EFFECTS OF ADDITIVES ON GROUNDNUT OIL EXTRACTION

BY

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PGD / AGRIC – ENG. / 2008/206

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NIGER STATE, NIGERIA.

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BEING A POSTGRADUATE DIPLOMA PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF POST GRADUATE DIPLOMA IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

SEPTEMBER, 2011

DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

SHEHU, AHMED RAMATU Date

CERTIFICATION

This is to certify that the project entitled "Effects of Additives on Groundnut Oil Extraction" by Shehu Ahmed, Ramatu meets the regulations governing the award of Post Graduate Diploma in Agricultural and Bioresources Engineering of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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Prof. (Mrs) S. N. Zubairu Dean, Postgraduate School	Date

DEDICATION

This project is dedicated to Almighty Allah, my lovely Husband Engr. A.A. Shehu and to the memory of my late brother Shehu Lukman.

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I am greatly indebted to Almighty Allah for his abundant protection and mercy, when kindness cannot be returned, it should be appreciated. (ALHAMDULILLAHI).

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ABSTRACT

One major problem in the oil extraction from groundnut is the poor yield. The needs to improve the yield therefore made it necessary to employ some additives that are not harmful to the consumers. This present work investigated the effects of some additives (Potash and Sorghum floor) on the oil yield from groundnut. 4kg of groundnut was used for each treatment with the following sample variables kept constant, temperature (25^0C), moisture content of the groundnut (10%), hydraulic pressure (1500KN/m^2) and extraction time (15mins). The additives were applied at two different levels, high or positive level and low or negative level, while the control experiment was coded (C*). The experiment was conducted using the factorial (2^2) experiment. Statistical software (SPSS 15.0) was employed for the analysis. The results obtained showed that oil expressed with potash has the best and highest average yield as compared with those obtained from sorghum floor and the control. The yield obtained when potash was added at low and high levels were 63.5Cl and 75Cl per 4kg of groundnut. When sorghum floor was added at low and high levels, the yield obtained were 52Cl and 57.5Cl per 4kg of groundnut. The yield obtained for the control treatment (no additives was added) was 37.5Cl per 4kg of groundnut cake. The treatment combinations of the two additives at different levels were analyzed statistically and the results obtained shows that the combinations of additives were not significant ($\alpha = 0.05$). It can be concluded that potash as additive facilitates oil yield when added to groundnut. Secondly, the sorghum floor does not increase oil yield but increase the quantity of residue (fried cake) and that combination of potash and sorghum floor does not show substantial increase of oil yield.

The research established the suitability of potash as good additive to increase oil yield from groundnut.

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CHAPTER ONE

1.0 INTRODUCTION

The Groundnut, (*Arachis hypogaea*), belongs to the family leguminosae and division papilionacaea. Groundnut probably originated from Brazil, widely grown in many parts of Nigeria. It is grown mainly for its edible oil and protein rich nuts.

There are different varieties of groundnut but the most popular types are two, the runner and the bunch types. Runner types are commonly grown in West Africa. Apart from these two, several hybrids exists, such as, Kano local, Kano 50, Castle cary, MK 374 or MS 539, Spanish 205, IITA series, Samaru 38, G 153 (Asiedu, 1989 and NSPRI, 2002).

Groundnut is generally andro-monoecious, hermaphrodite in nature, male and female on the same plant. It is grown as an annual crop on about 19 million hectares of land in tropical and sub tropical regions and the warmer areas of temperate regions of the world. It develops and matures below the soil surface (Woodroof, 2002).

It could be cultivated twice in a season following its ability of fast maturity. It requires temperature between $25^{0}C$–$30^{0}C$ and rainfall is 70cm -100cm per annum. Salunkhe and Desai (1986), revealed that African Countries contribute more than half of the total World production of groundnut and average yield of groundnut on farmers plot in Nigeria is about 750kg per hectare of decorticated nuts (NSPRI, 2002).

1.1 Groundnut: An Oil Bearing Seed

It is an oil bearing nut that produces edible oil. The seed contains a high percentage of oil. When nuts are broken or bruised, a sufficient number of cells are injured to cause tiny drops of free oil to ooze out and collect on the surface of the nuts. Groundnut has percentage oil content of about 45-55 percent oleic acid and 25 percent linoleum acid (Salnukhe and Desai 1986).

Chukwu and Bature (2010), classified oil derived from plants into dry, semi-dry and non – dry, according to their ability to absorb oxygen from the atmosphere. Vegetable oils are stored as small insoluble droplets within plant cells. They occur predominantly in seeds (mostly in the endosperm and fleshy cotyledons) and pericarp of the fruits as in olive and oil palms.

