 (500 gTTFP)	SEM
Red blood cell ($x10^6$/NL)	2.55	2.51	2.62	2.58	0.04
Haemoglobin (g/dl)	13.01	12.54	12.51	13.32	0.03
PCV (%)	35.78	35.81	36.23	36.34	0.03
White blood cell ($X10^3$/u)	9.31	9.05	9.34	9.23	0.01
MCV (fl)	91.31	90.55	91.14	91.20	0.01
MCH (pg)	37.01	36.52	37.13	36.55	0.02
MCHC (g/dl)	34.00	33.56	33.57	34.11	0.01

SEM = Standard Error of the mean, MCV = mean corpuscular volume, MCH = mean corpuscular Haemoglobin, MCHC = mean corpuscular haemoglobin concentration, PCV = Packed cell volume, TTFP = *Tetrapleura tetraptera* fruit powder

Table 4: Serum Biochemical Indices of Broiler Chickens fed *Tetrapleura tetraptera* Fruit Powder

Parameter	T_1 (0 gTTFP)	T_2 (300 gTTFP)	T_3 (400 gTTFP)	T_4 (500 gTTFP)	SEM
Total protein (g/dl)	5.15	5.07	5.13	5.13	0.03
Albumin (g/dl)	2.84	2.67	2.41	2.52	0.01
Globulin (g/dl)	2.31	2.40	2.82	2.51	0.01
AST (u/l)	80.12	80.31	80.43	80.11	0.01
ALT (u/l)	24.51	24.62	25.01	25.10	0.03
ALP (u/l)	35.10	34.71	35.23	34.81	0.03
Cholesterol (mg/dl)	140.31^{a}	121.44^{b}	117.03^{b}	91.02^{c}	1.34
Triglyceride (mg/dl	150.51^{a}	138.56^{b}	111.53^{c}	90.20^{d}	1.21

abcd: means along rows with different superscripts are significantly (P<0.05) different.

SEM = Standard Error of Mean, ALT = Alamine transaminase, ALP = Alkaline phosphatase, AST = Aspartate amino transferase, TTFP = *Tetrapleura tetraptera* fruit powder

Table 5: Apparent Nutrient Digestibility of Broiler Chickens Fed *Tetrapleura Tetraptera* Fruit Powder

Parameter	T_1 (0 gTTFP)	T_2 (300 gTTFP)	T_3 (400 gTTFP)	T_4 (500 gTTFP)	SEM
Dry matter	80.56^{d}	82.61^{c}	84.31^{b}	85.67^{a}	0.03
Crude protein	70.13^{d}	75.65^{c}	78.02^{b}	80.21^{a}	0.10
Crude fibre	60.78^{d}	62.41^{c}	63.10^{b}	65.37^{a}	0.02
Ether extract	75.61^{d}	76.37^{c}	77.59^{b}	80.11^{a}	0.01
Ash	82.11^{d}	83.92^{c}	85.37^{b}	88.53^{a}	0.01
Nitrogen free extract	71.53^{d}	73.41^{c}	74.51^{b}	76.29^{a}	0.03

abcd = means along rows with different superscripts are significantly (P<0.05) different.

SEM = Standard Error of Mean

TTFP = *Tetrapleura tetraptera* fruit powder

The result of the nutrient digestibility coefficient of the birds, as shown in Table 5, indicated significant (P≤0.05) differences in all the parameters across treatments. Digestibility was higher in T4 than in the rest of the group. Digestibility increased with the test material levels (*T. tetraptera*). Spices and herbal products are useful to humans and animals because of their nutritional and medicinal properties (Czarra, 2009). They act directly against microorganisms in the gastrointestinal tract, creating an enabling environment for protein and energy digestion, absorption, and utilization (Frankic *et al*., 2009). The birds effectively utilized the crude protein, fibre, ether extract, and ash contents of the broiler feed. The birds of T4 recorded the highest significant values, followed by T3, T2, and T1. Spices also increase the secretion of endogenous enzymes that help indigestion.

CONCLUSION AND RECOMMENDATIONS

Based on the results obtained in this research, Tetrapleura *tetraptera* could be incorporated into broilers' diets at 500 g/100kg feed for normal haematological and serum biochemical indices and to promote nutrient digestibility in broiler chickens.

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INVESTIGATING THE UNEXPLORED IMPACT OF *Justicia insularis* MEAL-BASED ON BROILER CHICKEN PERFORMANCE AND NUTRIENT DIGESTIBILITY

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ABSTRACT

The study was conducted using one hundred and sixty (Abor acre) broiler chickens to assess the impact of Justicia insularis leaf meal (JILM) on the broilers' growth performance and nutrient digestibility coefficient. The experiment involved formulating four diets labelled T1, T2, T3, and T4 during the starter and finisher phases. The control diet (T1) contained 0 % Justicia insularis leaf meal, while diets T2, T3, and T4 included Justicia insularis leaf meal at 2.5 %, 5.0 %, and 7.5 %, respectively. The birds were divided into four groups of forty birds, and each group was randomly allotted to one of the experimental diets using a completely randomized design. The birds were further subdivided into four replicates of ten birds per replicate. Feed and water were provided ad libitum. Data collected were analyzed using Statistical Package for Social Sciences (SPSS) and means separated using Duncan's Multiple Range Test. The results indicated a significant difference in the birds' final body weight, weight gain, and feed conversion ratio at both the starter and finisher phases. The feed intake of the birds at the starter and finisher phases were statistically similar. Birds in the T4 group recorded the lowest and best feed conversion ratios. The nutrient digestibility coefficient of crude protein, crude fibre, ether extract, ash, and nitrogen-free extract showed significant differences across treatment at both phases. The highest significant nutrient digestibility coefficient across treatment was recorded in T4 in all the parameters, followed by T3, T2, and T1. It was, therefore, concluded that 7.5% Justicia insularis leaf meal level could enhance growth performance and nutrient digestibility in broiler chicks at both starter and finisher phases.

Keywords: Broiler chicken, Growth performance, *Justicia insularis*, Nutrient digestibility, Starter and finisher

INTRODUCTION

The livestock sector, particularly in developing countries, is grappling with a significant challenge due to the remarkable surge in the human population and insufficient animal protein intake (Ekpo and Okon, 2023). Among various animal protein sources, the poultry industry stands out for its widespread contribution to egg and meat production (Essien *et al.,* 2022; Essien *et al*., 2023). Regrettably, this industry's growth and sustainability are hindered by multiple constraints, with economic factors taking the forefront – notably, the scarcity and high costs of feed ingredients. Feed expenses constitute 70 – 80 % of poultry production costs (Obioha and Anikwe, 1982). Cereal grains form the bulk of commercial poultry feeds. The supply of grains (maize and soybean) does not meet the demand for these products due to stiff competition between humans and livestock in their consumption (Essien and Udedibie, 2007; Essien and Sam, 2018). This has compelled researchers to explore readily available and cheaper feed ingredients that could serve as substitutes for the grains. In recent times, leaves from various plant species that have been processed and incorporated into poultry diet have yielded tremendous results in monogastric, especially layer and broiler production (Essien and Sam, 2018; Banjoko *et al.*, 2018, Olumide and Akintola, 2018; Ekpo and Okon, 2022, Christopher *et al*., 2023). Leaves from browse plants and legumes have been reported to contain essential nutrients (Okon *et al.*, 2023a; Okon *et al.*, 2023b). *Justicia insularis,* popularly known as "weed of plantation" or "Meme" in Efik and Ibibio, is a multipurpose herbaceous plant with great potential. The plant is 30 – 50cm long and has opposite and ascending branches. The leaves are simple and opposite, while the flowers are white, pink, or purple. *Justicia insularis* is found in cultivated land, gardens, and coastal areas. It grows abundantly in Southern Nigeria, especially in Akwa Ibom State. The leaves of *Justicia insularis* is used in most homes as soup for both adults and babies. It aids digestion and is a weaning agent (Telefo *et al.*, 2004). Traditionally, the leaves are harvested and squeezed in water to extract the juice as a drink to treat anaemic patients. Studies by Adeyemi and Babatunde (2014) highlighted the nutritional composition of *Justicia insularis* leaf meal to consist of 15.95 % ash, 4.48 crude protein, 2.14 % lipid and nitrogen-free extract 18.36 MJ/Kg in addition to minerals such as calcium, manganese, potassium, phosphorous, magnesium sodium, copper, iron, and zinc. In addition to the rich nutrient composition, the plant's phytochemistry reveals an appreciable amount of bioactive compounds that are not limited to phenols, flavonoids, alkaloids, terpenoids, and steroids. These compounds could be responsible for their varied biological and pharmacological activities, such as antioxidant, anti-inflammatory, hypoglycemic, antiviral, and antibacterial. (Ekpo and Okon, 2023; Okon *et al*., 2023a; Okon *et al*., 2023b). In order to assess the efficacy of nutrient contents in this plant, of which there is a paucity of information on its usage in broiler chickens' production, this research was conducted to determine the effect of *Justicia insularis* leaf meal on growth performance and nutrient digestibility of broiler chickens.

MATERIALS AND METHODS

The research was conducted at the Poultry Unit of the Teaching and Research Farm of Akwa Ibom State University, Obio Akpa Campus, Oruk Anam Local Government Area, Akwa Ibom State. Obio-Akpa is located between latitude 50170N and 50271N and between longitude 70271N and 70581E. The rainfall ranges from 3500 to 5,000mm, the average monthly temperature is 250 C, and the relative humidity is between 60 and 90 % (SLUS-AK, 1994).

Processing and Source of Experimental Leaf

The leaves of *Justicia insularis* used in this research were harvested within the university environs. The stalks were removed, and the leaves were sundried for five days until they became crispy while the green colour remained. The dried leaves were ground using a manual blender (Corona 1016, Landersy Y. CIA, South Africa). The leaf meal was later analyzed for its proximate and phytochemical composition according to the methods described by AOAC, 2005).

Experimental Diet

Four experimental diets labelled T1, T2, T3, and T4 were formulated and compounded for the experiment at the starter and finisher phases. T1 (control) had zero *Justicia insularis* leaf meal, while T2, T3, and T4 contained 2.5 %, 5.0 %, and 7.5 % of *Justicia insularis* leaf meal, respectively. Tables 1 and 2 present the ingredients composition of the experimental diets.

Management of Experimental Birds and Design

A total of one hundred and sixty-day-old (Abor acre) broiler chickens were used for the experiment. The birds were purchased from a reputable Uyo, Akwa Ibom State poultry distributor. The pens were cleaned and disinfected a week before the arrival of the birds. On arrival, the chicks were weighed to obtain their initial weight using a sensitive balance (Model

SF 400), divided into four groups of forty birds, and each group was assigned one of the experimental diets in a completely randomized design. Each group was divided into four replicates of ten (10) birds per replicate housed in a pen measuring 2 m x 2 m. Wood shaving was used as litter material. Feed and water were provided *ad libitum*. All routine medication and vaccines were administered. The experiment lasted for 56 days.

Table 1: Ingredient Composition of Broiler Starter Diets

Ingredients	**T_1**	**T_2**	**T_3**	**T_4**
Maize	50.00	50.00	50.00	50.00
Soya bean meal	28.00	25.50	23.00	20.50
JILM	0.00	2.50	5.00	7.50
Fish meal	3.00	3.00	3.00	3.00
Wheat offal	8.00	8.00	8.00	8.00
Palm kernel cake	6.00	6.00	6.00	6.00
Bone meal	4.00	4.00	4.00	4.00
Premix	0.25	0.25	0.25	0.25
Common salt	025	025	025	025
Lysine	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
Total	100	100	100	100
Calculated chemical composition (% DM)				
Crude protein	23.12	23.31	23.41	22.23
Crude fibre	4.21	4.23	4.33	4.35
Ether extract	3.56	4.01	4.21	4.26
Ash	4.52	5.36	5.41	5.51
ME (kcal/kg)	2911.31	2910.41	2902.01	2904.03

JILM – *Justicia insularis* leaf meal, ME – Metabolizable energy

Nutrient Digestibility Trial

A nutrient digestibility trial was conducted on the 23rd and 49th days of the experiment. Two birds per replicate were randomly selected and housed separately in appropriate metabolic cages for seven (7) days. The birds were allowed to acclimatize for three days before the commencement of four days of feeding and excreta collection. A total of 1000 g of feed was given to the birds, and excreta collected per bird per day were oven-dried at 850C until a constant weight was obtained. The faeces were bulked according to each treatment and taken to the laboratory for proximate composition analysis for dry matter, crude protein, ash, ether extract, and crude fibre using the standard method of AOAC (2005).

$$\text{Nutrient digestibility} = \frac{\text{Nutrient in feed intake} - \text{Nutrient in faeces voided}}{\text{Nutrients in feed intake}} \times 100$$

Table 2: Ingredient Composition (%) of Broiler Finisher Diets

Ingredient	T_1	T_2	T_3	T_4
Maize	55.00	55.00	55.00	55.00
Soyabean meal	26.00	23.50	21.00	18.50
JILM	0.00	2.50	5.00	7.50
Fish meal	3.00	3.00	3.00	3.00
Wheat offal	6.00	6.00	6.00	6.00
Palm kernel cake	5.00	5.00	5.00	5.00
Bone meal	4.00	4.00	4.00	4.00
Premix	0.25	0.25	0.25	0.25
Common salt	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
Calculated chemical composition (% DM)				
Total	100.00	100.00	100.00	100.00
Crude protein	20.45	20.31	20.10	19.34
Crude fibre	4.00	4.03	4.11	4.13
Ether extract	3.51	3.63	4.01	4.10
Ash	4.53	5.17	5.13	5.17
ME (kcal/kg)	2899.43	2895.36	2890.31	2887.51

JILM – *Justicia insularis* leaf meal, ME – Metabolizable energy

Data Collection

The weight gain of the experimental birds was calculated by subtracting the initial weight from the final weight using a 20 kg capacity weighing balance (Hana Spring) platform scale. The feed intake of the birds was calculated by subtracting the quality of leftover feed from the quantity of feed fed the previous day. The feed conversion ratio was calculated by dividing the daily feed intake by daily weight gain.

Data Analysis

Data collected from various parameters measured were subjected to a one-way analysis of variance using SPSS (2007). Where significant means were observed, the Duncan Multiple Range Test (Duncan, 1955) was employed for mean separation.

RESULTS AND DISCUSSION

The results of the proximate composition of *Justicia insularis* leaf meal are presented in Table 3. Results showed that the leaf meal contains crude protein (23.50 %), crude fibre (5.38 %), ether extract (4.33 %), ash (14.81 %), and Nitrogen free extract (52.33 %). This result showed that *Justicia insularis* contains an appreciable amount of crude protein (23.50 %), which could serve as a source of protein in non-ruminant diets. However, the crude protein value in this study differed from the value of 4.48% reported by Adeyemi and Babatunde (2014) and 10.15%

reported by Keke *et al*. (2023) for *Justicia secunda.* This result also indicated a rich amount of ash in *Justicia insularis*, which is close to the value reported by Adeyemi and Babatunde (2014). The disparities in the proximate composition of the leaf meal could be a result of the following factors: differences in soil characteristics in terms of fertility, mineral content and texture, varied climatic conditions of the area cultivated, differences in analytical procedure carried out at the period of evaluation (Ekpo *et al.,* 2020; Solomon *et al*., 2022; Okon *et al*., 2022). The phytochemical analysis revealed that *Justicia insularis* contains tannin, alkaloid, terpenoid, Stenoid flavonoid, and phenol (0.21, 0.34, 0.21, 0.16, 2.13, and 1.34 mg/100g) respectively. These compounds could be crucial in managing ailments such as fever, diabetes, inflammation, dysentery, arthritis, etc. (Okwu, 2003).

Table 3: Proximate and Phytochemical Composition of *Justicia insularis* Leaf Meal

Parameters	Composition (%)
Dry matter	88.56
Crude protein	23.15
Crude fibre	5.38
Ether extract	4.33
Ash	14.81
Nitrogen free extract	52.33
Phytochemical composition (mg/100g)	
Flavonoid	2.13
Tannin	0.21
Alkaloid	0.34
Phenol	1.34
Terpenoid	0.21
Steroid	0.16

The results of the growth performance of broiler chickens at the starter phase are presented in Table 4. Significant (P≤0.05) differences occurred in the birds' final body weight and weight gain values at the starter phase. The highest significant (P≤0.05) values were recorded, followed by T3, which was significantly higher than T2 and T1. T1 recorded the least final body weight and body weight gain. The feed intakes of the birds at the starter phase were statistically similar (P>0.05). The feed conversion ratio of the birds at the starter phase indicated a significant difference in their values across treatments. T4 had the best and the lowest feed conversion ratio. The experimental diets positively influenced the final weight, weight gain, and feed conversion ratio of broiler finisher birds. Significant variations were observed in final body weight, weight gain, and feed conversion ratio values. The results followed the same trend as in the starter phase, with T4 recording the highest significant (P≤0.05) final body weight and weight gain values. These results indicated that the diets were adequate in nutrients, especially protein, which is needed for growth and production. Okwu (2003) reported that phytochemical compounds enhance the secretion of digestive enzymes, creating an enabling environment for effective gut functioning to aid digestion and the absorption and utilization of nutrients. Okwori and Attah (2016) reported that protein in leaves positively affects feed intake, digestibility, and nutrient absorption, thus resulting in better performances in animals.

The diet did not influence the feed intake of the birds at the finisher phase. The birds recorded similar feed intake values. The non-significant (P>0.05) effect on the feed intake of the broiler chickens indicated that the diet was palatable. The feed conversion ratio of the birds indicated a significant difference in their values. Birds in T4 had the best and the highest feed conversion ratio. The feed conversion ratio shows the ability of the birds to convert feed to flesh. The feed conversion ratio of chicken is economically important and serves as a price determinant for broiler producers. This result could suggest that nutrients in the feed were enriched by adding *Justicia insularis* leaf meal.

Table 4: Performance Characteristics Starter of Broiler Chickens Fed *Justicia insularis* Leaf Meal (JILM)

Parameter	T_1	T_2	T_3	T_4	SEM
Initial body weight (g)	40.03	40.06	40.04	40.05	0.01
Final body weight (g)	831.43^d	855.56^c	891.71^b	950.11^a	1.25
Body weight gain (g)	791.40^d	815.5^c	851.67^b	910.06^a	1.31
Daily weight gain (g)	28.24^d	29.13^c	30.41^b	32.50^a	1.02
Feed intake (g)	55.51	55.81	56.51	56.31	0.01
Feed conversion ratio (g)	1.97^d	1.92^c	1.85^b	1.73^a	0.01
Mortality	0.00	0.00	0.00	0.00	0.00

abcd: means in the same row not sharing a common superscript are significantly different (P<0.05), SEM = Standard Error Mean

Table 5: Performance Characteristics of Finisher Broiler Chickens Fed *Justicia Insularis* Leaf Meal (JILM)

Parameter	T_1	T_2	T_3	T_4	SEM
Initial body weight (g)	825.51	823.61	826.53	824.81	0.01
Final body weight (g)	2351.11^c	2391.51^c	2511.52^b	2598.31^a	1.25
Body weight gain (g)	1525.60^c	1567.90^c	1684.99^b	1773.50^a	1.31
Daily weight gain (g)	54.49^c	55.99^c	60.18^b	63.34^a	1.02
Feed intake (g)	125.11	124.51	124.51	123.25	0.01
Feed conversion ratio (g)	2.30^c	2.23^c	2.01^b	1.95^a	0.01
Mortality	0.00	0.00	0.00	0.00	0.00

abc: means in the same row not sharing a common superscript are significantly different (P<0.05), SEM = Standard Error Mean

The nutrient digestibility of the broiler chicken at the starter and finisher phases is presented in Tables 6 and 7, respectively. In the starter phase, the nutrient digestibility of the birds indicated significant ($P \leq 0.05$) differences in all the parameters measured across treatments. Digestibility was superior in T4, followed by T3 and T2. T1 had the least apparent digestibility coefficient. The digestibility of the nutrient increased with increased levels of *Justicia insularis* in the diet. This could result from the rich nutrient profile of *Justicia insularis* and some phytochemical compounds that could aid in the digestion of nutrients. The nutrient digestibility of broiler chickens in the finisher phase followed the same trend. Significant ($P \leq 0.05$) differences existed across treatments in all the parameters determined. T4 had the highest significant ($P \leq 0.05$) value, followed by T3 and T1.

It was observed that the digestibility of nutrients in the finisher phase indicated higher values than in the starter phase. Although the high digestibility recorded by birds in T4 could result from rich nutrient content in a feed, it was observed that older birds digest nutrients more than the younger ones. This inference could suggest a better morphological, structural, and physiological development of the gastrointestinal tract and its contents. Moreover, phytochemicals have been reported by Upah *et al.* (2021) to initiate the modulation of intestinal morphology, thereby increasing the intestinal length, which is positively correlated to an increase in the villi's length, thus increasing the surface area available for absorption of nutrients.

Table 6: Apparent Nutrient Digestibility of Starter Broiler Chickens Fed *Justicia insularis* Leaf Meal (JILM)

Parameter	T_1	T_2	T_3	T_4	SEM
Dry matter	86.16^b	88.32^a	87.31^a	88.56^a	0.01
Crude protein	78.18^c	81.36^b	85.51^a	89.63^a	1.03
Crude fibre	67.70^c	81.81^b	76.30^a	76.51^a	1.11
Ether extract	81.23^c	87.31^b	90.17^a	90.32^a	0.04
Ash	78.54^b	79.01^b	80.13^b	81.56^a	0.03
Nitrogen free extract	70.21^d	71.81^c	74.39^b	86.14^a	0.03

abc: means in the same row not sharing a common superscript are significantly different ($P<0.05$), SEM = Standard Error Mean

Table 7: Apparent Nutrient Digestibility of Finisher Broiler Chickens Fed *Justicia Insularis* Leaf Meal (JILM)

Parameter	T_1	T_2	T_3	T_4	SEM
Dry matter	89.56^{b}	89.16^{a}	90.13^{a}	90.34^{a}	0.01
Crude protein	80.36^{b}	87.92^{b}	89.03^{a}	90.38^{a}	0.03
Crude fibre	70.11^{c}	75.71^{b}	78.91^{ab}	80.31^{a}	0.03
Ether extract	78.31^{c}	81.37^{b}	81.49^{b}	83.44^{a}	1.01
Ash	81.31^{c}	80.41^{c}	86.03^{b}	87.93^{a}	1.02
NFE	73.55^{b}	73.67^{b}	74.74^{b}	79.11^{a}	0.01

abc = means in the same row not sharing a common superscript are significantly different (P<0.05), SEM = Standard Error Mean

Conclusion

The findings of this study indicate that the incorporation of *Justicia insularis* leaf meal in the diet of broiler chickens at levels up to 7.5 % can improve broiler performance.

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EFFECT OF AGRICULTURAL LIME, ORGANIC AND INORGANIC FERTILIZER ON ARBUSCULAR MYCORRHIZAL FUNGI POPULATION AND DIVERSITY IN MAIZE RHIZOSPHERE SOIL IN NIGER STATE

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ABSTRACT

Knowledge of various soil amendments influencing soil microbial community is a vital soil health indicator. A field trial was conducted at Gidan Mangoro, Minna, Niger State, using five farmers' fields to evaluate the effect of agricultural lime, organic manure (cow dung), and inorganic fertilizers (N P K 20: 10: 10, urea and SSP) on Arbuscular Mycorrhizal Fungi (AMF) population and diversity on soil cultivated to maize. Soil samples were collected before and after maize cultivation at a 0-20 cm depth using a random technique using an auger. The experimental design used was a Randomized Complete Block Design with five replicates. The Minitab package (2017) was used for statistical analysis, and mean separation was done according to the Bonferroni method at a 95 % significance level. The results revealed significant differences in arbuscular mycorrhizal spore count and diversity in response to the various soil amendments used. The application of cow dung+Inorganic fertilizer recorded a significant ($P<0.05$) spore count of 779 spores / 50 g dwt in soil cultivated to maize compared to the control, which recorded 416 spore / 50 g dwt. Acaulospora and Funneliformis species of AMF were mostly observed. However, Glomus, Gigaspora, and Rhizophagus were also present in the soil of the study area. The effects of fertilizers, especially integrated soil fertility management, on Arbuscular Mycorrhizal fungal sporulation and species diversity varies, hence the need for further precise study.

Keywords: Maize: Agriculture lime, AMF spore count, AMF diversity, Rhizosphere, Integrated Soil Fertility Management (ISFM).

INTRODUCTION

Soil degradation processes influenced by soil erosion, compaction, lack of water holding capacity (WHC), reduced cation exchange capacity (CEC), acidification, poor fertility, organic and inorganic contamination, salinisation, urbanisation and changing climatic conditions jeopardise global food stability, therefore contributing to extreme economic restrictions that entail the creation of environmentally sustainable innovations that boost soil quality and resilience (Gisladottir *et al*., 2005). For soil health/fertility sustainability, integrated soil fertility management (ISFM) is one of the reliable technologies farmers have been encouraged to adopt recently, which implies the combination of different sources of soil amendments in small quantities to complement the limitations of each component. Arbuscular mycorrhizal fungi (AMF) are a major component of the rhizosphere microflora in natural ecosystems, which plays a significant role in ecosystems through nutrient cycling (Tabassum *et al*., 2011). These organisms form a root symbiosis with approximately 80 % of terrestrial plant species and improve nutrient and water uptake as well as pathogen resistance of their hosts in exchange for plant-assimilated carbon (Smith and Read, 2010). Therefore, it is becoming more widely acknowledged that AMF plays a significant role in agro-ecosystem functions. Many reports have shown fertilisers' negative or positive influences on AMF biodiversity, including readily soluble P and N, organic manure, and slow release of mineral fertilisers (Mar Alguacil *et al.,*2009). However, Zhong *et al.* (2010) confirm that readily soluble fertilisers negatively impact AMF diversity. However, organic manure and slow-release fertilisers do not suppress AMF and may stimulate the microbial population and diversity. Furthermore, changes in soil nutrient status in response to organic amendments, according to Lin *et al*. (2012), may have a stronger influence on AMF colonisation and abundance. More so, the AMF community's diversity and/or composition changes may reflect the need for specific nutrients in agricultural soils.

The microorganisms are important components of soil ecosystems that characterise soil fertility (Lueders *et al.,*2006); thus, it is important to understand the effects of organic and inorganic fertiliser applications on soil microbial communities, Arbuscular mycorrhizal fungi (AMF), which are fundamental microorganisms for soil fertility, plant nutrition and health may play an important role in organic agriculture by compensating for the reduced use of fertilisers and pesticides if given a conducive rhizosphere to operate, in other to sustain soil health and resilience, considering the soil amendment strategies put in place. There is scanty information concerning the diversity and population of AMF in response to the use of agricultural lime, organic, and mineral fertiliser in soil cultivated to maise in Niger State. Hence, there is a need to investigate the influence of integrated soil fertility management on AMF spore count and diversity in soil-cultivated maise in the State.

MATERIALS AND METHODS

The experiment was conducted in five farmers' fields at Gidan Mangoro, Minna, Niger State. Minna lies within Nigeria's southern Guinea savannah zone and has a sub-humid climate with a mean annual rainfall of 1248 mm and a distinct dry season of five months from November to March. The mean maximum temperature remains high at about 33.5ºC, particularly in March and June (Ojanuga, 2006).

Maise variety (Oba super 11) for the trial was obtained from Farm Centre, Minna, Niger state. Soil samples were collected from 5 points of each of the farmers' fields in Gidan Mangoro using soil auger before planting and before the addition of treatments. The soil sample was mixed and bulked together to make a composite from 0-20 cm depth, which was properly labelled and taken to the Soil Science Laboratory, School of Agriculture and Agricultural Technology, the Federal University of Technology Minna, air-dried, grounded, and passed through a 2 mm mesh sieve. The composite sample was kept in a sampling bag to assess the initial physical and chemical properties of the soil using the procedures described by Agbenin (1995) to obtain the soil texture (Bouyoucous hydrometer method), pH (Potentiometric method), organic carbon (Walkley and Black, 1934), total nitrogen (Kjeldahl method), available phosphorus (Bray P1), and exchangeable bases (Ca, Mg, Na, and K) using flame photometer. The same was repeated after harvest and reported as post-harvest soil analysis.

A land area measuring 6 X 6 m2 was used for the study in five farmers' fields at Gidan Mangoro. The land was cleared manually using a cutlass, and ridges were made manually using a hoe. Each field consisted of five plots with six ridges and an inter-ridge spacing of 75 cm (0.75 m). Plots were separated from one another by a 1 m alley. Treatments were laid out in a Randomized Complete Block Design with five replicates. Treatments were assigned to the plots as follows: T1 = Control (No input), T2 = NPK + Urea + SSP, T3 = Agric. lime + NPK+ Urea + SSP, T4 = Cow dung + Agric. lime + NPK+ Urea + SSP, T5 = Cow dung + NPK+ Urea +

SSP. Fertiliser rates applied per plot size (36 m2): Agricultural lime at 0.5 ton/ha = 1.8 kg, Cow dung at 5 tons/ha = 18 kg, NPK (20-10-10) fertiliser at 300 kg/ha = 1.08 kg, Urea (46 % N) at 130.4 kg/ha = 0.47 kg, SSP (18 % P2O5) at 167 kg/ha= 0.6 kg.

Determination and identification of Arbuscular Mycorrhizal fungi population and diversity in soil cultivated to maise:

The Soil samples were collected after harvest according to the treatments applied in three replicates and the spore of arbuscular mycorrhizal in soil was determined using wet sieving and decanting method (Gerdemann and Nicolson 1963) and the identification was done at the International Institute of Tropical Agriculture (IITA), Ibadan.

Data Analysis: All measured and calculated variables were subjected to analysis of variance using the Minitab (17) package. Treatment means were separated using Bonferroni simultaneous values were recorded.

RESULTS AND DISCUSSION

Initial Soil Physical and Chemical Properties

The physical and chemical properties of the soil (0-20 cm) at the experimental site in Gidan Mangoro, Niger State, before treatment application and maise cultivation are shown in Table 1. The soil texture at the various farmer's fields before the trial was sandy loam, with the pH of farmer's fields 1, 3, and 4 being moderately acidic while that of 2 and 5 were slightly acidic. The phosphorus content (P) of all the farmers' fields was high except for field 5, which was medium (12.15). The organic carbon content of farmer fields 2 and 4 was very low (3.71 g/kg), while farmer fields 1, 3, and 5 had low organic carbon content between 4.06-4.50 g/kg. The total nitrogen content of the entire farmer's fields was low. The exchangeable cation ranged from 3.10-6.92 among the various farmer's fields. Farmer's fields 2 and 4 had low Ca2+ (1.70 cmol/kg each), and farmer's fields 1, 3, and 5 recorded medium Ca2+ content (4.20 cmol/kg, 3.00 cmol/kg, 2.00 cmol/kg), respectively. The Na+ content of farmer's field 3 was very low at 0.18 cmol/kg, while farmer's fields 1, 2, 4, and 5 had high Content (0.40 cmol/kg, 0.47 cmol/kg, 0.47 cmol/kg, and 0.57 cmol/kg) respectively. The K+ of farmer's fields 1 and 5 were medium (0.16 cmol/kg and 0.18 cmol/kg)) respectively. The Mg+ content of farmer's fields 3 and 5 were medium, with 0.30 cmol/kg and 0.50 cmol/kg, respectively. The farmer's fields 1, 2, and 4 had high Mg^{+} content with 1.80 cmol/kg, 1.40 cmol/kg, and 1.40 cmol/kg, respectively.

The soil's low organic carbon, total nitrogen, Ca^{2+}, pH, and other nutrients are characteristics of tropical soils, as described by Ojeniyi (2010). Soils with < 7 pH value and low levels of nutrients need to be boosted with soil amendments in the form of Agricultural lime, organic, and/or inorganic fertilisers to enhance soil health for crop production. Maise takes Nitrogen, Phosphorus, and Potassium from the soil as primary nutrients required for growth and development. Hence, there is a need for balanced nutrient balance for plant and microbial existence in an ecosystem to ensure an increase in yield and to sustain soil fertility/health.

Cow Dung Analysis

The organic manure (cow dung), as shown in Table 2, contained nitrogen (2.52 %), phosphorus (0.04 %), and Potassium (0.39 %).

Post-Harvest Soil Chemical Properties

The physical and chemical properties of soil (0-20 cm) at the study site in Gidan Mangoro regarding the treatments applied (Agricultural lime, organic fertiliser (cow dung), and inorganic fertiliser (N P K 20: 10: 10 + UREA + SSP) after maise harvest are shown in Table 2. The control (untreated) plot was moderately acidic, with a pH of 6.00, while the treated plots were neutral, with a pH ranging from 6.67 - 7.00. The slight increase in pH could be attributed to using the various amendments. The organic carbon contents of the soils were very low; the value ranged from 1.35 – 2.80. The treatments did not positively influence the total nitrogen applied compared to the control (0.15 g/kg – 0.24 g/kg). The available phosphorus contents of the farmer's field were all very low. The result showed that Na^{2+}content significantly increased concerning the applied treatments while the control recorded the lowest. The K^{+} and Ca^{2+} content of the soil was highly enhanced, especially with the application of agricultural lime+Inorganic (NPK+UREA+SSP) and organic fertiliser (CD)+Inorganic fertiliser. The Mg^{2+} content of the soil was increased after harvest. The application of Agriculture lime+Inorganic fertiliser and CD+Inorganic fertiliser increased MMg^{2+} from medium to high, with the control recording the lowest value.

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Table 1:Initial Soil Properties of the Five Farmers' Fields

Sample	Sand	Clay	Silt	Textural class (g kg^{-1})	pH (water 1: 2.5)	TOC (g kg^{-1}) g kg^{-1}	TN (g kg-1)	Avail. P (mg/kg) mg kg^{-1}	Na^+	K^+	Ca^{2+}	Mg^{2+}	ECEC
F-1	748	192	60	SL	6.0	4.06	0.48	26.66	0.40	0.16	4.20	6.92	11.22
F-2	798	152	50	SL	6.2	3.71	0.27	26.10	0.47	0.22	1.70	3.86	7.35
F-3	788	162	50	SL	6.0	4.50	0.67	21.17	0.18	0.14	3.00	3.94	8.16
F-4	798	142	60	SL	6.0	3.71	0.21	29.51	0.57	0.24	1.70	4.07	6.12
F-5	808	132	60	SL	6.2	4.41	0.20	12.15	0.47	0.18	2.00	3.10	10.82

F= Farmer's field, EC= Exchangeable cations, TOC= Total Organic Carbon, TN= Total Nitrogen, ECEC= Effective Cation Exchange Capacity, SL= Sandy loam

Table 2. Post-harvest Soil Chemical Properties

Treatments	pH (water 1:2.5)	TOC (gkg^{-1})	TN (gkg^{-1})	Avail. P (mg/kg)	Na^+	K^+	Ca^{2+}	Mg^{2+}	Exch. Acid. (cmol/kg)
Control	6.00e	1.34c	0.15a	5.75e	0.39c	0.11b	2.65c	1.35ab	0.82a
NPK+UREA+SSP	6.74c	1.43c	0.18a	11.31a	0.62ab	0.15b	2.90b	2.05a	0.90a
NPK+UREA+SSP	6.67d	1.65b	0.17a	10.29b	0.50bc	0.80a	3.35a	1.54ab	0.89a
CD+AGRIC LIME+ NPK+UREA+SSP	7.0a	2.75a	0.20a	7.70d	0.64a	0.13b	2.70c	1.85ab	0.87a
CD+ NPK+UREA+SSP	6.85b	2.77a	0.24a	8.59c	0.62ab	0.85a	3.30a	1.24b	0.89a

Means with the same letter on same column are not significantly different from each other according to Bonferroni simultaneous at 95 % CI, NPK= Nitrogen Phosphorus Potassium, SSP= Single Super Phosphate, CD= Cow Dung, TOC= Total Organic Carbon, TN= Total Nitrogen

Effect of Agricultural Lime, Organic and Inorganic Fertilizer on Arbuscular Mycorrhizal Colonization and Diversity in Soil Cultivated to Maize

This experiment revealed that soil amendments (Agriculture lime, organic fertilizer, and inorganic fertilizer) positively affected the Arbuscular mycorrhizal fungi (AMF) population and diversity in the soil of the study area. Research has expressed controversial reports on the effect of soil amendments on AMF; Nitrogen supply at the initial stage sometimes offers a potential benefit in establishing mycorrhizae (Getman-Pickering *et al*., 2021). However, organic and mineral fertilization shows an increase and decrease in the formation of mycorrhizal associations in agro-ecosystems and general (Gryndler *et al.*, 2006). Likewise, it has been reported that Glomus species in agricultural soils have been promoted by organic fertilizer (Gryndler *et al*., 2006; Vestberg *et al*., 2011). However, Alquacil *et al*. (2011) reported that soil treated with both chemical and organic fertilizers slightly, but not significantly, increased the AMF richness and diversity compared to soils with chemical-only fertilizer. This is contrary to the findings in this study, where distinct significant differences were observed and attributed to a combination of fertilizer (Organic+inorganic) as compared to Inorganic only with regards to Acaulspora, Rhizophagus, and Funneliformis. It could, therefore, be speculated that the application of organic manure would instigate certain changes in the composition of the AMF community, as confirmed by Yu *et al*. (2013). AMF appears to thrive in organic matter.

Dumbrell*et al*. (2011) suggested that maize rhizosphere soils contain abundant AMF resources compared to other ecosystems. Similar to the findings in this study, where the mycorrhiza spore count was as high (779 spores / 50 g dwt of soil), and the control had 416 spores / 50 g dwt of soil. However, it contradicted other reports (Hijri *et al*., 2006; Wang *et a*l., 2008).

It is widely reported that different fertilization regimes could change the secretion of root exudates (Yoneyama *et al*., 2013; Kumar *et al*., 2016), which could alter the composition of the AMF community. This is in line with the finding of this study, where the combination of different sources of soil amendments resulted in variation in population and species of AMF found in maize rhizosphere at a certain point in time. However, from this study, a total of six mycorrhizae species were found on the farmer's field in this order: *Acaulospora>Funneliformis>Glomus>Gigaspora>Rhizophagus* and lastly *Scutelospora* as shown in Table 3. This conforms with Lumini *et al. (*2010), who suggested that maize rhizosphere soils contained abundant AMF resources compared to other ecosystems, as mentioned earlier. Arbuscular Mycorrhizal fungal species of the genus *Glomus*are often dominant in agro-ecosystems, according to Daniell *et al.* (2001) and Öpik *et al.* (2009). In this study, Glomus and Gigaspora were dominant in the maize rhizosphere, given that their population was in the control plot compared to the treated plots. However, the organic+inorganic treated plots had the genus*Acaulospora* as dominant. This was probably due to the soil's acidic condition, which aligns with the report of Aguilera *et al*. (2014, 2017) that *Acaulospora* and *Scutellospora we*re dominant genera in acidic soils under wheat cropping. At the same time, Castillo *et al*. (2016) found *Acaulospora* and *Claroideo-glomus* in acidic soils.

Oehl*et al.* (2004) also reported that species belonging to certain AMF fungal genera (e.g. *Glomus*) occurred in both organic and conventional soil amendment systems in small quantities, similar to the observation in this study. A*caulospora* and *funneliformis* appeared to be more favoured using CD+Inorganic and CD+Agric. lime+Inorganic fertilizer, resulting in the highest diversity and spore count (52.7, 21.7, and 779, 714 spores 50 g dwt) respectively. Zoe et *al*. (2021) also found that low to moderate doses of fertilizer application, especially organic fertilizer compared to inorganic, increased AMF-mediated plant growth and biocontrol ability. ThoughGryndler *et al.* (2008) reported that applying organic manures negatively impacted AMF diversity. Dominant AMF species varied in conventional (*Funneliformis* spp.) and organic systems (*Claroideoglomus*spp.) (Dai *et al*., 2014), indicating variation of AMF efficiency with fertilizers, especially P (Cruz-Paredes *et al*., 2017). The findings in this research agree with those of Chen Zhu *et al.* (2016), who reported that the application of organic manure was the key factor bringing about changes in AMF community composition in maize rhizosphere. This may be due to the synergy resulting from the combination of nutrients, soil conditions, plant growth status, and AMF, supported by Guttay's (1983) report. Entry *et al.* (2002) reported that AMF sporulation would be reduced under adverse soil conditions, including extremely low soil fertility and nutrient supply imbalance, especially high or low levels of N and P and extreme pH. This implies that the colonization and diversity of AMF are not static; they depend on what is obtainable and operational in the soil system at a point in time.

CONCLUSION AND RECOMMENDATION

Integrating agricultural lime, organic manure (CD) and inorganic fertilizer (NPK+ Urea+SSP) exhibited significant differences in AMF colonization and diversity. The application of CD or Agriculture lime in combination with Inorganic fertilizer resulted in the highest spore count of 779 and 714 spores / 50 g dwt of soil from maize rhizosphere. It is therefore concluded that the combination of inorganic fertilizer with either agric. Lime or organic manure (CD) resulted in some synergy, which made the maize rhizosphere conducive to the existence, diversification, and increase of Arbuscular mycorrhizal fungi. The effect of fertilizers, especially combined fertilizers, on Arbuscular mycorrhizal fungal sporulation was different and hence requires further investigation. However, there is a need for the combination of fertilizers from different sources (agricultural lime, organic fertilizer and mineral fertilizer) to make the best use of the synergy, which, of course, will increase maize yield and enhance soil fertility/health for a sustainable agro-ecosystem.

Table 3: Effect of Agricultural Lime, Organic and Mineral Fertilizer on Arbuscular Mycorrhizal Population on Soil Cultivated to Maize

Sample	Acaulospora	Gigaspora	Scutelospora	Glomus	Rhizophagus	Funneliformis	Spore/50 g dwt)
Conrol	25.9e	21.4a	5.3b	21.1a	9.1c	17.3b	416e
NPK+Urea+SSP	50.0b	6.4c	1.1e	6.4c	9.6b	15.7d	561c
Agric lime+ NPK+Urea+SSP	45.2c	11.1b	6.7a	1.1b	8.7d	17.1c	714b
CD+Agric lime+ NPK+Urea+SSP	39.0d	5.5e	2.7c	6.2d	13.6a	21.8a	523d
CD+ NPK+Urea+SSP	52.7a	6.2d	1.5d	5.6e	8.5e	21.7a	779a

Means with the same letter on same column are not significantly different from each other at according to Bonferroni simultaneous 95 % CIs

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RAM FIGHTING: ASSESSING THE ETHICAL IMPLICATION OF USING ANIMALS FOR SPORTS AND RECREATIONAL ACTIVITIES IN NIGERIA – A REVIEW

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ABSTRACT

There is an increasing need to reassess our treatment of animals in ways that prioritise their welfare. Animals have long been involved in various sports and recreational activities, serving as companions, performers, and participants. However, the ethical implications of using animals in such practices have been scrutinised recently. This review critically analyses the ethical implications of employing animals in sports and recreational activities, focusing on ram fighting in Nigeria. It explores the various perspectives surrounding this practice and examines the ethical concerns raised by its proponents and opponents. The study also delves into the cultural and historical context of ram fighting in Nigeria, shedding light on its significance and the conflicts it presents between animal welfare and cultural heritage. Considering both sides of the debate, this paper aims to foster a balanced understanding of the ethical considerations and propose possible alternatives or solutions to mitigate the concerns raised.

Keywords: ethical implications, ram fighting, recreation, sports, welfare

INTRODUCTION

Using animals in sports and recreational activities has been a long-standing practice in various cultures worldwide, including Nigeria (Connor, 2010). One such activity is ram fighting, which holds cultural and historical significance within the Nigerian context. However, the ethical implications of employing animals in these activities have become increasingly concerning. Ram fighting is deeply rooted in Nigerian culture and has been practised for generations (Vanguard, 2016). It is often associated with cultural events, festivals, and traditional celebrations. The practice holds symbolic significance, representing strength, power, and bravery. Ram fighting events attract large audiences and foster a sense of community engagement and entertainment. Understanding the cultural and historical context of ram fighting is crucial for comprehending the practice's conflicting viewpoints and ethical considerations (Senior, 2008; Connor, 2010).

The use of animals in sports and recreational activities raises several ethical concerns. Animal welfare is a primary consideration, as the well-being of animals involved in such activities may be compromised. Ram fighting, in particular, raises concerns about cruelty, harm, and stress inflicted on the animals during fights and training processes (Hussain, 2021). Consent and agency are also relevant, as animals may not willingly participate in these activities. Moreover, using animals in sports can be seen as a form of speciesism, where animals are exploited for human entertainment without sufficient moral consideration. (Hopster, 2019). The ethical implications of using animals in sports and recreational activities, including ram fighting, can significantly impact Nigeria's public perception and image. Animal welfare concerns and the perception of a country's ethical practices have become important factors in shaping international reputation and attracting tourism (Bulbeck, 2005). How Nigeria addresses these ethical considerations can affect its cultural heritage preservation and standing in the global community.

The debate surrounding the ethical implications of using animals in sports and recreational activities in Nigeria involves diverse stakeholder perspectives. Proponents of ram fighting argue for preserving cultural traditions and highlighting the economic and social benefits associated with the practice (Premium Times, 2013). On the other hand, opponents emphasize ethical concerns and advocate for animal welfare, emphasizing the need for alternative forms of entertainment that do not involve animal exploitation (Heinich, 2014). Understanding these perspectives is crucial for developing a comprehensive understanding of the topic. This review, therefore, aims to provide an overview of the cultural, historical, and ethical dimensions of using animals, specifically in the context of ram fighting, in sports and recreational activities in Nigeria.

Understanding Ram Fighting in Nigeria

Ram fighting is a traditional sport in some cultures, particularly in certain regions where it is considered a significant part of local heritage. In Nigeria, it usually occurs during religious festivals, especially the Muslim Festivals, or at other times deemed suitable by the organizers. The origin of Ram-fighting in Nigeria is traced to the Muslim festival of Eid al-Fitr, which marks the end of Ramadan. Rams are bought to commemorate the event but are used by some faithful for ram fighting before it is slaughtered (Sports Intelligence Magazine, 2017). Typically, male rams with large horns are pitted against each other in a competitive arena, engaging in head-on collisions until one ram submits or cannot continue. Supporters argue that it displays strength, skill, and natural behavior, and that the rams are not seriously harmed. However, examining the ethical implications through a critical lens is essential. During ram fighting activity, rams are deprived of feed and water, and most of these animals are slaughtered for meat soon after the fight (Ferguson and Warner, 2008). Meat from such animals often turns out to have compromised quality (Cappellozza and Marques, 2020). Pre-slaughter stress on animals could lead to Dark, Firm, and Dry (DFD) meat. Ram fighting puts rams through immense physical torture, which often results in bruised bodies, damaged skin, and broken bones. Consumer tastes and preferences are negatively affected as there would be a decline in the general acceptance of meats from such stressed animals (Food Marketing Institute, 2019). A set of rules governs ram fighting in Nigeria. According to a report by Vanguard (2016), the Nigerian ram fighting rules state that at the start of a tournament, rams are allowed to hit 30 “blows” before the referee calls a tie. By the finals, the Rams can head-butt up to 100 times. Sometimes, however, fights never take place at all because some rams could run to their owners for safety amid laughs and jeers from the crowd.

During a typical ram fighting event in Nigeria, organizers display an array of exciting prizes to be won. These may include cars, motorcycles, electronic appliances, or cash gifts. Hundreds of spectators gather to watch ram fights. Other interesting games like gambling also occur on this occasion as a side attraction. It is common to see fans of specific rams placing bets in monetary value on such rams. Vendors of petty items (mostly food items) also seize the opportunity to make

Source: Vanguard (2016)

brisk sales at the event. Common snacks at a typical ram fighting event include popcorn, FanMilk® ice cream, and Suya (spicy grilled meat served with onions and tomatoes). A group of young entertainers (mostly young boys and girls) may be called up to entertain the dignitaries and spectators with dance and music at intervals. Although ram fighting is regarded as one of the bloody sports, it rarely results in the death of the ram soon after a fight. The same cannot be said of bullfighting, which often results in the death or slaughter of one or both bulls involved soon after a fight.

Ethical Considerations in Ram Fighting

The use of animals in sports and recreational activities raises several ethical concerns. The primary concern in ram fighting revolves around the animals' welfare. Ram fighting raises concerns about cruelty, harm, and stress inflicted on the animals during fights and training processes. Even though supporters claim that the Rams are not seriously injured, the nature of the sport inherently exposes them to physical harm. Collisions between rams can result in injuries such as broken bones, horns, concussions, and internal damage (Mitchell, 1991). The stress of the event (ram fighting event) and the confined space further compromise their well-being. As sentient beings capable of experiencing pain and suffering, it is crucial to consider their interests and minimize harm. The concept of animal sentience connotes the ability of animals to react to pleasurable states, such as joy, and undesirable states, such as pain and fear (Broom, 2007). The debates about the ability or otherwise of animals to experience pain, suffering, or pleasure have been ongoing for many decades. While some early thinkers viewed animals as automata, lacking the ability for any form of feeling (Duncan, 2006), others, especially from the 18th century, were of the view that animals possess the ability to react to unfavourable states such as suffering or pain (Senior, 2008). Studies over the years have shown that most vertebrate species are sentient (Broom, 2007; Elwood et *al.,* 2009), and some countries have promulgated laws ensuring vertebrate protection (Turner, 2006).

Consequently, many proponents of animal rights are of the view that better human-animal relationships should be encouraged. Because animals such as rams have feelings, their physical and mental welfare needs must be considered (Royal Society for the Prevention of Cruelty to Animals, 2023). Although non-human animals are often seen as the 'property' of their owners, it is advocated that these animals should be cared for by their human owners, and it has also been suggested that they deserve to have rights similar to those of humans (Ladwig, 2023).

The ethical implications of ram fighting revolve around the principles of respect, fairness, and intrinsic value of animals. Advocates for animal rights argue that animals should not be exploited for entertainment purposes, especially when it involves causing harm and distress (Heinich, 2014; Tienda-Palop, 2018). Ram fighting can be seen as a violation of these principles, as it prioritizes human entertainment and monetary gain over the animals' well-being. Additionally, the practice may perpetuate a culture of violence and cruelty, normalizing the mistreatment of animals for the sake of human enjoyment. While it is argued that the rams engage in similar behaviours in the wild, it is important to recognize the significant differences. In their natural environment, rams compete for resources, social status, and mates, driven by instinct and survival (Begon *et al.,* 2006). Sometimes, conflicts over territory or access to parental care could trigger intraspecific fights between animals in the wild. These fights could be openly aggressive or simply non-violent competition over limited resources. The resultant effect of animal fights in the wild is that individual animals suffer from violence or deprivation. The dominant animals take control of the territory to show their superiority over the weaker ones; those without territories often struggle to find enough food.

Similarly, those animals who lose out in competitions for mates may not be killed by stronger males, but they will be unable to breed and may suffer from sexual frustration. Non-human animals often find themselves struggling to survive from the very moment they are born, and much of the dangers they encounter come from animals of their species (Animal Ethics, 2023). For some species, even their parents and siblings can pose a threat. In ram fighting, the animals are intentionally placed in an artificial and controlled environment solely for human entertainment. Exploiting animals for our amusement raises questions about the moral justifications for such practices.

Addressing Welfare Concerns Associated with Ram Fighting

Developing Alternative Forms of Entertainment

The debate surrounding the ethical implications of using animals in sports and recreational activities in Nigeria involves diverse stakeholder perspectives. Understanding these perspectives is crucial for developing a comprehensive understanding of the topic. Considering the ethical concerns associated with ram fighting, it is important to explore alternative forms of entertainment that do not involve the use of animals. Society has progressed in recent years, embracing more compassionate and humane alternatives. Sports and recreational activities that prioritize the well-being and dignity of animals, such as agility competitions, can provide engaging entertainment without subjecting animals to harm or exploitation. Agility competition is fast becoming popular in dogs and horses and could be popularized in other species like rams. In agility competitions, the animal (ram, dog, horse) is directed through some pre-set obstacle under a given time limit within which to complete certain tasks, and these tasks may include racing through a tunnel, tyre jumps, and seesaws (American Kennel Club, 2022). The fascinating thing about these agility tasks is that they are done following the clues and instructions of the animal's owner. It further presents an avenue for bodily exercise for the animal and its owners. Before any agility competition, the owner of the animal holds several practice sessions with the animal over a considerable period, during which the animal is expected to have mastered the trickeries involved in agility games through the use of certain equipment that the owner may have purchased or fabricated for such home practice.

Promoting Awareness and Change:

Addressing the ethical implications of using animals in ram fighting requires a multi-faceted approach. Raising awareness among the public about the welfare issues involved is crucial. The first step towards discouraging ram fighting is discouraging attendance at ram fighting events. During ram fighting, community sports centres, school playgrounds, or even a stadium could be used for such events. These venues are often packed with people, and most spectators do not even find anywhere to sit.

In most cases, spectators buy tickets to go and watch a typical ram fight. Often, most of them end up getting disappointed after seeing how bloody the event could become, especially judging from the angle of the torture the animals have to go through to amuse spectators. The use of venues for such activities should be banned. Furthermore, educating individuals about the potential harm inflicted on the animals and the moral considerations at stake can foster empathy and encourage critical thinking. This awareness can lead to shifts in societal attitudes and eventually influence policymakers to reevaluate the legality and ethics of such activities. Such awareness efforts can start in our schools. As a matter of responsibility, teachers and caregivers should teach their children and wards about the dangers of animal cruelty, which encapsulates animal fighting (ram fighting). Textbooks, charts, and video and audio messages discouraging ram fighting should be incorporated into our school curriculum. By extension, owners of pets or companion animals (dogs, cats, rams) should also be taught about responsible ownership. They should also respect that these animals, though not humans, are aware in all regards. Parents can protect animals and combat animal cruelty on the home front if they lead by example. This can be achieved by teaching their children how to safely and respectfully interact with animals. Children are always quick to learn. A simple walk through the neighbourhood behaving as a responsible, loving pet owner can make a huge difference. Awareness campaigns should focus on the fact that cruelty to any species of animal means cruelty to all animals in any form. Animal rights groups and government authorities should place monetary rewards for those reporting offenders of ram fighting around them.

Regulation and Enforcement

Implementing and enforcing animal welfare regulations specifically tailored to sports and recreational activities involving animals is vital. Governments and regulatory bodies should assess animal welfare's impact and ensure that existing practices adhere to ethical standards. Stricter guidelines, including regular veterinary inspections and the provision of appropriate care, can help mitigate the harm inflicted on the animals. Penalties should be met to offenders or those found guilty of organizing or participating in animal fighting. Although laws against animal cruelty exist in Nigeria. According to World Animal Protection (WAP, 2020), the government of Nigeria is urged to forbid the organization and attendance of entertainment events that cause animal suffering. Such a prohibition should cover circuses, rodeos, animal fights, animal races, rides on wild animals, and all other forms of entertainment. However, these laws have not been properly adhered to, probably because there may not have been proper awareness about their existence or because violators of such anti-animal cruelty laws see animals as mere 'properties' of their human owners, which should not be accorded any special care.

CONCLUSION

Using animals for sports and recreational purposes is an age-long practice in most parts of the world, including Nigeria. Assessing the ethical implications of using animals in sports and recreational activities, particularly ram fighting, in Nigeria requires a comprehensive examination of cultural, historical, and ethical dimensions. Balancing the preservation of cultural heritage with animal welfare considerations presents a complex challenge. This study provided an initial overview of the topic, setting the stage for a deeper exploration of the ethical concerns, stakeholder perspectives, and potential solutions to address the ethical implications of using animals in sports and recreational activities in Nigeria. There is an increasing need to reassess our treatment of animals and consider alternative forms of entertainment that prioritize their welfare. This is because greater attention is now being paid to the quality of animal meat and meat products. Using animals for sports constitutes great physical stress on them. This has resulted in loss of weight, carcass damage, and alteration of meat quality. It also caused an increase in meat pH, which resulted in products (meat and skin) being compromised in quality. Therefore, efforts should ensure that rams are subjected to minimal stress conditions to enhance the quality of their products. Animals, being sentient, should be handled in the most humane conditions. Moreover, by fostering a culture of compassion and respect, we can create a more ethical and sustainable future for humans and animals.

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ASSESSMENT OF FACTORS INFLUENCING POULTRY PRODUCTION AMONG RURAL FARMERS IN KATCHA AND LAPAI LOCAL GOVERNMENT AREAS OF NIGER STATE, NIGERIA

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ABSTRACT

The study assessed factors influencing poultry production among small-scale farmers in Katcha and Lapai Local Government Areas of Niger State. A three-stage sampling procedure was used to select 132 small-scale poultry farmers, to whom structured questionnaires were administered to collect primary data. The data collected were analyzed using descriptive statistics (frequency count, percentages, and means), inferential statistics (multiple regressions), and farm budgeting techniques. The socio-economic characteristics of the farmers showed that most (45.5%) were between 30-40 years of age with a mean age of 36 years, 70.1% of the farmers were male, and 57.5% were married. The mean household size was six persons, while the mean farming experience was 5.2 years. Over half (53.0%) of the farmers had primary and secondary school education. The costs and returns evaluation result revealed that the farmers incurred more expenses in purchasing feeds (₦68,616.34). In contrast, returns on poultry production were ₦357,103.54 with a profitability and efficiency ratio of 1.28 and 2.28, respectively, per 100 birds. The multiple regression results revealed that feeds (0.0561), drugs/vaccines (0.0577), credit (0.0520), age (-0.0192), education (0.0122), household size (0.0425) and farming experience (0.1617) significantly influence poultry output at 1% and 5% level of probability. Meanwhile, the high cost of feed ($\dot{x}$=2.45) and high temperature ($\dot{x}$= 2.29) were the most severe constraints faced by the poultry farmers. These findings showed that the poultry *farmers were making reasonable returns from poultry farming. The government and other relevant stakeholders should encourage the farmers to adopt climate-smart agricultural practices to mitigate the effects of temperature on poultry birds. Also, extension services should be intensified, for increased poultry production in the study area.*

Keywords: Assessment, Factors influencing, Poultry production, Small-scale farmers

INTRODUCTION

The poultry industry, a prominent sub-sector of animal husbandry, plays a crucial economic and nutritional role in the livelihood of urban and rural poor households in many developing nations, including Nigeria. It occupies a significant position by providing high-quality animal protein, minerals, and vitamins to balance the human diet (Adeniran *et al.,*2018). Poultry production, the raising of domestic birds for food, either meat or eggs, includes birds such as chickens, ducks, turkeys, geese, quail, and guinea fowl (Osuji, 2019).

Poultry products such as meat and eggs are highly nutritious and give farmers good economic returns. According to Okunola and Olofinsawe (2007), poultry meat is a good source of animal protein, which is always preferred to beef and pork, owing to its adaptability, taste, ease of processing, health consideration, nutrient composition, and contribution to food security. On the other hand, the Food and Agriculture Organization (FAO) (2013) reported poultry eggs contain the highest Net Protein Utilization (NPU) of about 87%, which doubles the 40% NPU value of grains, except rice, which contains slightly higher NPU of about 60%. Inyang and Eko (2015) posit that poultry provides ready income and development to many households in Nigeria in addition to having the fastest and highest rate of returns to investment, ease of management, and small space requirement.

The poultry industry is one of the most dynamic and fastest-growing segments of the livestock sub-sector. It constitutes about 58.7% of the total livestock resources of the nation (National Bureau of Statistics (NBS), 2023). In Nigeria, poultry contributes about 15% of the total annual protein intake, with approximately 1.3kg of poultry products consumed per head per annum (Osuji, 2019). Besides, the poultry industry also serves as a source of employment and poverty alleviation. It is worth noting that approximately 80% of rural households in Nigeria are engaged in small-scale to medium-scale poultry production (Heinke *et al.*, 2015; NBS, 2023).

It is, however, unfortunate that in recent times, the poultry industry has experienced a steep decline in output attributed to some factors such as poor market access, high cost of feeds and chicks, untimely delivery of inputs, inadequate capital, and poor extension services and these factors bring a lot of uncertainties in poultry production (Ebukiba and Anthony, 2019). Owing to these underlying factors, the poultry industry now lags behind the other livestock sub-sectors, and the gap between demand and supply of poultry products has grown wider. In 2022, there was an estimated supply gap of 529,000 metric tonnes of poultry meat in Nigeria (NBS, 2023). In this respect, there is a need to assess the factors that influence poultry production in the study area and suggest ways to narrow the demand and supply gap. Thus, the specific objectives of the study were to:

- Describe the socio-economic characteristics of small-scale poultry farmers.
- Analyze the costs and returns in small-scale poultry production.
- Determine the factors that influence small-scale poultry production and examine the constraints associated with small-scale poultry production.

METHODOLOGY

Study Area

The study was carried out in Katcha, and Lapai Local Government Areas of Niger State Agricultural Zone I. Niger State lies between Latitude 8o – 10o North and Longitude 3o – 8oEast with an estimated total land area of 74,244 square kilometres (Muhammad *et al.*, 2011). As of the 2006 census, the human population stood at 3,950,249 (NPC, 2006). However, as of the end of 2022, the projected population with a 3.4% growth rate was 6,744,655 (NBS, 2023). Niger State experiences two distinct seasons, wet and dry, with mean annual rainfall ranging from 1000mm-1500mm. The basic pattern of land ownership is a communal system, while crop and livestock production form the primary occupation of the people.

Sampling Procedure and Sample Size

The study used a three-stage sampling procedure to select the respondents. The first stage was a purposive selection of two Local Government Areas (LGAs) due to the preponderance of poultry-rearing activities. The second stage randomly selected eight communities from Katcha LGA and ten from Lapai LGA to get eighteen communities. The third stage involved selecting eight poultry farmers from each community selected in Katcha LGA and seven from each community selected in Lapai LGA to get a total sample size of 134 poultry farmers used as respondents for the study.

Method of Data Collection and Analysis

Primary data were obtained through a semi-structured questionnaire complemented with an interview schedule. The data were subjected to descriptive statistics (frequency count, percentage, and mean) and inferential statistics (farm budgeting technique and multiple regression analysis). Meanwhile, a three-point Likert-type rating scale of very severe (VS) = 3, Severe (S) = 2, and Not Severe (NS) = 1, was used to measure the constraints faced by the farmers. The decision rule was determined by adding the scores together (3 + 2 + 1) and dividing by 3 to get a mean score of 2.0 was used as a benchmark. Therefore, a calculated mean score greater than or equal to 2.0 implies a severe constraint, while a mean value less than 2.0 implies no severe constraint.

Model Specifications

Farm Budgeting Technique

The farm budgetary technique was used for costs and returns analysis. The analysis comprises Fixed Costs (FC), Variable Costs (VC), Total Costs (TC), Total Revenue (TR), Gross Margin (GM), and profit.

$$TC = TVC + TFC \quad (1)$$

$$TR = P*Q \text{ (P = Price and Q =Total output (kg))} \quad (2)$$

$$GM = TR - TVC \quad (3)$$

$$Profit = GM - TFC \text{ or } TR - TC \quad (4)$$

Multiple Regression Model

The multiple regression analysis was used to determine the factors that influence the output of poultry farmers. The model as applied by Muhammad *et al.* (2020) is implicitly expressed as:

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9) \quad (5)$$

The explicit functional forms of the multiple regression model are:

Linear:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots\ldots + \beta_9 X_9 + u \quad (6)$$

Cobb-Douglas:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \ldots\ldots + \beta_9 \ln X_9 + u \quad (7)$$

Semi-log:

$$Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \ldots\ldots + \beta_9 \ln X_9 + u \quad (8)$$

Exponential:

$$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots\ldots + \beta_9 X_9 + u \quad (9)$$

Where;

Y = Output of poultry farmers (kg)

X_1 = Feeds (kg)

X_2 = Drugs (kg)

X_3 = Labour (man-days)

X_4 = Amount of credit (Naira)

X_5 = Age (years)ducation (years)

X_7 = Household size (number)

X_8 = Farming experience (years)

X_9 = Extension contacts (number)

u = error term

RESULTS AND DISCUSSION

Socio-economic characteristics of the respondents

Results in Table 1 reveal that 45.5% of poultry farmers were in the age bracket of 30-40 years, with a mean of 35.6 years, implying that the farmers were in their active age, which was likely to impact positively on their output. This finding agrees with the study of Ebukiba and Anthony (2019), who found that the poultry farmers in their study area had a mean age of 36 years. The majority (70.1%) of the farmers were male and 29.9% were female. These revealed that poultry production in the study area was mainly dominated by the male gender, which is often related to specific factors such as biological, cultural, and economic considerations. This finding conforms with that of Muhammad *et al.* (2020), who reported that poultry production was mostly by male gender. Table 1 also shows that more than half (57.5%) of the farmers were married, while 43.3% had household sizes of 5-10 people with a mean of 6 persons. These results imply that most respondents had relatively large households and could be a source of family labour in poultry production. Most (69.4%) of the farmers had formal education, while 30.4% had no formal education. Thus, a high proportion of the respondents were educated, which positively influenced their poultry production decision-making. More so, 45.5% of the farmers had less than ten years of poultry-rearing experience. A considerable proportion of the farmers were new to poultry production in the study area. This finding agrees with the study of Adeniran *et al.* (2018), who reported that several poultry farmers in their study area had formal education and experience in the enterprise. Furthermore, the majority (85.1%) of the farmers were members of cooperatives. This high membership of cooperatives was likely to enable them to access government assistance and other interventions geared toward enhancing poultry production

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Table 1: Socio-economic Characteristic of Small-Scale Poultry Farmers

Variable	Frequency	Percentage (%)	Mean
Age (years)			
<30	35	26.1	
30-40	61	45.5	35.6
41-50	15	11.2	
>50	23	17.2	
Sex			
Male	94	70.1	
Female	40	29.9	
Marital Status			
Single	42	31.3	
Married	77	57.5	
Divorce	5	3.7	
Widow	10	7.5	
Household size (number)			
<5	54	40.3	
5-10	58	43.3	6
>10	22	16.4	
Educational level			
Non formal	41	30.6	
Primary	38	28.4	
Secondary	33	24.6	
Tertiary	22	16.4	
Farming experience (years)			
< 10	61	45.5	
10-20	54	40.3	
>20	19	14.2	5.2
Cooperative membership			
Yes	114	85.1	
No	20	14.9	
Extension contacts			
Yes	68	50.7	
No	66	49.3	

Source: Field Survey, 2021

Costs and Returns of Poultry Production

The farm budgeting technique was used to analyse the costs and returns of the poultry farmers in the study area, as presented in Table 2. This comprises the gross margin, net farm income, revenue, and total cost (variable and fixed costs). The result revealed that the average variable costs per 100 birds of the poultry farmers was ₦119,683.51 representing 76.4% of the total cost, while the fixed costs per 100 birds were ₦37,011.12, representing 23.6% of the total costs. Among the variable costs of poultry production includes the cost of feed (₦68,611.34) representing 43.8% and the highest cost incurred by the farmers. This is followed by the cost of purchasing day-old chicks (₦21,478.36), representing 13.7% of the total production costs. Other costs incurred include the cost of vaccines (₦3,552.24), cost of drugs (₦6,695.5), cost of water (₦3,202.99), cost of litter materials (₦5,343.28) and cost of labor (₦10,850.75) representing 2.3%, 4.2%, 2.0%, 3.4%, and 6.9%, respectively. This implies that feed usage recorded the highest variable cost incurred in poultry production by the respondents in the study area. The total revenue realized by the poultry farmers in the study area was ₦357,103.54 per 100 birds, while the gross margin and net farm income were ₦237,402.03 and ₦200,403.91 per 100 birds, respectively. The profitability and efficiency ratios were 1.28 and 2.28, respectively, per 100 birds, implying the profitability of poultry production in the study area. This finding corroborates the study of Heinke *et al*. (2015) and Osuji (2019), who reported that poultry production in their study area is profitable.

Factors Influencing the Output of Poultry Farmers

Table 3 presents the results of multiple regression analysis, which estimates the factors that significantly influence the output of poultry farmers in the study area. We chose the double-log functional form of the multiple regression as the lead equation, which yielded a high coefficient of determination (R2) value of 0.9321. This means that approximately 93% of the variation in the output of the poultry farmers can be explained by the independent variables included in the model. Notably, seven out of the nine independent variables specified in the model (feed, cost of drug, labour, amount of credit, household size, extension contact, and farming experience) were found to be significant at a 1% level of probability based on the t-value from the regression estimates.

Drugs/vaccines (-0.0577) and age (-0.0192) had negative coefficients and significant at 1% level of probability, respectively. This implies that a high drug/vaccine administration dosage could reduce the farmers` output level, while the increase in age affects performance, leading to low output. Thus, a unit increase in drug/vaccine application and age of the farmers could lead to a decrease of about 5% and 2% in the poultry output respondents in the study area. This finding is in line with the study of Ebukiba and Anthony (2019), who reported that poultry farmers' medication and age negatively influenced poultry production in their study area.

Furthermore, feed, credit access, education, household size, and farming experience all had positive coefficients and were significant at a 1% probability level. The observation means that these factors positively influenced the output of poultry farmers in the study area. A unit increase in any of these variables could lead to a rise of about 6%, 5%, 1%, 4%, and 16%, respectively, in the poultry output of respondents in the study area. This is a promising finding and agrees with the study of Osuji (2019), who reported that feeds, education, and credit positively influenced the output of poultry production in their study area.

Table 2: Costs and Returns Analysis of Small-Scale Poultry Production per 100 Birds

Cost of items/Revenue	Average cost (₦)	% of total cost	Revenue (₦)
Returns			**357,103.54**
Variable cost			
Cost of feed	68616.34	43.79	
Cost of chicks	21478.36	13.71	
Cost of vaccine	3552.24	2.27	
Cost of drugs	6639.55	4.24	
Cost of water	3202.99	2.04	
Cost of litter material	5343.28	3.41	
Cost of labour	10,850.75	6.92	
Total variable cost (TVC)	**119,685.51**	**76.38**	
Fixed cost			
Depreciation of farm assets	37,011.12	23.62	
Total fixed cost (TFC)	**37,011.12**	**23.62**	
Total cost (TC)	**156,694.63**		
Gross Margin (GM)=GI-TVC			**237,420.03**
Net Farm Income (NFI)=GM-TFC			**200,408.91**
Profitable Ratio=NFI/TC			**1.28**
Efficiency Ratio TR/TC			**2.28**

Source: Field Survey, 2021

Constraints Faced by the Respondents

The results of the constraints associated with poultry production in the study area, as presented in Table 4, align with previous studies. The high cost of feed (X = 2.45) ranked 1st among the severe constraints indicated by the respondent, a finding consistent with other research that shows feed is a key component of poultry production (Adeniran *et al.*, 2018). This is followed by poor extension service (X = 2.32), high-temperature effect (X = 2.29), high cost of medication (X = 2.20), and unstable price of chicks (X = 2.01), ranked 2nd, 3rd, 4th, and 5th, respectively, among the severe constraints faced by the poultry farmers in the study area. This finding is in line with the study of Adeniran *et al.* (2018) and Osuji (2019), who reported similar constraints associated with poultry production in their study areas.

Table 3: Regression Estimates of Factors Influencing Poultry Production

	Linear		**Semi-log**		**Double-log**		**Exponential**	
Variables	**Coeff.**	**t-value**	**Coeff.**	**t-value**	**Coeff.**	**t-value**	**Coeff.**	**t-value**
Constant term	5441.57	24.43***	5610.58	18.76***	8.6591	15.27***	8.5827	22.63***
Feed	-0.2008	-4.69***	317.65	8.36***	0.0561	7.98***	-0.0003	-4.31***
Drugs/Vaccines	0.0586	3.99***	-336.61	-3.79***	-0.0577	-3.14***	-0.0001	-3.31***
Labour	-0.0641	-2.82***	197.21	1.67	0.0118	1.22	0.0001	3.20***
Credit	-0.0378	7.48***	27.54	8.16***	0.0502	8.25***	6.91e-06	8.05***
Age	-1.7971	-0.57	-100.19	-1.90*	-0.0192	-3.00***	-0.0003	-0.57
Education	4.3349	0.53	64.21	3.06***	0.0122	3.14***	0.0008	0.60
Household size	197.44	10.92***	216.09	10.38***	0.0425	11.03***	0.0359	11.67***
Farming experience	56.61	1.68	876.44	31.11***	0.1617	31.01***	0.0123	1.15
Extension contacts	522.53	6.54***	7.54	0.27	0.0016	0.31	0.0901	6.63***
R^2	**0.9210**		**0.9100**		**0.9321**		**0.9293**	
R^2-Adjusted	**0.9153**		**0.8931**		**0.9289**		**0.9241**	
F-statistic	**16.59*** **		**19.55*** **		**21.03*** **		**19.76*** **	

Source: Field Survey, 2021

CONCLUSION AND RECOMMENDATIONS

Poultry production in the study area is a profitable enterprise, despite the challenges faced by farmers such as the high cost of feed, poor extension service, and high-temperature effects. In light of these challenges, the study recommends that the government and relevant stakeholders take immediate action. By encouraging the adoption of climate-smart agricultural practices, they can help mitigate the effects of temperature on poultry birds and ensure an efficient feed conversion ratio at reduced costs. Equally important is the need to intensify the delivery of extension services, as this will be a key factor in boosting poultry production.

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Table 4: Constraints Associated with Small-Scale Poultry Production

Constraints	VS (3)	S (2)	NS (1)	WS	WM ($\overline{X}$)	Rank	Remark
High cost of feeds	73	48	13	328	2.45	1st	Severe
Poor extension service	70	37	27	311	2.32	2nd	Severe
High temperature effect	49	85	-	307	2.29	3rd	Severe
High cost of medication	27	107	-	295	2.20	4th	Severe
Unstable price of day-old chicks	13	12	-	281	2.01	5th	Severe
Inadequate capital	37	51	46	259	1.93	6th	Not severe
Lack of quality vaccine	40	48	46	262	1.96	7th	Not severe
Problem of bio-security	13	121	-	255	1.90	8th	Not severe
Lack of fast-growing birds	40	-	94	214	1.59	9th	Not severe

Source: Field Survey, 2021

Note: Very Severe = VS (3), Severe = S (2), Not Severe = NS (1), Weighted Sum = WS, Weighted Mean = WM and $\bar{X}$ = Bench Mean Score of 2.0

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EFFECTS OF AGRICULTURAL EXTENSION ACTIVITIES ON FOOD SECURITY STATUS OF RURAL FARMERS IN FEDERAL CAPITAL TERRITORY (FCT) ABUJA, NIGERIA

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ABSTRACT

This study assessed agricultural extension activities and food security status among rural farmers in the Federal Capital Territory (FCT), Abuja, Nigeria. The three-stage sampling procedure was employed to select 145 rural farmers, on which a structured questionnaire was administered and complemented with an interview schedule. Primary data collected were analysed using descriptive statistics and a logit regression model. Findings from the study revealed that the mean age of the respondents was 40 years, implying that the respondents are still actively engaged in agriculture. In contrast, the mean farm size was 3.0 hectares, implying medium-scale farming operation and the mean annual income was ₦646,483, implying a relatively fair income considering the country's minimum wage. The results of the extension activities to the farmers in the study area revealed that the majority (93.1%) of the respondents had contact with extension agents and benefitted from various extension services. Some of the extension activities they benefited from include extension advice on the use of improved fertilizer (97.9%), animal health management (97.2%), training and outreach (97.2%), crop protection (95.9%), the use of improved seeds (94.5%), storage and preservation (94.5%) and sales of crop produce (93.1%) among others. Based on the estimated FGT food security line of

₦15,946.80, the majority (77.9%) of the respondents were found to be above the line, hence food secured, while 22.1% were found to be below the line, hence food insecure. Logit regression result revealed that sex (-2.16, $p<0.05$), household size (-2.45, $p<0.05$), education (3.25, $p<0.01$), farming experience (2.54, $p<0.01$), and extension activities (2.02, $p<0.05$) were statistically significant and influenced food security status of the farmers in FCT, Nigeria. In conclusion, the study revealed a positive and significant impact of agricultural extension services on the food security status of the respondents. It was therefore recommended that relevant extension agencies, in partnership with NGOs, and with the active involvement of the audience, implement robust extension activities that guarantee self-sufficiency in food production.

Keywords: Effects, Agricultural extension activities, food security status, rural farmers

INTRODUCTION

Agricultural extension is the application of scientific research and new knowledge to agricultural practices through farmer education. Rivera and Alex (2004) state that extension is the political and organizational tools implemented to facilitate development. It ranges from the transfer of mono-crop technology to participatory problem-solving educational approaches, which aim at reducing poverty and increasing community involvement in development processes. Nwuzor (2009) views agricultural extension as a service or system that assists farm people through educational procedures in improving their farming methods and techniques, increasing their production efficiency and income, and bettering their levels of living. It also helps to lift the social and educational lives of rural people. It ensures information obtained and assembled from research studies based on experience is tried and demonstrated to extend knowledge to rural dwellers.

It may not always be possible to quantify the precise contribution of extension services to agricultural development, but effective extension service contributes significantly to the production of crops and livestock. According to Muhammed *et al.* (2019), a practical extension information service meets farmers' needs, and the content of the information is specific, straightforward, and valuable. Ibrahim *et al.* (2015) posited that agricultural extension education is a teaching and learning process in which the farmers are taught better farming methods to raise their productivity and standard of living. Agricultural extension activities have become a strategy for transforming traditional agriculture into a progressive and modern one.

It is also a rural transformation and development strategy in which the entire rural areas, including human and non-human resources, are improved (Ibrahim *et al.,* 2015). Thus, it enhances farmer's capacity to produce more and impacts their standard of living.

In recent times, agricultural extension activities have gone beyond educating and teaching farmers. It involves the transfer of scientific knowledge farmers require to utilize modern technologies. Undoubtedly, farming is associated with problems, and for local farmers to solve the farming problems within them, they need comprehensive information on the use of modern technology. Therefore, agricultural extension integrates innovations into extension services delivery to promote agriculture and make it a lasting solution to crises such as food shortage and low yield. According to the Federal Ministry of Agriculture and Rural Development (FMARD) (2018), food production has not kept pace with population growth, resulting in rising food imports and declining levels of national food self-sufficiency. The main factors undermining production could be over-reliance on rain-fed agriculture, small landholding, low productivity due to poor planting material and date, low fertilizer application, and weak agricultural extension system.

According to Mgbenka and Mbah (2016), about 90% of Nigeria's agricultural output comes from smallholder farmers operating small farms. Most rural farmers need more access to fertilizers, irrigation, modern inputs, and extension services. They could not produce enough food for their family's consumption and sales, leading to food insecurity due to unavailability or poor access to food. Food and Agriculture Organization (FAO) (2015) defined food security as "all people at all times having both physical and economic access to the basic food they need." However, Saleh and Mustapha (2018) posited that food security entails producing food that will go around every citizen in terms of quality and quantity. In a broader sense, food security has to do with having an adequate level of food products at all times to meet increasing consumption demand and mitigate fluctuation in output and price (Fashina *et al.,* 2020).

There is a significant problem of food insecurity in Nigeria, as demonstrated by the widening food gap that is bridged chiefly through food importation. It is worth noting that the government's past agricultural strategies and extension activities for economic development have yet to lead to a drastic turnaround in the agricultural sector. Meanwhile, the current emphasis on private sector extension activities to achieve agricultural development aligns with the worldwide approach. Still, it poses some problems for Nigeria's resource-poor farmers, who need help securing production assistance. Thus, the increasing lack of access to agricultural extension services by rural farmers has hindered increased food production and the realization of self-sufficiency, thereby leading to food insecurity. There is a severe knowledge gap that must be filled to ensure food security. It is against this backdrop that this study was conceived, and the specific objectives of the study were to:

i. Describe the socio-economic characteristics of the rural farmers in the study area;

ii. examine the various agricultural extension activities available to the rural farmers;

iii. estimate the food security status of the rural farmers, and

iv. determine the effects of agricultural extension activities on the food security status of rural farmers in the study area.

METHODOLOGY

Study Area

The study was carried out in Federal Capital Territory (FCT), Abuja, which lies between Latitudes 8°25′and 9°25′ North of the equator and Longitudes 6°45′and 7°45′ East of the Greenwich Meridian with a population of 3,950,249 (National Population Commission (NPC), 2006). The projected population as of 2022 was 6,144,893, given growth rates of 2.8% (National Bureau of Statistics (NBS), 2023). The major ethnic groups are Amwamwa, Bassa, Gade, Ganagana, Gbagyi, Gwandara, and Koro, although other minor ethnic groups also settle in the area. Federal Capital Territory covers a total land area of 8,000 square kilometres and the vegetation falls mainly on Savanna Zones. It experiences three weather conditions annually; the rainy season and dry season, and in between the two seasons, there is a brief interlude of harmattan occasioned by the North East Trade Wind, with the main feature of dust haze, intensified coldness, and dryness. The rainfall ranges between 1100mm to 1600mm, while the average temperature is about 32oC. Agriculture is the main occupation of the people as most of the communities are predominantly rural.

Sampling Procedure and Sample Size

A three-stage sampling procedure was used to select respondents for this study. The first stage randomly selected two Area Councils of FCT Abuja (Kuje and Bwari). In the second stage, three (3) communities were randomly selected from each of the Area Councils to get six communities. The third stage was a proportionate selection of respondents based on a total list of 483 registered rural farmers (238 from Kuje and 245 from Bwari Area Councils) obtained from FCTADP using Yamane (1967) sample size determination formula as used by Muhammed *et al.* (2019) at 7% level of precision. This gave a total of 145 rural farmers (72 from Kuje and 73 from Bwari Area Councils) used as respondents for the study. The Yamane's formula was used (equation 1):

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

Where;

n = sample size

N = finite population

e = limit of tolerable error (level of precision at 0.07 probability)

Method of Data Collection and Analysis

This study used a cross-sectional survey in which primary data were obtained directly from the respondents, using a structured questionnaire complemented with an interview schedule. It is a type of data collection in which the researcher has complete control over its accuracy and usage. The primary data collected were analysed using descriptive statistics such as frequency counts, percentages, and mean to achieve objectives I and ii. The Foster Greer and Thorbecke (FGT) formula was used to achieve objectives ii, and the advanced inferential statistics of the Logit regression model was used to achieve objectives iv, demonstrating the depth of our analysis.

Model Specification

Foster Greer and Thorbecke (FGT)

The Foster et *al*. (1984) FGT formula, a key component of this study, was used to estimate the food security status of rural farmers. The FGT formula, as used by Ajayi *et al.* (2023), is expressed in equation (2):

$$F\alpha = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{Z-y_1}{z}\right)^{\alpha} \quad (2)$$

Where;

$F\alpha$ = food security Index

N = total number of households

q = the number of households below the food security line

z = the food security line for the household

y_i = household expenditure

Σ = summation sign

α = food security aversion parameter takes on value of 0, 1, 2 representing incidence, gap and severity of the food insecurity respectively. The measure relates to different dimensions of food security status.

Thus, when α = 0 representing food security incidence, FGT model is expressed in equation (3):

$$F_O = \frac{Ho}{N} \quad (3)$$

Where;

F_0 = food security incidence

Ho = number of households below food security line

N = total number of households

when α = 1 representing food insecurity gap, FGT model is expressed in equation (4):

$$F_1 = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{Z-y_1}{z}\right)^1 \quad (4)$$

Where;

F_1 = food insecurity gap

when α = 2 representing food insecurity severity, FGT model is expressed in equation (5):

$$F_2 = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{Z-y_1}{z}\right)^2 \quad (5)$$

Where;

F_2 = food insecurity severity

Logit Regression Model

The logit regression model was used to determine the effects of agricultural extension activities on the food security status of rural farmers. It is a model used to estimate the probability of an event based on a dichotomous dependent variable. A dichotomous dependent variable assumes only two values of zero or one. The Logit model is specified implicitly in equation (6):

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8) \quad (6)$$

The explicit form of the Logit model is presented in equation (7):

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + e \quad (7)$$

Where;

Y is food security status of the rural farmers measured as dichotomous variable of 1 if food secured, 0 if otherwise.

β_0 = Intercept

$\beta_1 - \beta_8$ = Coefficient of the independent variables

$X_1 - X_8$ = Independent variables

X_1 = Age of the respondent (years)

X_2 = Sex (1 if male, 0 if otherwise)

X_3 = Household size (numbers)

X_4 = Education (years)

X_5 = Farming experience (years)

X_6 = Distance from residence to farm (kilometers)

X_7 = Extension activities (number)

X_8 = Cooperative membership (years)

e = error term

RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Respondents

The socio-economic characteristics of the respondents described include age, gender, marital status, household size, education, farming experience, farm size, extension contact, and cooperative membership. Table 1 reveals that 44.8% of the respondents were 36–55, with a mean age of 40. This implies that the rural farmers were agile at this age and could do much farm work for increased output, ensuring food security. This result agrees with the work of Fashina *et al.*(2020), who reported that the mean age of the respondents in their study area is 40 years, indicating an active farming age. The majority (83.4%) of the respondents were males, implying that males were more involved in farming than females, hence their dominance. This result agrees with the work of Ofune (2010), who reported that males dominated the workforce in Nigeria's agricultural communities. Also, the majority (73.8%) of the respondents were married, which, in essence, is for the procreation of younger ones who will assist in future farming. This finding agrees with Odoemekun and Anyim (2019), who reported in their study that most respondents were married purposely for the procreation of young ones who will assist in future farming activities.

As revealed in Table 1, more than half (55.2%) of the respondents had household sizes ranging between 6–10, with a mean household size of 6 people. This relatively large household size could provide the needed family labor to minimize cost and maximize output toward achieving food security. The majority (89.0%) of the respondents acquired formal education (primary, secondary, and tertiary), a significant factor in promoting food security. This high literacy level, with most respondents having acquired secondary education, is fundamental to enhancing food production. This result aligns with the work of Ajayi *et al.* (2023), who reported a similar trend in their study area. More so, Table 1 revealed that more than half (51.0%) of the respondents had farming experience of less than 11 years, although with a mean farming experience of 15 years. This implies that an average proportion of the respondents had been into farming for a relatively long period, which could help them make rational decisions regarding their farming operations that will ensure food security. This finding agrees with the study of Olaosebikan *et al*. (2019), who reported that most of the respondents in their study area had long years of farming experience, which enabled them to make sound decisions regarding farming operations.

The majority (78.6%) of the respondents had farm sizes between 1.1 – 3.0 hectares, with a mean farm size of 2.2 hectares. This implies that a more significant proportion of the rural farmers were operating at a small-scale production level. Small farm size impedes productivity, crop diversification, and consequently, the food security status of rural households. This finding agrees with the work of Kolade and Harpham (2014), who reported that small to medium-scale farmers make up a significant proportion of Nigeria's food production.

Regarding institutional variables assessed by the respondents, the majority (93.1%) had contact with an extension agent, a positive sign of the transfer of scientific knowledge required by farmers to understand the use of modern technology. Additionally, 84.1% were members of cooperative societies, a factor that significantly influences agricultural production among rural farmers. This finding underscores the potential for collective action to enhance food security. **Socio-Economic**

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Table 1: Distribution of the respondents based on socio-economic characteristics (n = 145)

Variables	Frequency	Percentages	Mean
Age (years)			
< 36	60	41.4	
36 – 45	35	24.1	
46 – 55	30	20.7	
> 55	20	13.8	40
Sex			
Male	121	83.4	
Female	24	16.6	
Marital status			
Married	107	73.8	
Single	29	20.0	
Widower	7	4.8	
Divorced	2	1.4	
Household Size (number)			
< 6	62	42.7	
6 – 10	80	55.2	
> 10	3	2.1	6
Educational Status			
No Formal	16	11.0	
Primary	15	10.3	
Secondary	81	55.9	
Tertiary	33	22.8	
Farming Experience (years)			
< 11	74	51.0	
11 – 20	46	31.7	
21 – 30	18	12.5	
> 30	7	4.8	15
Farm Size (hectares)			
< 1.1	29	20.0	
1.1 – 3.0	114	78.6	
> 3.0	2	1.4	3.2

Source: Field Survey, 2019

Table 2: Distribution of Respondents Based on Institutional Variables Assessed (n = 145)

Variables	Frequency	Percentages
Extension contact		
Contact	135	93.1
No contact	10	6.9
Cooperative membership		
Member	122	84.1
Not member	23	15.9

Source: Field Survey, 2019

Agricultural Extension Activities received by the respondents

The distribution of the respondents based on agricultural extension activities received from extension agents is shown in Figure 1. It revealed that advisory services on the use of improved fertilizer (97.9%), advisory services on animal health management (97.2%), outreach and extension training (97.2%), and advisory services on crop protection (95.9%)were the top most agricultural extension activities received by the respondents in the study area. Others include advisory services on storage and preservation of produce (94.5%), advisory services on the use of agricultural seeds (94.5%), advisory services on sales of crop produce (93.1%), advisory services on sales of livestock produce (87.6%) and advisory services on the use of improved animal breeds (75.2%). This implies that various extension activities are being implemented through the change agents to ensure the food security of rural farmers in the study area. This finding agrees with the work of Ayinde (2016), who reported that the objective of extension programme or activities is to make the farmers have a positive attitude towards farming to increase output. The most minor agricultural extension activities received by the respondents was training on the use of farming technologies (10.3%), implying poor dissemination of agricultural technologies that could have boosted food production and ensured security.

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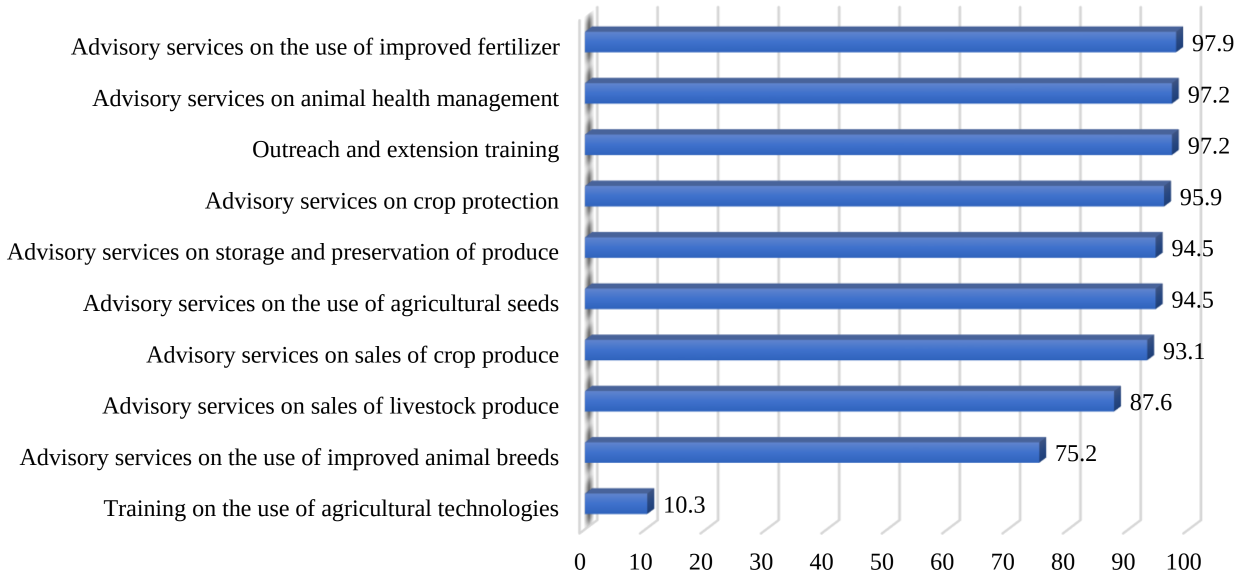

Figure 1: Extension Activities received by the respondents

Food Security Status of the Respondents

The results of the food security status of the respondents are presented in Table 2. A food security line was calculated to categorize the respondents' food security status at the household level. The household's monthly consumption expenditure was used to establish the food security line, which was ₦15,946.80. Thus, based on the food security line, the majority (77.9%) of the rural farmers were found to be food-secured, while 22.1% of the rural farmers were food-secured. The food security incidence was 0.2207, implying that about 22.0% of the rural farmers were food insecure. The food security gap, which measures the extent to which the respondents were below the food security line, was 0.0876. It implies that about 9% of the food security line (₦15,946.80), which is ₦1,435.20, is required to bring the food insecure households to the food security line. The depth of food insecurity given as a severity of 0.0513 implies that about 5% of the rural farmers were severely food insecure. This finding underscores the urgent need for further action to improve the food security situation. It also contrasts with the work of Saleh and Mustafa (2018), who found that a larger proportion of the households in their study area were food insecure.

Table 3: Distribution of the Respondents Based on Food Security Status

Categorization	Frequency	Percentages
Food secure	113	77.9
Food insecure	32	22.1
Total	145	100.0
Food Security Indices		
Food security line / month	₦15,946.80	
Food insecurity incidence	0.2207	
Food insecurity gap	0.0876	
Food insecurity severity	0.0513	

Source: Field Survey, 2019

Effects of Agricultural Extension Activities on the Food Security Status of the Respondents

The result of Logit regression analysis on the effects of agricultural extension activities on the food security status of the respondents in the study area is presented in Table 3. It revealed a Pseudo R-square value of 0.5917, implying that about 59% of the variation in the food security status of the respondents was explained by the predictor variables included in the model. From z – the value of the regression, five out of the eight independent variables included in the model were found to be statistically significant. Sex (-2.16), household (-2.45), and extension activities (2.02) were significant at 5%, while education (3.25) and farming experience (2.54) were significant at a 1% level of probability.

The coefficient of sex (-1.2266) was negative and significant at a 5% probability level, hence inversely influencing the food security status. This implies that more male farmers decreased the probability of being food-secured. Thus, male farming households are more likely to be food insecure due to several factors, including caring for more prominent families. This finding disagrees with the work of Fashina *et al.* (2020), who reported that the food insecurity situation in their study area is worse for female-headed households than for male-headed household heads.

The coefficient of household (-0.2508) was also negative and significant at a 5% probability level, hence inversely influencing the food security status. This implies a higher probability of a more enormous household being food insecure. Large household size translates into more mouths to feed, leading to higher consumption and expenditure. This agrees with the work of Ahmed (2011), who reported that large household size is related to increased household consumption expenditure that could negatively influence the food security status of rural farmers.

Table 4: Logit Estimates of Effects of Agricultural Extension Activities on Food Security Status

Variables	Coefficient	Standard error	z-value	Marginal effects
Constant	-4.1564	3.1213	-1.33	-
Age	-0.0203	0.0205	-0.99	-0.0562 (-1.32)
Sex	-1.2266	0.5690	-2.16**	-1.4682 (-2.35**)
Household size	-0.2508	0.1025	-2.45**	-0.4732 (-2.68***)
Education	0.1602	0.0492	3.25***	0.1965 (3.54***)
Farming experience	0.0654	0.0258	2.54***	0.1672 (2.71***)
Farm size	0.2935	0.2789	1.05	0.4165 (1.32)
Extension activities	0.6626	0.3282	2.02**	0.8152 (2.27**)
Cooperative membership	0.0155	0.0479	0.32	0.0346 (0.67)
Pseudo R^2	0.5917			
LR Chi^2	89.04***			
Prob > chi^2	0.0000			

*****significant at 1%, **significant at 5% and *significant at 10% level of probability**

The positive and significant coefficient of education (0.1602) at a 1% probability level directly influences the food security status. This finding underscores the crucial role of education in enhancing food security among rural farmers. It suggests that the more educated the respondents are, the higher the likelihood of being food-secured. Educated households are better equipped to secure additional jobs that can supplement farm income and make efficient use of available resources for higher yields. This aligns with the findings of Ishaya (2014), who also found a positive correlation between education and food security in his study area.

The positive and significant coefficient of farming experience (0.0654) at a 1% probability level directly influences the food security status. This finding underscores the importance of practical knowledge in ensuring food security among rural farmers. It suggests that the more experienced the respondents are in farming, the higher the likelihood of being food-secured. Households with more farming experience are likely to have accumulated the skills necessary for effective farm operations, leading to better resource use and higher output, thereby enhancing food security. This finding is consistent with the work of Fashina et *al.* (2020), who also found a positive relationship between farming experience and food security in their study area.

The positive and significant coefficient of extension activities (0.6626) at a 5% probability level directly influences the food security status. This finding underscores the significant role of extension activities in improving food security among rural farmers. It suggests that an increase in the number of extension activities or services received by the respondents leads to a higher likelihood of being food-secured. Agricultural extension activities or services play a crucial role in educating rural farmers on improved farming methods and techniques, thereby increasing their production efficiency, income, and food security. This finding is in line with the work of Muhammed *et al* .(2019), who also found that effective extension services significantly influence the food security status of farmers.

CONCLUSION AND RECOMMENDATIONS

Based on the empirical evidence from the study's findings, most farmers were in their most active and productive age, which determines the quality and quantity of farm operations needed to be food secure. They were predominantly males, married, and acquired formal education fundamental to promoting food security. Several agricultural extension activities were rendered through extension agents and received by the rural farmers in the study area. However, poor technology dissemination was a component of the extension activities. Meanwhile, a larger proportion of the rural farmers were food-secured, which could be due to the agricultural extension activities and advisory services received, with very few percentages experiencing severe food insecurity. Socio-economic and institutional factors that significantly affected the food security status of the rural farmers were sex and household size, which had inverse effects. In contrast, education, farming experience, and extension activities had direct effects. Therefore, several extension activities received by the rural farmers positively and significantly affected their food security status. The study, therefore, recommended that relevant agricultural extension agencies, in partnership with Non-Governmental Organizations (NGOs), should scale up the implementation of robust extension activities with emphasis on disseminating improved farming technologies that will guarantee self-sufficiency in food production. More so, improving the food security status of the rural farmers depends on their economic and social environment. Therefore, stakeholders like financial institutions and NGOs should facilitate increased access to finance, productive resources, extension services, and cooperative membership by poor resource farmers.

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Effect of Soil Proximity to Homestead, Nitrogen Source on Nodulation and Nodule Activity of some Cowpea (*Vigna unguiculata* (L.) Walp) Varieties

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ABSTRACT

Integration of Bradyrhizobial inoculation with improved cowpea varieties is one viable option to enhance cowpea nodulation and nitrogen fixation, resulting in sustainable cowpea production. This study was conducted in a screen house to determine the effects of soil proximity to the homestead, nitrogen source on nodulation, and nodule activity of some cowpea varieties. This study involved the factorial combination of soil proximity to homestead: close and far; nitrogen source: control (no nitrogen application), application of urea (100 kg N ha-1), inoculation with Bradyrhizobium strain BR 3262, Bradyrhizobium strain BR 3267, and cowpea varieties: Kanannado, IT93K-452-1, IT97K-499-35, and IT90K-277-2, arranged in a completely randomized design and replicated three times. Results revealed that the Most Probable Number (MPN) count of the cultivated soils to cowpea varieties ranged from (9.26 - 12.27 x 106). Results show that the field's proximity to the homestead did not significantly (P > 0.05) differ from that away from the homestead. Inoculation with BR 3262 significantly (P < 0.05) improved nodule number and dry weight by 62% and 66%. Kanannado significantly increased nodulation compared to the improved varieties. Inoculation with BR 3267 had more nodules than un-inoculated control and N treatment. The result indicates that using Bradyrhizobium strain BR 3262 or BR 3267 and Kanannado variety could improve cowpea *nodulation. Further study should, however, be carried out under field conditions to affirm this study.*

KEYWORDS: *Bradyrhizobium* inoculants, Cowpea, Nitrogen, Rhizobia, Soil proximity, Varieties

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp] is a leading grain legume crop that is grown on an estimated 12.3 million ha in Africa, with West Africa accounting for the bulk of the production on 10.6 million ha of farmlands (Kyei-Boahan *et al*., 2017). In West Africa, Niger, Nigeria, Burkina Faso, Mali, and Senegal are the leading producers of cowpea (Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT, 2016). In Nigeria, it is grown on an estimated land area of over 2.8 million ha with an average yield of 914 Kg ha-1(FAOSTSAT, 2018). It is mostly grown as sole or intercrop with cereals like millet (*Pennisetum glaucum*) or sorghum (*Sorghum bicolor*) and to a lesser extent with maize (Zea mays) (Horn and Shimelis, 2020). It is widely grown as a major source of cheap and quality protein (food) for both rural and urban dwellers and fodder. Also, it is an essential component of the cropping systems of most farmlands in the semi-arid regions of sub-Saharan Africa (Kyei-Boahan *et al.,* 2017).

The gap between the average and potential yield of cowpeas in Nigeria is mostly due to several factors. This includes poor planting arrangement in intercrop situations that leads to shading of companion crops, low plant population, low soil fertility, inappropriate planting time, the use of traditional cowpea cultivars with low yielding potential, pest and disease attack, lack of inputs use (Kyei-Boahan *et al*., 2017). Besides, continuous cropping of the land with no external inputs has resulted in a progressive decline in the yield of cowpeas due to the mining of the soil of its nutrients (Sprent and James, 2007; Woldeyohannes *et al.,* 2007; Dube and Fanadzo, 2013; Kyei-Boahen *et al*., 2017).

One feasible and effective method that can be adopted by farmers to increase cowpea yield is to adopt a sustainable intensification approach. This involves the integration of growing more drought-tolerant cultivars, the use of improved crop management such as time of planting and plant population, residue management, tillage, and inputs, such as crop protection chemicals, mineral fertilizers, and use of Rhizobium inoculants (Kyei-Boahen *et al*., 2017).

Application of nitrate and ammonium through the addition of nitrogen fertilizers or Biological Nitrogen Fixation (BNF) fertilizers are necessary inputs that can contribute significantly to the yield of cowpeas. Biological Nitrogen Fixation (BNF) is an economically viable and environmentally pleasant N source. Besides, some soils may not have an adequate number of native rhizobia in terms of quantity, quality, or effectiveness to enhance biological nitrogen fixation (BNF). Thus, Biological fixed N via rhizobia - legumes symbiosis accounts for the largest amounts of nitrogen to agriculture. For example, Herridge *et al*. (2008) reported that more than 20 million tonnes of N are fixed by grain legumes to agriculture each year. Cowpea, similar to the majority of leguminous crops, establishes a mutually beneficial relationship with native rhizobia in intercropping setups. This association leads to the nitrogen-rich aboveground portion of the plant, comparable to approximately 55-96 kg of nitrogen fertilizer per hectare per season (Cong *et al.,* 2015). Cowpeas can fix about 240 kg ha-1 of atmospheric nitrogen and make available about 60-70 kg ha-1 nitrogen available for succeeding crops grown in rotation with it (Aikins and Afuakwa, 2008). Although cowpeas can meet all or part of their N requirement through BNF (Hungria and Kaschuk, 2014). In a previous study, it has been shown that the crop may benefit from Rhizobial inoculation with specific strains of Rhizobia (Fening and Danso, 2002). Many soils, however, do not have an adequate amount of native Rhizobia in terms of quantity, quality, or effectiveness to enhance biological nitrogen fixation (BNF) (FAO, 2012).

This situation suggests the use of Rhizobia inoculant. Inoculation is the manipulation of Rhizobia populations to the amount that could have been naturally fixed for improved nodulation and crop yield. Inoculation of cowpea with *Bradyrhizobium* strains resulted in a significant increase in cowpea nodulation and yield (Koskey *et al*., 2017 Yoseph *et al.,* 2017). An increase in the yield of cowpeas due to inoculation with *Bradyrhizobium* strains BR 3267 and BR 3262 has been reported in Brazil (Martins *et al*., 2003).

One other way to improve the yield of cowpeas is by using improved varieties. In Nigeria, cowpea varieties, IT90K-277-2, IT97K-499-35, IT98K-131-2, and IT89KD-288 resulted in significantly higher grain yield compared to the local and other varieties tested (Kamai *et al*., 2014). In Nigeria, there is no information on whether inoculating some available cowpea varieties in Nigeria with *Bradyrhizobium* strains BR3267 and BR3262 could exhibit similar yield responses in soils of a Nigerian Savanna location. The question we seek to answer is whether inoculating cowpea varieties with *Bradyrhizobium* strains can address the problem of low soil N and increase BNF and cowpea production. Hence, the present study had the following objectives;

1. To evaluate the effect of soil proximity to homestead, nitrogen source, and cowpea varieties on nodulation.
2. To assess the nodule activity of cowpea varieties as affected soil proximity to homestead and nitrogen source.

METHODOLOGY

Experimental Site, Soil Sample Collection, and Preparation: A screen house experiment was conducted in 2016 at the Federal University of Technology, Gidan Kwano, Minna; located in the Southern Guinea Savannah (SGS) of Nigeria within longitudes 90 30' and 90 40' E and latitudes 6° 30' and 6° 35' N, and at an altitude of 258.5m above sea level. Soil samples for laboratory analysis and screen house study were collected from Paiko, Niger State. Based on cropping history, the field has been put into continuous cultivation with different mixtures of yam, maize, and cowpea between the years 2014 and 2015.

Soil samples were collected randomly across the field using sterilized soil auger and bulked to form composite samples. The sampling depth was (0-20 cm) for both physical and chemical analysis and screen house experiments. The composite samples were taken to the laboratory. Part of the soil samples were air dried and passed through a 2 mm mesh for routine analysis while the remaining sample was prepared moist and kept in the refrigerator for Most Probable Number (MPN) determination.

Application rates of the treatments and experimental layout:

All treatments received a basal dressing of (P, K, Mg, Zn, Mo, and B) at the rate of 372.6 mg per pot which was calculated based on 2.5 Kg soil per pot, nutrient added was thoroughly mixed. N (urea 100 Kg Nha-1) was split applied as 25% of the (81.60 mg) at sowing and the remaining 75% N (244.80 mg) at two weeks after planting. The factorial combination was used to assign each treatment and treatment combinations to their respective pots. The test crop was cowpea (*Vigna unguiculata*(L.) Walp) varieties: Kanannado, IT93K-452-1, IT97K-499-35, and IT90K-277-2. Cowpea seeds were inoculated before planting with a peat-based inoculum of *Bradyrhizobium* sp. strain (BR 3262 or BR 3267) at the rate of 5 g per kilogram of seed using the slurry method as described by Woomer *et al*. (1994).

Laboratory Analysis

Physical and chemical analyses were carried out by standard methods (IITA, 1989). Soil particle size was determined by the hydrometer method. Soil pH was determined using a pH meter in water (soil solution ratio 1:2.5). Soil organic carbon was determined by the Walkley and Black Oxidation method. Exchangeable bases were extracted with 1 N ammonium acetate (NH4OAc) solution at pH 7.0. Potassium in the extract was measured using a Gallen Kamp flame photometer. Calcium and magnesium were determined by titration. Exchangeable acidity (H+, Al3+) was determined by titrimetric method after extraction with 1N KCl). Total nitrogen was determined by the Kjeldahl method. Available phosphorus was extracted using the Bray P1 method and was estimated colorimetrically. Effective Cation Exchange Capacity (ECEC) was determined by the summation of exchangeable bases (Ca2+, Mg2+K+, Na+) and exchangeable acidity (H+, Al3+).

Sowing: Before planting, the seeds were first surface sterilized by immersing them in 70% ethanol for 10 seconds after which it was drained; the seeds were then submerged in 1.5% sodium hypochlorite for 3 minutes and then drained and then rinsed six times with sterile distilled water. The plants were watered daily with Sandsman's N-free nutrient solution 200 ml (at field capacity of the moist soil) per pot for the first four weeks and later one-quarter strength of the solution or just sterile distilled water. Three seeds per pot were sown and later thinned to one seedling per pot a week after sowing.

Most Probable Number (MPN) Method

MPN was used to estimate the number of viable rhizobia present in the experimental soil. The assay was conducted using a modified Leonard jar method using coarse sand as the potting medium (Howieson and Ballard, 2014). The coarse sand was washed several times with tap water to remove all traces of dissolved nutrients, rinsed with sterile distilled water, sun-dried, and autoclaved before pot filling. Plants were inoculated with 1 ml aliquots of the soil suspensions made from the serial dilution of the soil samples. The soil serial dilution was a 20-fold six-step dilution (20-1 to 20-6) by adding 10 g of soil in 190 ml of sterile distilled water (Woomer, 1994). The presence of nodules on the root of the cowpea at the end of seven weeks was used as an indication of the presence of rhizobia in the soil. Rhizobia count was determined using an MPN table with a confidential interval of $P < 0.05$ (Somasegaran and Hoben, 1985).

Inoculation

Cowpea seeds were inoculated before planting with a peat-based inoculum of *Bradyrhizobium* sp. strain (BR 3262 or BR 3267) at the rate of 5 g per kilogram of seed using the slurry method as described by Woomer *et al*. (1994).

Treatments and Experimental Design

The treatment was a factorial combination of soil proximity to homestead: close and far, nitrogen source: control (no nitrogen application), application of urea (100 kg N ha-1), inoculation with *Bradyrhizobium*strain BR 3262, *Bradyrhizobium* strain BR 3267, and cowpea varieties: Kanannado, IT93K-452-1, IT97K-499-35, and IT90K-277-2, arranged in a completely randomized design and replicated three times. The cowpea varieties were IT93K-452-1 (extra-early Maturing), IT97K-499-35 (Early Maturing), IT90K-277-2 (Medium Maturing), and Kanannando (Late Maturing).

Data Analysis

The data obtained were subjected to analysis of variance (ANOVA) using MINITAB 17.0 Means were separated using the Tukey Test at a 5 % significance level ($p \leq 0.05$).

RESULTS AND DISCUSSION

This study reveals that the experimental soil had an adequate number of native rhizobia (>103 cells g-1 of soil) for cowpea nodulation (Table 1). The findings of Amarger (2001) show that rhizobia is prevalent in tropical soils due to the natural distribution and cultivation of legumes. Indigenous rhizobia population density, effectiveness in forming nodules, and ability to fix N2 can be characterized functionally for N2 fixation potential (Singleton and Travers, 1986).
Soil proximity of field to homestead did not significantly affect nodulation in this study, this result does not affirm the observation that fertile plots are often closest to homesteads, as a result of continuous accumulation of organic amendment and household waste applied directly surrounding the settlements (Zingore *et al.,* 2007).

Despite the relatively high population density of native rhizobia in the study location. Inoculation with BR 3262 improved nodule number and dry weight by 62% and 66% respectively compared to the un-inoculated treatment. This implies that strains BR 3262 inoculant used for this experiment have a competitive ability and may have performed a greater role in nodule occupancy and nitrogen fixation. Sanginga *et al*. (1996) and Houngnandan *et al.*

(2000) reported that response to inoculation may occur when the native rhizobia population is (< 5 or 10 cells g-1 of soil). Contrary to this finding despite the high number of native rhizobia responses to inoculation was observed in this study. Meaning that the native populations may be sufficient in number but not effective enough to impede significant response. More so, other factors aside from the native rhizobia population may have reduced the symbiotic performance of the native strains. Giller (2001) also observed that the presence of a large population density of compatible rhizobia does not, however, preclude the possibility that responses to inoculation can be obtained if competitive and highly effective strains are introduced in high-quality inoculants.

The success of Rhizobium inoculation primarily depends on the rhizobial strain, the legume genotype, the environmental conditions, and crop management (Woomer *et al*., 2014). Nodulation in the non-inoculated control and N treatment suggested that the indigenous strains were effective in forming nodules, although the inoculant strain was superior. These did not only show that cowpeas responded to inoculation but also indicated that the introduced strains were highly viable, especially with BR 3262 thereby aggravated a substantial level of increase in nodule number and dry weight. This result conforms to the findings of Martins *et al*. (2003) who reported a significant increase in the nodule number of cowpea after inoculation with *Rhizobium* inoculant. More so, nodule dry weight is very important in strain assessment as it serves as an indicator of symbiotic proficiency (Graham *et al.,*2004). The N-treated plant recorded the least nodule number and dry weight but was at par with the uninoculated control. More so research has recognized that plants that received mineral nitrogen at a rate of 100 kg N ha-1 recorded the least nodulation. Such results were expected because high levels of nitrogen have been affirmed to affect rhizobia activity in the soil by hindering the host plant from producing lectin which attracts the rhizobia to infect the roots. more so, the use of N at the rate of 100 kg N ha-1 as a control reveals an ideal situation when N is not a limiting factor in cowpea growth.

Nodule number and dry weight were significantly ($p<0.05$) affected by the cowpea varieties in this study although, in some cases, there were marginal differences among the varieties used. Nodulation is an important indicator for evaluating symbiotic potential among cowpea varieties. The highest nodule number and nodule dry weight was produced by kanannando (local variety) compared to the improved varieties used in this study, this could be attributed to the genetic makeup of the local variety and hence will set up more nitrogen in the system compared to the improved variety. More so, as a local variety, Kanannado is more adapted to the environmental condition and thus has the best symbiotic potential compared to the improved variety. Ayodele and Oso (2014) also observed that significant variation in nodulation per variety could be attributed to differences in the genetic makeup of the individual varieties. Integrating the Kanannado variety into the cropping system because of its nodule weight may have a positive effect on biological nitrogen fixation. Also, Moharram *et al*. (1992), and Bell *et al*. (1994) reported that there is a relationship between nodulation and nitrogen fixation, the local variety will set more N2 in the system than the improved varieties. IT90K-277-2 and IT97K-499-35 were observed to be low-yielding due to their production of fewer nodules. Low nodule production means less nitrogen will be fixed by the varieties.

The fewer nodule number and dry weight observed with IT90K-277-2 compared to Kanannado when inoculated with BR 3267 in the interaction between Nitrogen sources and varieties could be attributed to differences in the genetic makeup of the varieties. Varietal differences account for nodule differences since the pattern of nodulation, most often reflects the physical distribution of the root system in the soil. Fall *et al.* (2003) also reported that the differences in nodulation and nitrogen fixation could be attributed to the genetic structure of the different varieties. More so, the observed significant difference with plants among varieties in this study is consistent with the earlier work done by Terao *et al*., (1995) who observed that cowpea varieties with spreading growth habits collected more light than those with erect growth habits and consequently produced more leaves which resulted in more nodules.

The production of more nodule number and dry weight with Kanannado variety when inoculated with BR 3267 for soils sampled away from homestead in the interaction between proximity of field to homestead, Nitrogen sources, and varieties. Indicating that the effectiveness of BR 3267 inoculant in this study cannot be underestimated.

Also, plants that received mineral nitrogen at a rate of 100kgNha-1 recorded the least nodulation. Such results were expected because high levels of nitrogen have been reported to affect rhizobia activity in the soil by inhibiting legume host production of lectin which attracts the rhizobia to infect the roots. In this study, cowpea modulation can be improved by the use of the kanannado variety with BR 3267 inoculant.

Characteristics of Soil used in the Study

The results obtained from physical and chemical analysis of the experimental soil (Table 1) showed that soils from both close and far proximities to the homestead were slightly acidic and loamy sandy in texture. Organic carbon (3.60 - 4.35 g kg-1), total nitrogen (0.11 - 0.18 g kg-1), and available P (6.00 - 7.00 mg kg-1) were low, exchangeable cations (0.19 - 5.04 C mol kg-1), and effective cation exchange capacity (6.71- 6.76 C mol kg-1). The result of ECEC reveals that the experimental soil was low in nutrients.

MPN count of the Indigenous rhizobia

The MPN count of indigenous rhizobia in the soil using four cowpea varieties with respect to proximities to homestead showed native rhizobia level for Kanannado and IT93K-452-1 was similar (12.27 × 106 - 11.28 × 106 cell g-1 of soil), IT97K-499-35 (9.26 × 106 - 12.27 × 106 cell g-1of soil), and IT90K-277-2 (10.94 × 106 cell g-1 of soil) these result reveals that the native rhizobia strains had high fixing ability for cowpea.

Table 1: Soil characteristics of the study site

Parameters	Values (Close Proximity)	Values (Far Proximity)
Sand (g kg^{-1})	857	847
Silt (g kg^{-1})	80	80
Clay (g kg^{-1})	63	73
Textural Class	Loamy Sand	Loamy Sand
pH (CaCl)	5.36	5.80
Organic Carbon (g kg^{-1})	3.60	4.35
Total Nitrogen (g kg^{-1})	0.11	0.18
Available Phosphorus (mg kg^{-1})	6.0	7.0
Sodium (C mol kg^{-1})	0.50	0.49
Potassium (C mol kg^{-1})	0.19	0.22
Calcium (C mol kg^{-1})	4.80	5.04
Magnessium (C mol kg^{-1})	1.12	0.80
Exchangeable Acidity (C mol kg^{-1})	0.10	0.21
ECEC	6.71	6.76

Table 2: MPN count of soils cultivated to cowpea varieties for both proximities to homestead

Varieties	MPN (Cell g^{-1} of soil) (Close proximity)	MPN (Cell g^{-1} of soil) (Far proximity)
Kanannado	12.27×10^6	11.28×10^6
IT93K-452-1	12.27×10^6	11.28×10^6
IT97K-499-35	9.26×10^6	12.22×10^6
IT90K-277-2	10.94×10^6	10.94×10^6

Cowpea Nodulation

Cowpea nodulation, i.e., nodule number and dry weight, were not significantly different under soil proximities to the homestead (Table 3). However, nitrogen sources significantly ($p<0.05$) affected the cowpea nodulation (Table 3). Nodule number and nodule dry weight increased substantially with the BR 3262 inoculant strain, which was at par with the BR 3267 inoculant strain for nodule dry weight compared to the other nitrogen sources. The Kanannado variety recorded more and heavier nodules compared to the IT93K-452-1, IT97K-499-35, and IT90K-277-2 varieties. The use of variety IT97K-499-35 and IT90K-277-2 had similar least and lighter cowpea nodules in this study. In addition, a significant interaction was observed between Nitrogen sources and varieties on nodulation and the combination of proximity to homestead, Nitrogen sources, and varieties on nodule number and nodule dry weight of cowpea (Table 3).

Interaction Effects between Nitrogen Sources and cowpea varieties on cowpea Nodulation

The interaction between nitrogen sources and varieties (Table 4) revealed that irrespective of the varieties used in this study, inoculation with BR 3262 improved the nodule number and cowpea's dry weight, respectively. Although the highest number of nodules was found in the kanannado variety with BR 3267 inoculant strain, it was not significantly ($p>0.05$) different from nodules obtained using un-amended control and BR 3262. A similar trend occurred in nodule dry weight (Table 5). The kannanado variety had the heaviest nodule dry weight, which was at par with that from other treatments except for the urea treatment.

Interactive effect of Nitrogen sources, Soil proximity, and Varieties on nodulation of cowpea

A significant interaction was observed between the proximity of the field to the homestead, nitrogen sources, and varieties on nodule number (Table 6). Heavier nodules were produced with BR 3267 inoculant using kanannado followed by IT93K-452-1 variety for soils sampled further away from the homestead. Similar nodules were produced by plant inoculated with BR 3262 using the four cowpea varieties except for kanannado and IT97K-499-35 under proximity to the homestead. However, they were significantly at par with the control treatment using kanannado for proximity close to the homestead.

Significant interactions were also recorded among the combination of proximities, nitrogen sources, and varieties on nodule dry weight of cowpeas (Table 7). Inoculation with BR 3267 using the kanannado variety resulted in the highest nodule dry weight though not significantly ($p < 0.05$) different from the nodule dry weight gotten from IT93K-452-1 for soils sampled away from the homestead and BR 3262 using the four cowpea varieties except for Kanannado and IT97K-499-35 using soils away from the homestead. Similar nodule dry weight was also observed with the un-inoculated control with kanannado variety for soils sampled near the homestead.

Table 3: Effect of Nitrogen sources, Soil proximity to homestead and Varieties on growth parameters of cowpea

Nitrogen sources	Varieties			
	Kanannado	IT93K-452-1	IT97K-499-35	IT90K-277-2
Control	0.09abc	0.07bcd	0.04bcd	0.05bcd
Urea	0.05bcd	0.04bcd	0.04bcd	0.04bcd
BR3262	0.09abc	0.11ab	0.09abc	0.10abc
BR3267	0.15a	0.10abc	0.07bcd	0.02d
SE±			**0.01**	

Means with the same letters in a treatment column are not significantly different according to Tukey test at P≤0.05

*Significant at (P≤0.05), NS (not significant)

Table 4: Interaction effect between nitrogen sources and cowpea varieties on nodule number (count plant^{-1}) of cowpea

Treatment	Nodule Number (Count plant^{-1})	Nodule dry Weight (g plant^{-1})
Proximity (P)		
Close	14.31a	0.07a
Far	15.75a	0.07a
SE±	0.87	0.00
Nitrogen sources (N)		
Control	13.08c	0.06b
Urea (100 kg N ha^{-1})	8.50d	0.04b
BR 3262	21.25a	0.10a
BR 3267	17.29b	0.08ab
SE±	1.24	0.01
Varieties (V)		
Kanannado	19.71a	0.10a
IT93K-452-1	15.75b	0.08ab
IT97K-499-35	13.13bc	0.06b
IT90K-277-2	11.54c	0.05b
SE±	1.24	0.01
Interaction		
P × N	**NS**	**NS**
P × V	**NS**	**NS**
N × V	*	*
P × N × V	*	*

a,b,c,d Means with the same letters are not statistically different (P>0.05)

Table 5: Interaction effect between nitrogen sources and cowpea varieties on nodule dry weight (gplant^{-1}) of cowpea

	Varieties			
Nitrogen sources	Kanannado	IT93K-452-1	IT97K-499-35	IT90K-277-2
Control	18.83a-e	13.00b-f	9.83c-f	10.67b-f
Urea	10.67b-f	7.00ef	9.00def	7.33ef
BR3262	20.50a-d	22.50ab	20.17 a-d	21.83abc
BR3267	28.83a	20.50a-d	13.50b-f	6.33f
SE±			**2.48**	

a,b,c,d Means with the same letters are not statistically different (P>0.05)

This study reveals that the experimental soil had an adequate number of native rhizobia (>103 cells g-1 of soil) for cowpea nodulation (Table 2). This finding is significant as it supports Amarger's (2001) findings that rhizobia is prevalent in tropical soils due to the natural distribution and cultivation of legumes. The population density of indigenous rhizobia, their effectiveness in forming nodules, and their ability to fix N2 can be functionally characterized for N2 fixation potential (Singleton and Travers, 1986). The soil proximity of the field to the homestead did not significantly (p>0.05) affect nodulation in this study (Table 3). This result did not affirm the observation that fertile plots are often closest to homesteads due to the continuous accumulation of organic amendment and household waste applied directly surrounding the settlements (Zingore *et al.,* 2007).

Despite the relatively high population density of native rhizobia in the study location. Compared to the un-inoculated treatment, inoculation with BR 3262 improved nodule number and dry weight by 62% and 66%, respectively. This implies that strains of BR 3262 inoculant used for this experiment have a competitive ability and may have performed a more significant role in nodule occupancy and nitrogen fixation. Sanginga *et al*. (1996) and Houngnandan *et al.* (2000) reported that response to inoculation might occur when the native rhizobia population is (< 5 or 10 cells g-1 of soil). Contrary to this finding, despite the high number of native rhizobia responses to inoculation, it was observed in this study. This means that the native populations may be sufficient in number but not adequate to impede significant response. Other factors aside from the native rhizobia population may have reduced the symbiotic performance of the native strains. Giller (2001) also observed that a large population density of compatible rhizobia does not preclude the possibility that responses to inoculation can be obtained if competitive and highly effective strains are introduced in high-quality inoculants.

The success of Rhizobium inoculation is a complex process that primarily depends on the rhizobial strain, the legume genotype, and importantly, the environmental conditions and crop management (Woomer *et al*., 2014). This understanding underscores the intricate nature of agricultural practices and the need for careful management. Nodulation in the non-inoculated control and N treatment suggested that the indigenous strains were effective in forming nodules, although the inoculant strain was superior. These showed that cowpeas responded to inoculation and indicated that the introduced strains were highly viable, especially with BR 3262, thereby aggravating a substantial increase in nodule number and dry weight. This result conforms to the findings of Martins *et al*. (2003), who reported a significant increase in nodule number of cowpea after inoculation with *Rhizobium* inoculant. More so, nodule dry weight is substantial in strain assessment as it indicates symbiotic proficiency (Graham *et al.,* 2004). The N-treated plant recorded the least nodule number and dry weight but was at par with the uninoculated control. More so, research has recognized that plants that received mineral nitrogen at a rate of 100 kg N ha-1 recorded the least nodulation. However, such results were expected because high levels of nitrogen have been affirmed to affect rhizobia activity in the soil by hindering the host plant from producing lectin, which attracts the rhizobia to infect the roots. Using N at the rate of 100 kg N ha-1 as a control reveals an ideal situation when N is not a limiting factor in cowpea growth.

Nodule number and dry weight were significantly ($p \leq 0.05$) affected by the cowpea varieties in this study, although, in some cases, there were marginal differences among the varieties used. Nodulation is an essential indicator for evaluating symbiotic potential among cowpea varieties. The highest nodule number and nodule dry weight were produced by kanannando (local variety) compared to the improved varieties used in this study; this could be attributed to the genetic makeup of the local variety and hence will set up more nitrogen in the system compared to the improved variety. As a local variety, Kanannado is more adapted to the environmental condition and thus has the best symbiotic potential compared to the enhanced variety. Ayodele and Oso (2014) also observed that significant variation in nodulation per variety could be attributed to differences in the genetic makeup of the individual varieties. Integrating the Kanannado variety into the cropping system because of its nodule weight may positively affect biological nitrogen fixation. Also, Moharram *et al*. (1992) and Bell *et al*. (1994) reported a relationship between nodulation and nitrogen fixation; the local variety will set more N2 in the system than the improved varieties. IT90K-277-2 and IT97K-499-35 were observed to be low-yielding due to their production of fewer nodules. Low nodule production means the varieties will fix less nitrogen.

The fewer nodule number and dry weight observed with IT90K-277-2 compared to Kanannado when inoculated with BR 3267 in the interaction between Nitrogen sources and varieties (Tables 4 and 5) could be attributed to differences in the genetic makeup of the varieties. Varietal differences account for nodule differences since the pattern of nodulation most often reflects the physical distribution of the root system in the soil. More so, the observed significant difference with plants among varieties in this study is consistent with the earlier work done by Terao *et al*. (1995), who observed that cowpea varieties with spreading growth habits collected enough sunlight than those with erect growth habits and consequently produced more leaves which resulted in more nodules.

The production of more nodule number and dry weight with Kanannado variety when inoculated with BR 3267 for soils sampled away from homestead in the interaction between proximity of field to homestead (Tables 6 and 7), Nitrogen sources, and varieties, indicating that the effectiveness of BR 3267 inoculant in this study cannot be underestimated. Also, plants that received mineral nitrogen at a rate of 100kgNha-1 recorded the least nodulation. Such results were expected because high nitrogen levels have been reported to affect rhizobia activity in the soil by inhibiting legume host production of lectin, which attracts the rhizobia and infects the roots. In this study, cowpea

The findings of this study suggest a promising avenue for improving nodulation. By using the kanannado variety with BR 3267 inoculant, significant improvements in nodulation can be achieved, offering a hopeful prospect for future agricultural practices.

Table 6. Interactive effects of nitrogen sources, proximity to homestead and cowpea varieties on Nodule Number (count plant^{-1})

		Varieties			
Proximity	Nitrogen sources	Kanannado	IT93K-452-1	IT97K-499-35	IT90K-277-2
Close	Control	19.33a-d	13.33bcd	7.67cd	9.33cd
Far		18.33bcd	12.67bcd	12.00bcd	12.00bcd
Close	Urea	9.33cd	7.33cd	6.67cd	6.33cd
Far		12.00bcd	6.67cd	11.33bcd	8.33cd
Close	BR3262	23.67abc	22.33a-d	22.00a-d	23.00abc
Far		17.33bcd	22.67a-d	18.33bcd	20.67a-d
Close	BR3267	19.00bcd	11.33bcd	19.00bcd	9.33cd
Far		38.67a	29.67ab	8.00cd	3.33d

a,b,c,d Means with the same letters are not statistically different (P>0.05)

Table 7. Interactive effects of nitrogen sources, proximity to homestead and varieties on Nodule dry weight (g plant^{-1}) of cowpea

		Varieties			
Proximity	Nitrogen sources	Kanannado	IT93K-452-1	IT97K-499-35	IT90K-277-2
Close	Control	0.10a-d	0.08bcd	0.03cd	0.05bcd
Far		0.08bcd	0.06bcd	0.05bcd	0.06bcd
Close	Urea	0.05bcd	0.06bcd	0.04cd	0.03cd
Far		0.06bcd	0.03cd	0.04cd	0.04cd
Close	BR3262	0.11abc	0.11abc	0.10a-d	0.11abc
Far		0.08bcd	0.11abc	0.08bcd	0.10a-d
Close	BR3267	0.09a-d	0.06bcd	0.10a-d	0.04cd
Far		0.20a	0.15abc	0.04cd	0.00d

a,b,c,d Means with the same letters are not statistically different (P>0.05)

CONCLUSION AND RECOMMENDATIONS

The results obtained in this study suggest that the proximity of the field to the homestead did not significantly affect nodulation. Also, *the bradyrhizobia* strain BR 3262 was more effective on cowpea nodulation and could be recommended for cowpea cultivation in soils with a high native rhizobia population. This study also revealed that the local variety had better nodulation compared to the improved varieties. It's important to note that further studies will be required for validation under field conditions, demonstrating the thoroughness of our research.

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EFFECT OF DIFFERENT PROCESSING METHODS ON NUTRIENTS AND ANTI-NUTRIENT COMPOSITION OF LEBBECK (*Albizia lebbeck*) SEEDS

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ABSTRACT

A study was carried out on the effect of different processing methods on nutrients and the anti-nutrient composition of Albizia lebbeck seeds. A completely randomized design was used. Three different processing methods (boiling, sprouting and toasting) were carried out on A. lebbeck seeds and a control without treatment formed the treatments. All the seeds were milled, labelled accordingly before taken to the laboratory for proximate, amino acid, phyto-chemical, vitamins and minerals analysis. Chemical analysis was done in triplicate with each analysis formed a replicate. All data generated were subjected to a one-way analysis of variance. Results of the study showed that raw A. lebbeck seed contains 92.44 % dry matter, 5.57 % ash, 46.17 % nitrogen free extract and energy value of 3730 kcal/kg. Processing significantly ($P \leq 0.05$) affected the contents of all the amino acids analysed except tryptophan ($P > 0.05$). Raw seeds were found to contain high antinutritional factors such as phytate (4.74 mg/100 g), saponin (6.39 mg/100 g), tannin (6.89 mg/100 g), and oxalate (6.51 mg/ 100 g). Antinutritional factors were significantly ($P \leq 0.05$) reduced by the processing methods, although boiling gave the highest percentage reduction. Boiled seeds are significantly ($P \leq 0.05$) higher in manganese and phosphorus contents. It was concluded that processing could improve the nutrients and reduce the antinutritional contents of A. lebbeck seeds, thus making them available for food and feed.

Keywords: *Albizia lebbeck*, anti-nutrients, boiling, nutrients, raw, roasting and sprouting

INTRODUCTION

Nigeria has many natural endowments that are sufficient to produce animal protein for itself and other countries, but there is an insufficiency of animal protein production in Nigeria. Over some time, commercial poultry farmers have increased universally; however, the demand for animal protein is still far higher than the supply. Hence, animal protein is expensive, especially in developing countries. The high cost of animal protein has made it unaffordable for the average Nigerian (Ugwuene, 2003; Ani and Adiegwu, 2005). This has been attributed to feed and feeding, which account for about 70 to 80 % of the total variable cost of poultry production. This is due to the use of conventional feedstuff (maize, groundnut cake, and soya beans), which men demand for food and industrial purposes. This has led to prolonged competition for feed ingredients between the poultry industry and the human population. Therefore, to reduce this problem, several researchers have recommended using non-conventional feedstuffs in poultry nutrition (Agiang*et al*., 2007; Idahor *et al*., 2011). There are many non-conventional feedstuffs in poultry nutrition. Many non-conventional feeds or agricultural by-products with substantial nutritional value are inexpensively available in large quantities. However, only a few numbers are in use either due to lack of adequate dietary information or the presence of some harmful constituents like alkaloids, toxic amino acids, phenolic compounds, tannins, trypsin inhibitors, carcinogens, and glucosinolates, among other reasons. Various sources of agricultural by-products and their nutritional characteristics have been reviewed (Ousman *et al.*, 2005*;* Mbaiguinam *et al.*, 2005; Nuha *et al.*, 2010). However, some works were done on fermentation, germination, boiling, and toasting processing methods on the nutritional and anti-nutritional composition of *Albizia lebbeck* seed but comprehensively. Therefore, the study determined the effect of different processing methods on the composition of nutritional and anti-nutritional vitamins, minerals, and amino acids of *A. lebbeck* seeds.

The research work was conducted at the Teaching and Research Farm of the Department of Animal Production, Federal University of Technology, Bosso Campus, Minna, Niger State, Nigeria. Minna is located between latitudes 90 39′3.82’N to 90 39′25.90’ N. Longitude 60 31′27.65’E to 6031′27.65’ E within Bosso Local Government Area of Niger State. Bosso Local Government Area is bordered by Shiroro to the North, Paiko to the East, Katcha to the South, and Wushishi to the West, as cited by Odekunle *et al.* (2018).

Sample Collection and Methods of Processing: *Albizia lebbeck* pods were harvested within the Federal University of Technology, Minna (Bosso campus). The pods were opened, and the seeds were removed. The seeds were sorted by removing dirt and other impurities. The seeds were then divided into four batches and processed using the following methods:

Sprouting

Echendu *et al*. (2009) adopted the method for sprouting processing. Five kg of *Albizia lebbeck* seeds were moistened with water and covered with a jute bag. The seeds were moistened daily until the shoot came out. The sprouted seeds were packed and sun-dried to a 10 – 15 % moisture level. The sun-dried seeds were milled and labelled Sprouted *Albizia lebbeck* Seed Meal (SALSM). They were stored in a plastic airtight container to prevent them from getting spoilt from air and moisture until they were required for analysis.

Raw

The method described by Madubuike *et al*. (2003) was used to prepare the raw *Albizia lebbeck* seed for analysis. Five kg of the legume seeds were cleaned by picking up dirt and washing with clean water; thereafter, they were sun-dried to a moisture level of about 10 – 15 %. The sun-dried seeds were milled and labelled Raw Albizia Seed Meal (RALSM). They were stored in an airtight plastic container to prevent them from getting spoilt from air and moisture until they were required for analysis.

Toasting

Five kg of *Albizia* seed were toasted at 700C for 30 minutes using a popcorn machine with an automatic stirrer (assembled for Wilson International Limited United Kingdom, Model: EB-08) as described by Makinde *et al*. (2017). The seeds were automatically stirred continuously during toasting to ensure uniform toasting and to prevent burning until the seeds turned brown. The roasted seeds were spread out to cool, after which they were milled using a hammer mill with a sieve size of 3 mm and labeled Toasted Albizia Seed Meal (TALSM). They were stored in a plastic air-tight container or leather to prevent them from getting spoilt from air and moisture until when required.

Boiling

Five kg of *Albizia* seed was subjected to boiling at 100 0C for 30 minutes following the procedure described by Jimoh *et al*. (2014). The water was drained using a 10 mm sieve, and the boiled seeds were sun-dried to a dry matter of 10 to 15 %. Thereafter, the seeds were milled using a hammer mill and then sieved with a 3 mm sieve size and labeled Boiled Albizia Seed

Meal (BALSM). They were stored in an air-tight plastic container to prevent them from getting spoilt from air and moisture until when required for analysis.

Chemical Analysis

Each processed sample was subjected to laboratory analysis to determine the nutrient and anti-nutrient compositions at the Animal Science Laboratory, University of Ibadan, Oyo State. The gross energy was determined using the Gallenkamp Ballistic Bomb Calorimeter (Model 1266, Parr Instrument Co., Moline, IL.) with benzoic acid as an internal standard. This measurement provides an indication of the energy content of the seeds. Each sample analysis was done in triplicate to ensure the accuracy and reliability of the results.

The amino acids were quantitatively measured by the procedure of Benitez (1989) using Applied Biosystems PTH automated amino acid analyzer (Technic on Sequential Multi-sample Analyzer, TSM, (40405), Model 120A, Version1.4B, USA). The samples were hydrolyzed to determine all amino acids except tryptophan, which was destroyed during the acid hydrolysis of a protein by 6N HCl at a high temperature that precedes the analysis of the liberated other amino acids by chromatography used in this study.

Mineral composition (manganese) was determined using an atomic absorption spectrophotometer and Perkin Elmer 5000 model, made in Jersey City, New Jersey. The phosphorus content was determined by the phosphor-vanamolybolate method of AOAC (2006). Potassium was determined using a flame photometer, model EEL, and brand name SKZ, which was made in Germany. Calcium and magnesium contents were determined using the method of AOAC (2006)

The rapid carr-price method described by Egan *et al.* (1981) determined the vitamin B content, in which the blue colour formed with antimony trichloride was measured using the ultra-violet absorbance in an organic solvent. The content of ascorbic acid (vitamin C) was determined by the titration method described by Osborne and Voogt (1978), as cited by Abolaji and Adiaha (2015). The anti-nutritional factors were determined using the method of AOAC (2000), as described by Makinde *et al.* (2019)

Data Analysis

Data generated were subjected to one-way analysis of variance (ANOVA) at P≤0.05 using the Statistical Package for Social Sciences version 16.0 (SPSS, 2007). Means were separated using the Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Proximate Composition

As shown in Table 1, the results showed that the processing method influenced all the measured parameters (P<0.05). Dry matter (92.44 %) and nitrogen-free extract (46.17 %) contents were significantly P<0.05) highest in raw seeds, followed by boiled, roasted, then sprouted *Albizia lebbeck* seeds. The low DM observed in the sprouted treated seed could mean the seed imbibed high moisture during sprouting. The dry matter value of 92.44 % observed in this study was slightly lower than 93.50 % dry matter, as Michael *et al.* (2019) reported in their study on *Jatropha curcas* seed meals.

The Sprouted *A. lebbeck* seeds had the highest (P>0.05) crude protein (33.26 %) content, followed by roasted, boiled, and raw seeds (26.30 %); they were all significantly (P≤0.05) different from one another. Contrary to the expected higher crude protein in the raw *lebbeck* seeds. All the processed seeds had higher CP values. The higher value observed in sprouted seeds could be that metabolic enzymes such as proteinases are activated during spouting, which may lead to the release of some amino acids and peptides, and synthesis or utilization of these may form new proteins. Consequently, the nutritional quality of proteins may be enhanced by sprouting in legumes and other seeds Gulewicz *et al*. (2008). The low crude protein observed in the raw *A. lebbeck* seeds could probably result from the antinutrients that bind the protein matrix. (Tannins are a class of antioxidant polyphenols that may bind to proteins and other inorganic molecules and impair the digestion of these nutrients. They commonly occur in tea, coffee, and legumes).

Ether extract values ranged between (9.68 to 6.92%). Boiled seeds had the highest (P>0.05) ether extract contents, followed by raw, sprouted, and then roasted seeds. The ether extract value of 6.92 % in roasted seeds observed in this study had the lowest value. They were, however, all significantly different (P<0.05) from one another. Raw seeds of *A. lebbeck* had higher (P>0.05) contents of ash when compared to the other treatments. This was followed by sprouting, roasting, and boiling; they were all significantly (P≤0.05) different. These were expected as the seed-inert contents were not tampered with. Makindeet al. (2019) observed a similar result in the African star apple. The ash content of raw *A. lebbeck* seeds (5.57 %) was gradually decreased by the different processing methods, with the boiled seeds having the least ash content (3.34 %). The observed low ash content may be attributed to the effects of seed processing.

Table 1: Proximate and Energy Analysis of Different Processed *A. lebbeck* Seed Meal

Parameters (%)	RALSM	BALSM	SALSM	RoALSM	SEM	P-Value
Dry matter	92.44[a]	88.72[b]	86.69[d]	86.89[c]	0.87	0.01
Crude Protein	26.30[d]	28.05[c]	33.26[a]	31.52[b]	1.04	0.01
Crude Fibre	5.19[d]	8.45[b]	6.63[c]	8.68[a]	0.54	0.01
Ether extract	9.22[b]	9.68[a]	7.24[c]	6.92[d]	0.45	0.01
Ash	5.57[a]	3.34[d]	4.99[b]	4.74[c]	0.31	0.01
NFE	46.17[a]	39.21[b]	34.58[d]	35.03[c]	1.76	0.01
Energy(kcal/Kg)	3730[a]	3560[b]	3360[c]	3280[d]	6.54	0.01

*All values are means of triplicate determinations expressed in dry weight basis, abc = means with different superscripts on the same row are significantly different (P<0.05), SEM=Standard error mean, P=Probability value. RALSM= Raw Albizia lebbeck Seed Meal, BALSM=Boiled Albizia lebbeck Seed Meal, SALSM=Sprouted Albizia lebbeck SeedMeal, RoALSM=Roasted Albizia lebbeck Seed Meal, NFE: Nitrogen Free Extract= 100- (% CP+ % CF +% EE +% Ash)

Amino Acid Composition

The results from Table 2 showed that processing influenced all the parameters measured (P<0.05). Methionine had significantly (P≤0.05) highest contents in roasted *A. lebbeck* seeds, followed by boiled seeds. The raw and sprouted seeds had similar (P<0.05) methionine contents, which are lower than those of the roasted and boiled seeds. Sprouting affects amino acid content, increasing partly or all essential and nonessential amino acids except methionine. Boiling reduces the contents of methionine. Aremu and Audu (2011) reported that transamination and deamination reactions might be responsible for the slight changes in amino acid profiles of raw processed kidney bean seed flour. The authors observed that as heating proceeded in boiling, protein quality increased to a maximum before declining again with continued heating. Thus, the reduction was likely related to increasing Maillard browning, causing methionine to be rendered unavailable.

Phenylalanine had the significantly (P≤0.05 content in roasted *A. lebbeck* seeds, followed by sprouted, raw, and then boiled seeds; they were all significantly different (P<0.05) from one another. The high phenylalanine content in the roasted seed could be due to the continuous heating of the seeds. Roasting transfers an amino group from one molecule to another, especially from an amino acid to a keto acid. Threonine had the highest (P<0.05) content in roasted *A. lebbeck* seeds, followed by raw, sprouted, then boiled seeds. They were all significantly (P≤0.05) different from one another. The low threonine content observed in sprouted and boiled seeds may be due to the leaching away of the amino acids during their processing.

Valine had significantly (P≤0.05) highest values in roasted *A. lebbeck* seeds, followed by sprouted seeds. The raw and boiled A. *lebbeck* seeds had similar (P>0.05) contents. However, it was significantly (P<0.05) lower than those of roasted and sprouted *A. lebbeck* seeds. The reduction in the content of valine due to toasting and sprouting, as observed in this study, agrees with what Aremu and Audu (2011) had earlier reported, that transamination and deamination reactions might be responsible for slight changes in the amino acid profiles of raw and processed red kidney bean seed flour.

The values of histidine in this study ranged between 1.51 mg/100 g protein and 1.73 mg/ 100 g protein, with 1.56 mg/100 g in raw seeds and 1.73 mg/100 g protein in roasted seeds. The range values of histidine in this study are similar with 1.57 mg/100 g in raw and 1.75 mg/100 g protein in roasted seeds for African star apple, as reported by Makinde *et al.* (2019) in their study on the effects of different processing methods on nutrient and anti-nutrient composition of African Star Apple (*Chrysophyllum albidum*) Kernels.

Phyto Chemical Composition

Results on the effects of processing on the anti-nutritional factors of *A. lebbeck* seeds are presented in Table 3. The results revealed that processing significantly (P≤0.05) influenced all the parameters measured, indicating statistical significance). Phytate, tannin, and oxalate contents were higher but not statistically significant (P>0.05) in the raw *A. lebbeck* seeds, followed by roasted, sprouted, and boiled *A. lebbeck* seeds. The highest percent reduction of all the parameters was observed in boiled seeds. Boiling reduces anti-nutrients in seeds, as they (anti-nutrients) are leached out into the water during processing. This confirms the reports of Abdullahi *et al*. (2012), McEwan *et al*. (2014), Saulawa *et al*. (2014) and Makinde *et al*. (2019) that the boiling method was very effective in reducing anti-nutrients in Mango seed kernels, Boabab seed, Amadumbe (*Colocasia esculenta*) and African Star Apple, respectively, when compared to other processing methods.

Table 2: Amino Acids Analysis of Different Processed *A. lebbeck* Seed Meal

Amino acids (mg/100g)	RALSM	BALSM	SALSM	RoALSM	SEM	P-Value
Arginine	1.87^{b}	1.36^{c}	1.87^{b}	3.66^{a}	0.33	0.01
Histidine	1.56^{c}	1.51^{d}	1.59^{b}	1.73^{a}	0.03	0.01
Isoleucine	0.80^{d}	0.96^{c}	0.98^{a}	0.97^{b}	0.01	0.01
Leucine	1.23^{d}	1.27^{c}	1.34^{a}	1.29^{b}	0.12	0.01
Lysine	1.37^{c}	1.32^{d}	1.41^{b}	1.53^{a}	0.03	0.01
Methionine	0.02^{c}	0.05^{b}	0.03^{c}	0.16^{a}	0.02	0.01
Phenylalanine	1.24^{c}	0.61^{d}	1.27^{b}	1.52^{a}	0.13	0.01
Threonine	0.69^{b}	0.48^{d}	0.65^{c}	0.71^{a}	0.04	0.01
Trytophan	0.18	0.18	0.63	0.19	0.12	0.55
Valine	0.97^{c}	0.97^{c}	0.01^{b}	1.17^{a}	0.03	0.01

*All values are means of triplicate determinations abc=means with different superscripts on the same row are significantly different (P<0.05), SEM=Standard error mean, P=Probability value, mg/100g =Milligram per 100grams. RALSM= Raw Albizia lebbeck Seed Meal, BALSM=Boiled Albizia lebbeck Seed Meal, SALSM=Sprouted Albizia lebbeck SeedMeal, RoALSM=Roasted Albizia lebbeck Seed Meal

Raw and roasted seeds had statistically similar (P>0.05) saponin contents, and their contents were significantly higher (P<0.05) than all the others, followed by sprouted and then boiled *A. lebbeck* seeds. The boiling method was the best method for removing saponin from the seeds. Saulawa *et al*. (2014) reported that boiling gave the best result when baobab seeds were processed using different techniques (boiling, toasting, soaking, and sprouting). This might be due to the leaching out of the anti-nutrients into the boiling water.

Table 3: Anti Nutritional Analysis of Different Processed *Albizia lebbeck* Seed Meal

Parameters (%)	RALSM	BALSM	SALSM	RoALSM	SEM	P-Value
Phytate	4.74^{a}	1.87^{d}	2.82^{c}	3.15^{b}	0.40	0.01
% reduction		60.55	40.51	33.54		
Saponin	6.39^{a}	2.58^{c}	4.19^{b}	6.34^{a}	0.60	0.01
% reduction		59.62	33.44	0.78		
Tannin	6.89^{a}	2.21^{d}	3.25^{c}	5.43^{b}	0.69	0.01
% reduction		67.92	52.83	21.19		
Oxalate	6.51^{a}	3.64^{d}	5.19^{c}	5.76^{b}	0.40	0.01
% reduction		44.09	20.28	11.52		

*All values are means of triplicate determinations abcd =means with different superscripts on the same row are significantly different (P<0.05), SEM=Standard error mean, P=Probability value. RALSM= Raw Albizia lebbeck Seed Meal, BALSM=Boiled Albizia lebbeck Seed Meal, SALSM=Sprouted Albizia lebbeck SeedMeal, RoALSM=Roasted Albizia lebbeck Seed Meal

Vitamins and Minerals Composition

Results on the effects of processing on some vitamins and minerals of *Albizia lebbeck* seeds are presented in Table 4. The results revealed that processing influenced all the parameters measured significantly (P≤0.05). Vitamin B in raw *A. lebbeck* seeds (0.19 mg/100 g) was observed to be higher in values, followed by the sprouted seeds (0.17 mg/100 g), the roasted seeds (0.09 mg/100 g), and lastly the boiled seeds (0.07 mg/100 g). The decreased values observed in vitamin B (riboflavin) and vitamin V. C (ascorbic) contents of the toasted seed are not unexpected. This is because it has been shown that vitamins (particularly water-soluble vitamins) are water and heat-labile (Okudu and Ojinnaka, 2017). When seeds are boiled, the mineral content leaches with the water. In the toasting of seeds, Maillard browning occurs due to increased heating of the seeds to a maximum before they decline again with continuous heating. The sprouted and roasted *A. lebbeck* seeds also had similar (P>0.05) vitamin C values. They were not influenced (P>0.05) by processing. Raw, boiled, and sprouted *A. lebbeck* seeds had similar (P>0.05) Calcium contents of 105.78, 105.15, and 105.08 mg/100g) respectively. These values were comparable to 102 mg/100g reported for boiled soya beans by Cakiri *et al*. (2019). The contents were, however, higher (P<0.05) than those of roasted *A. lebbeck* processed seeds observed in the present study. This could be due to the heating effect on the seeds while toasting it. Boiled *A. lebbeck* seeds had the highest (P>0.05) manganese values, followed by sprouted, raw, and lastly roasted seeds; they were all significantly (P<0.05) different from one another. Phosphorus contents in the *A. lebbeck* seeds were higher (P>0.05) in the boiled seeds. Raw and sprouted *A. lebbeck* had similar (P>0.05) contents. Their values were, however, lower (P<0.05) than those of boiled but significantly higher (P<0.05) than those of roasted processed seeds. They were all significantly different (P<0.05) from one another. The result of vitamin composition is raw and differently processed. *lebbeck* seeds show that processing did not considerably influence only vitamin C (P>0.05).

Table 4: Vitamins and Minerals Analysis of Different Processed *A. lebbeck* Seed Meal

Treatments (mg/100g)	RALSM	BALSM	SALSM	RoALSM	SEM	P-Value
Vitamin B	0.19^{a}	0.07^{d}	0.17^{b}	0.09^{c}	0.02	0.01
Vitamin C	44.64^{a}	45.88^{a}	39.05^{ab}	38.43^{b}	1.42	0.10
Calcium	105.15^{a}	105.78^{a}	105.08^{a}	93.41^{b}	1.92	0.01
Manganese	28.58^{c}	30.64^{a}	30.48^{b}	27.40^{d}	0.51	0.01
Phosphorus	1.23^{b}	1.29^{a}	1.23^{b}	1.16^{c}	1.72	0.01

*All values are means of triplicate determinations abc= means with different superscripts on the same row are significantly different (P<0.05), SEM= Standard error mean, P=Probability value. RALSM= Raw Albizia lebbeck Seed Meal, BALSM=Boiled Albizia lebbeck Seed Meal, SALSM=Sprouted Albizia lebbeck SeedMeal, RoALSM=Roasted Albizia lebbeck Seed Meal

CONCLUSION

Results from this study revealed that the proximate amino acids, minerals, vitamins, and phytochemical compositions of raw and differently processed *A. lebbeck* seeds differ significantly. Processing methods made the nutrients more available than when the seeds were used in the raw form. Amino acid profile results showed that roasting can make more of its content available than raw seed. This study also showed that boiling had a higher percent anti-nutritional reduction when compared to all the other processing methods. Finally, the vitamins and minerals determined in this study indicated that cooking, on average, has a higher value. Thus, boiling and toasting are recommended as processing methods for the raw seeds of *A. lebbeck*, as they bring out the highest nutrients, vitamins, and minerals in the seeds.

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Impact Assessment of Banana Fruit Peels Powder on *M. incognita* inoculated on Sweet Pepper (*Capsicum annuum* L) plants

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ABSTRACT

A screenhouse experiment was conducted at the landscape garden of Modibbo Adama University, Yola, to evaluate the efficacy of Banana fruit peel powder for the control of root-knot nematode on sweet pepper. The experiment consisted of five treatments replicated four times and was laid out in a Completely Randomized Design (CRD). Banana Fruit peel powder was incorporated at different levels into the bucket containing 4kg of sterilized soil. The plant powder was incorporated at 20, 25, 30 and 35g and tagged T1, T2, T3 and T4. Respectively. T5 was the control treatment with no level of powder. In the potted experiments, treatments with 35g of banana fruit peel powder had the best effect on M. incognita. Higher plant height, stem girth, number of leaves, galling index and least final nematode of both soil and roots were recorded. Therefore, from these findings, banana fruit peel powder at 35g exhibited a nematicidal effect on M. incognita in pepper plants, followed by 30, 25, and 20g, respectively. It was concluded that banana fruit peel powder, in addition to its nematicidal effect, is not phytotoxic on sweet pepper plants, providing a safe and effective solution for crop protection. More so, the nematicidal characteristics exhibited by this plant material might be due to some bioactive constituents present in banana fruit peel powder.

Keywords: Banana Fruit Peels Powder, *M. incognita*, Nematicidal, sweet pepper.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is a cultural plant in tropical Central and South America, and it originates from Mexico and Guatemala (Nizomov and Khushvaktov, 2018). It is ranked third in the world after tomato and onion (FAOSTAT, 2012; Mustapha *et al*., 2021). It is one of the essential classes of vegetables extensively cultivated in sub-Saharan African countries (Baba *et al*., 2014; Obayelu *et al.*,2021). In Nigeria, pepper is the second most cultivated vegetable (Abu *et al*., 2020), which accounts for almost half of the African production, and it is grown all year round (under rain feed and irrigation) (Ayo-John and Odedara, 2017; Mustapha *et al*., 2021).

However, it thrives well under irrigation due to its sensitivity to abundant moisture and excessive temperatures (Almuktar *et al.,* 2015). It can also be grown in well-drained, fertile loam soil. However, it grows optimally at a temperature range between 21o C and 29o C (Nickels, 2012). It is sensitive to high salinity levels but thrives well in salinity conditions below 1280 mg L-1 (Food and Agriculture Organization FAO, 2003). According to Haifa Chemicals (2016), peppers produce well in light and well-drained soil rich in organic matter, such as sandy loam or loams with a pH value between 6.5 and 7.5.

Fresh pepper is usually used for salad and other meals, and most of it is used in processed form and also for the production of various preparations, condiments and powders (Nizomov and Khushvaktov, 2018). Pepper is a vital commercial crop cultivated for vegetable, spice, and value-added processed products (Kumar and Rai, 2005). Besides vitamins A and C, the fruits contain various antioxidants, notably carotenoids, ascorbic acid, flavonoids and polyphenols (Nadeem *et al*., 2011). This makes it an essential constituent of many foods, adding flavour, colour and spice and an important source of human nutrition. Its average consumption per person per day is about 20% (Ogunbo *et al*., 2015).

Although pepper is valuable and essential in the human diet, its production could be optimized to meet the market demand all year round. In Nigeria, the low production of pepper is attributed to many factors, such as poor varieties, poor cultural practices and the prevalence of pests/pathogens and diseases. Among such pests are Plant Parasitic Nematodes (PPN). Plant Parasitic Nematodes (PPN) significantly reduce crop yields in quantity and quality, a growing economic concern for the global agricultural industry (Shakeel *et al*., 2022). These nematodes were reported to have caused about 8.8–14% of the annual crop losses worldwide at an estimated cost of approximately USD 173 billion (Ahuja and Somvanshi, 2021). The three most economically significant groups of PPNs include cyst nematodes, lesion nematodes, and root-knot nematodes, which infect and proliferate on a wide range of plant species (Sikora, 2018) Root-knot nematodes (RKNs) (*Meloidogyne*sp.) are one of the groups with the highest pathogenic capacity and have the most significant number of hosts with about 105 described species in the genus *Meloidogyne: Meloidogyne arenaria, Meloidogyne hapla, Meloidogyne incognita, and Meloidogyne javanica,* in particular parasitize many vital crops (Ghaderi and Karssen, 2020). These RKN species attack the root vascular system of a plant, causing symptoms of water and nutrient transport deficiencies, which results in wilting and chlorosis, and eventually retard plant growth and reduce yields (Tapia-Vázquez *et al*., 2022). Control and management have become necessary considering the economic losses and damage caused by plant parasitic Nematodes.

For decades, the control of Plant Parasitic Nematodes largely relies on synthetic nematicides. However, the use of synthetic nematicides such as methyl bromide, 1, 3-dichloropropene, carbamates (oxamyl), and organophosphates (fenamiphos), among others, is being restricted because of their high toxicity coupled with the environmental risk associated with their use. (Walia *et al*., 2018). As a result of this, there has been an increased interest in the development of alternative methods of nematode control, and such alternatives include the use of plant parts in the control of plant parasitic nematodes. These plant parts can either be in extracts or powder form (Oka *et al*., 2000). Therefore, this study evaluates the effect of dry banana fruit peel powder on *M. incognita* inoculated on pepper plants.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out in May/June 2022 in the laboratory of the Crop Protection Department, School of Agriculture and Agricultural Technology, Biochemistry Laboratory, School of Life Science. The potted experiment was carried out at the landscape Garden of Modibbo Adama University Yola. Yola lies between Latitude 90 12'30.20" N and Longitude 120 28' 53.26" E at an altitude of 185.9m above sea level (Google GPS).

Source of experimental materials and Preparation of Banana Fruit Peels Powder

Sweet Pepper seeds were purchased from an Agrochemical shop in Jimeta's ultra-modern market in Yola, Adamawa state. And banana fruits were purchased from the market. Two hundred and sixty-five grams (265 g) of banana fruit Peels were washed, chopped into smaller pieces and were covered with black cloth, kept under sunlight for (8) eight days and ground into powder using pistil and mortar (Otaviana and Atmaka, 2011).

Inoculum Source and Extraction of Nematode Juvenile

The second stages of juvenile (J2) *M. incognita* were extracted from an infested tomato plant cultured earlier in the landscape garden Modibbo Adama University Yola. The roots of the tomato were washed under running tap water. Clean roots were cut into 1-2 cm lengths, put in a sieve (25 mm pore), and gently placed in a large tray with water in it. The setting was undisturbed for 24 hours, and active nematodes passed through a sieve and sank to the bottom of the tray.

Treatment and Experimental Design

The experiment consisted of five treatments (T1, T2, T3, T4, and T5) replicated four times and was arranged in a Completely Randomized Design (CRD) on the laboratory bench the laboratory. (Ononujo and Nzewa, 2011).

Soil Sterilization

Sandy loam soil was collected from the landscape Garden of Modibbo Adama University, Yola, at a depth of 1 – 10 cm using a hand trowel. The soil was sterilized on fire in a large metal drum for 4 hours to get rid of another pathogen that may influence the plant growth. The soil was allowed to cool for 72hours, after which 4 kg from the soil was weighed and filled into each of the experimental buckets (Gautam and Goswani, 2007; Nkechi *et al.*, 2016),

Incorporation of Plant Powder

Ground powder of 20, 25, 30 and 35g were weighed and mixed thoroughly with sterilized soil and was allowed to decompose for 2weeks before transplanting Sweet pepper seedlings into each of the experimental pots.

Nursery Preparation

Sweet pepper seedlings were raised on a plastic tray containing sterilized soil for three weeks before transplanting into the experimental bucket. The seedlings were transplanted after 21 days of emergence into the experimental buckets containing 4 kg of sterilized soil mixed with the plant materials. Two seedlings were transplanted into each bucket after a week. The pepper plants were irrigated at interval of three daysand weeding was done manually with hand at two-week interval.

Inoculation of *M. incognita*

The extracted juveniles (J2) of *M. incognita* were used to inoculate each of the pepper stands contained in the bucket with approximately 100 J2 of *M. incognita* contained in 100 ml suspension after two weeks of transplanting. The suspension was applied using 10 ml syringe into the root zone of the plant.

Data Collection

The data were collected on some growth, yield and nematode parameters.

Growth Parameters

Plant height and stem girth (cm) of each plant for all treatments were measured weekly starting from one week after inoculation (WAI) at an interval of one week for five weeks with a flexible measuring tape. For plant height, the measurement was done from the base of the plant to the terminal bud (Sowley *et al.,* 2013). The stem circumference of each plant in the pots was measured to obtain stem girth measurement. The number of leaves of each plant for all treatments was counted weekly, starting from one week after inoculation of seedlings at an interval of one week for a period of five weeks. The number of fruits from each plant was also counted at harvest.

Nematode Parameters

At harvest, sweet pepper plants were uprooted, and the number of galls was rated using a scale described by Bridge and Page (1980), which involved the use of a gall rating chart as follows:

0 = no knots on roots
1 = A few small knots difficult to find
2 = small knots only but clearly visible; main roots clean
3 = some larger knots visible, but main roots clean
4 = larger knots predominate, but main roots clean
5 = 50% of roots knotted; knotting on parts of main root system
6 = knotting on some of the main roots
7 = majority of main roots knotted

8 = all main roots knotted; few clean roots visible

9 = all roots severely knotted; plant usually dying

10 = all roots severely knotted; no root

Final Nematode Population

The final nematode population was determined from both soil (200 cm3) and root (5g). For the soil, 250 cm3 from each pot was used to determine the final nematode population (Coyne *et al*., 2007). A tissue paper was placed underneath a sieve, and soil was poured into it. The sieve was then placed in a tray, and water was poured gently on the tray, and the setting was left undisturbed for 24 hours. Active nematodes that passed through the sieve were collected and counted using a grid line Petri dish under a microscope, and their numbers were recorded. A similar procedure but without the tissue paper was adopted for extracting nematodes from the root, using 5g of roots from each pot.

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA), and the means were separated using Least Significant Difference (LSD) at $p \leq 0.05$.

RESULTS AND DISCUSSION

Effect of Dry Banana Fruit Peel Powder on Growth and Yield of Sweet Pepper

Plant Height at 6 and 8 Weeks After Inoculation

The result shows that there was a significant difference ($p \leq 0.05$) between the treated and untreated (control) sweet pepper plants (Figure 1). Sweet pepper plants treated with 35g of banana fruit peel powder had the highest mean plant height, 39.21 and 42.18 cm, at 6 and 8 weeks after inoculation (WAI), respectively. The control (treatments with no powder) recorded the shortest plant height, 5.39 and 6.24 cm at 6 and 8 WAI, respectively (Figure 1). This indicates that applying plant powder into the experimental pots created a conducive and enabling edaphic condition for the plant to thrive and flourish. The control treatments clearly show the interruption of the growth potential of the plants as a result of the presence of PPN nematodes, whose action causes water and nutrient transport deficiency and eventually retard plant growth (Tapia-Vázquez *et al*., 2022).

Stem Girth at 6 And 8 Weeks After Inoculation

There were significant differences ($p \leq 0.05$) between the treated and untreated pots (control) at 6 and 8 WAT. However, sweet pepper plants treated with 35g of banana fruit peel powder had the widest stem girth (3.2 and 3.8 cm at 6 and 8 WAT), followed by those treated with 20, 25, and 30g which recorded 2.1, and 2.2 cm, 2.2 and 2.4 cm, 2.6 and 2.8 cm at 6 and 8 weeks respectively. In contrast, the control (0g of banana fruit peel powder) had the tiniest stem girth (1.3 and 2.6 cm at 6 and 8 weeks, respectively) (Table 2). This result is in line with that of earlier researchers (Sowley *et al.*, 2013; Solomon and Constance, 2018 and Ikram *et al*., 2022;) whose study revealed that the addition of plant powder to nematode-infested pots reduced nematode population density and increased the growth and performance of the test plant. Similarly, Oka (2010) observed that using plant parts can alter the physical structure and fertility of the soil, resulting in greater plant tolerance to nematode infection in terms of plant growth.

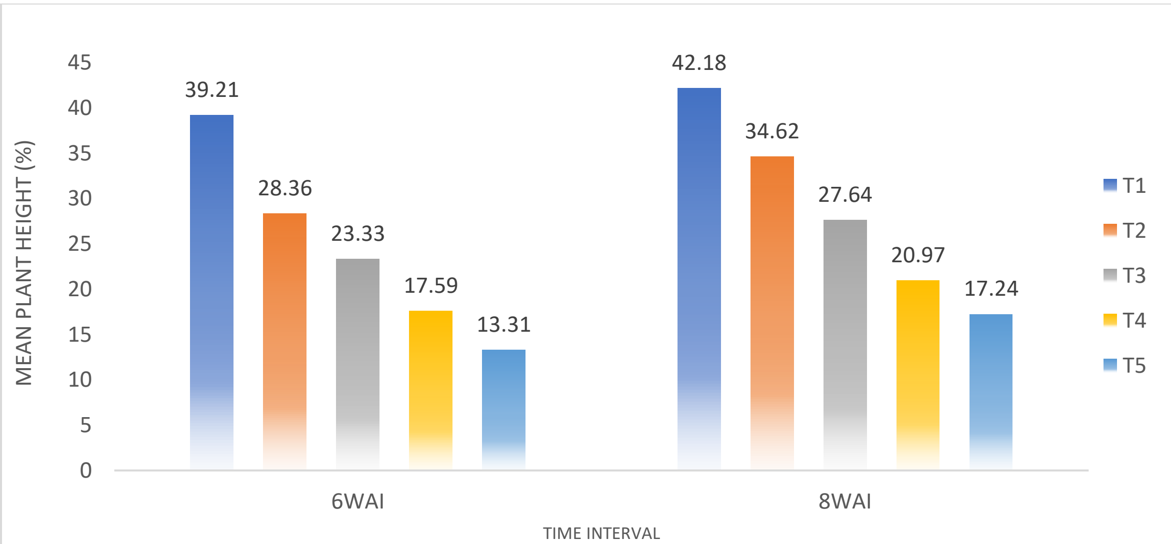

Figure 1.: Effect of Dry Banana Fruit Peels Powder on Plant Height

T1= 35g Dry Banana Fruit Peels Powder, **T2**= 30g Dry Banana Fruit Peels Powder

T3= 25g Dry Banana Fruit Peels Powder, **T4**= 20g Dry Banana Fruit Peels Powder

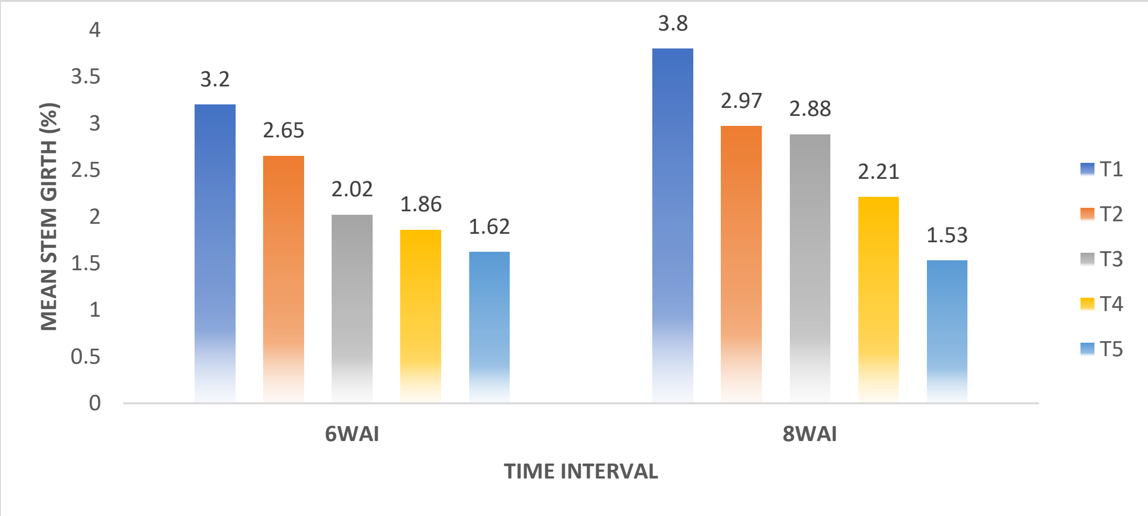

Figure 2. Effect of Dry Banana Fruit Peels Powder on Stem Girth

T1= 35g Dry Banana Fruit Peels Powder, **T2=** 30g Dry Banana Fruit Peels Powder

T3= 25g Dry Banana Fruit Peels Powder, **T4=** 20g Dry Banana Fruit Peels Powder

Number of Leaves and Fruits

The application of various levels of banana fruit peel powder had a significant impact on the test plant, particularly in terms of the number of leaves and fruits at 6 and 8 WAI. Notably, treatments with 35g of plant powder demonstrated the highest number of leaves (18.2 and 22.3) at 6 and 8 WAI and the highest number of fruits (19.36) at harvest. This promising result suggests that the application of the plant powder can significantly ($P \leq 0.05$) influence both the leaves and yield parameters. This aligns with the findings of Aktar and Malik (2000), who observed that organic amendment of plant powder can have beneficial effects on the soil physical and chemical conditions of plants, including the number of leaves, number/weight of fruit, stem girth, and plant height of the test plant.

The control plants, unfortunately, exhibited the least number of leaves, and the leaves appeared yellow due to nematode infestation at the root zone. This infestation hindered the uptake of water and nutrients, leading to the production of unhealthy leaves and a reduction in the plant's rate of photosynthesis. This sequence of events can ultimately lead to leaf discoloration and stunted growth. This observation is in line with the findings of TapiaVázquez *et al*. (2022), who highlighted the destructive nature of Root Knot Nematode (RKN) species. These nematodes attack the root vascular system of a plant, causing water and nutrient transport deficiencies, which result in wilting and chlorosis, and eventually retard plant growth and reduce yield.

Table 1. Effects of powder on No. of leaves and No. of Fruits After Harvest

Treatments	Effects of powder on No. of leaves		Effects of Powder on No. of Fruits After Harvest
	6WAI	8WAI	
35g	47	58.13	19.36
30g	38.33	48.62	14.25
25g	27.66	36.17	11.28
20g	11.66	17.64	8.71
0g (control)	8.74	13.42	4.35
P<F (p-value)	0.02	0.01	0.05
Standard Error	7.90	10.63	8.25

Effect of Dry Banana Fruit Peel Powder on Nematode Parameters

Galling Index

The results revealed significant differences between the treated and untreated plants with banana fruit peel powder. The treated pepper plants had a significantly lower galling index than the control pots. Plants treated with 35g of banana fruit peel powder recorded a galling index of 2.1, followed by 30 g and 20g, which recorded 3.5 and 4.2, respectively. The control recorded the highest galling index of 5.00 (Table 2).

Final Nematode Population in The Roots and Soils

The result indicated that the control pots (0g powder) had the highest nematode population in the test plants' roots and the experimental pots' soil compared to the treated pots. This could be due to the absence of banana fruit peel powder, which has the potential to inhibit nematodes in the test plants' roots.

The population of nematodes in the soils of the experimental pots was significantly ($p \leq 0.05$) reduced by all the banana fruit peel powder levels. As a result, the number of galls formed on the roots of the sweet pepper plants was also reduced. This could be due to the direct contact of the powder with the juveniles, which ensured that the active ingredients in the plant powder were essentially released to the juveniles. This result coincides with that of Godwin *et al.*

(2015), who discovered that the use of botanicals of *Azadirachta indica, Vernonia amygdalina, Manihot esculenta, Carica papaya*, and *Citrus sinensis* prevented the multiplication of nematode on sweet pepper, thereby reduces the severity of galls formation on the roots and enhanced plants growth due to their toxicity level.

Table 2. Effect of Dry Banana Fruit Peels Powder on Galling Index and Nematode Population

Treatments	Effects of powder on Nematode Population		Effects of Powder on Galling Index
	In Roots	In Soils	
35g	19.16	13.66	0.33
30g	31	23.13	1.29
25g	48.63	36.83	2.66
20g	73.21	50.31	3.36
0g (control)	89.72	79.38	6.48
P<F (p-value)	0.04	0.02	0.01
Standard Error	6.19	4.25	0.37

CONCLUSION AND RECOMMENDATION

The results of this study, which revealed the toxic nature of banana fruit peel powder to PPN and its role in enhancing the growth and yield of sweet pepper plants, offer promising benefits for the field of plant science. The potential bioactive compounds in banana fruit peel powder that proved lethal to *Meloidogyne incognita* in the experimental pots present a hopeful prospect for future research. Therefore, it is recommended that this study be replicated under field conditions with higher levels of plant powder (banana fruit peels) to determine its efficacy in the field.

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