Groundnut oil is a non – drying oil, that remain liquid at normal temperature and capable of forming elastic films even after long exposure to air as they do not react with atmospheric oxygen. Non-drying oils are largely glycosides of saturated acids and oleic acids, with little or no linoleum and lanoline acids. The iodine value is less than 100. Non –drying oils are found notably in plants of tropical regions (Kochhar, 1981).

Salnukhe and Desai (1986), described edible oil or non drying oil as those that could be take as food while non-edible oils are mainly processed industrially as raw material. Groundnut oil is a clear, light yellow-brown with a mild characteristic odour of peanuts. It is used extensively for cooking and gives flavour to many traditional dishes in West Africa, because of its resistance to rancidity. It is therefore considered particularly suitable for effleurage.

1.2 Economic Importance and Uses of Groundnut

Production of groundnut is a major source of income and employment in many countries. According to FAO (1986), groundnut is rated the second most important source of vegetable oil in the World. Groundnut is principally grown for its edible oil, protein rich kernels. Oil and meal derived from them (vegetable residue), serve as human food. The kernel is eaten raw, lightly roasted or boiled, sometimes salted or made into a paste, which is known as peanut butter and several peanut confectioneries. Oil extracted from groundnut are used domestically for cooking, industrially for the manufacturing of soaps, margarines, for shortening in pastries and bread, pomade, cosmetics, shaving cream, lubricants and synthetic fibre (Woodroof, 1983). Groundnut oil is also used in pharmaceuticals and cosmetic products, as a lubricant and emulsion for insecticides and as a fuel for diesel engines (Akindele, 1996).The cake remaining after oil extraction is a valuable raw material for use in snack foods, in stews or soups or as animal feed. In Senegal, the leaves of the plant are used as a vegetable in soups. Shelled seed (ground raw) are also used in preparing groundnut soup (Montgomery, 1991). The residue (press cake) after oil has been extracted contains protein and valuable feed for poultry. Groundnut cake is also used for livestock feeding (animal forage), the dry pericarp of groundnut seed (kernel coat) could be used as source of fuel and soil conditioner (enriching the soil).

Groundnuts are a highly nutritious food; whole groundnuts and groundnut meal, produced by expressing the oil, are rich in protein and minerals. Groundnuts are rich in calcium, phosphorus, iron and they constitute an excellent source of the vitamins thiamin, riboflavin and niacin (Onwueme and Sinha 1990).

Table 1.1: Nutritional Values of the Groundnut in Percentage.

	Carbohydrate	Protein	Oil (fat)	Fibre	Ash	Water
Shelled Groundnut	11.7	30.4	47.7	2.5	2.3	5.4
Decorticated Groundnut	23.4	46.8	7.5	6.4	5.8	10.3

Source: Onwueme and Sinha (1990).

1.3. Statement of the Problem

One major problem in the oil extraction from groundnut is the poor yield for some of the varieties. It is therefore necessary to improve on this yield by employing some additives which are not harmful. Some additives have been used to enhance oil yield from oil seeds including groundnut (Chukwu and Bature, 2010), However other materials could be tried to ascertain their suitability, hence the needs for this present study.

1.4 Aim and Objectives of the Study

The main objective of this project work is to determine the effects of some natural products (additives) on oil extraction rate and yield.

The specific objectives are to:-

i. Find if the addition of potash and sorghum floor has any significant effect on the oil yield from groundnut.

ii. Determine the quantity of natural additives per unit weight of groundnut for maximum yields of oil.

iii. Find if the additives have any effects on the sensory parameters of oil extracted from the groundnut.

1.5 Justification of the Study.

Extraction efficiency in oil production is evaluated in terms of yield and extraction rate. The local methods take long period owing to effort to ensure that much oil is extracted. Several researches have been carried out to determine the factors affecting oil extraction such as moisture content, pressing time, pressing pressure, particle size, temperature and cake thickness.

However, much scientific work had not been done on factors such as additives especially at the rural areas. This is a local practice and the effect on oil yield and extraction rate need to be investigated and given a scientific basis. It has been observed under home conditions that oil is released faster from paste of melon and groundnut seeds, when additives such as onion or potash were added before cooking. These two observations call for an investigation of the effect of additives on oil extraction from oil seed paste. The quantity added during local production of oil is relatively small. It is then justified to determine a quantity that will give a higher yield and faster rate.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Food Additives and their Uses

Wilson (2007), stated that, it is often forgotten that, the overall purpose is the same – to prepare, preserve, process and, as the case may be, cook basic raw ingredients to convert them into wholesome, attractive, better tasting and nutritious food, ready to be consumed, transform an everyday dish into something special. Food manufacturers do much the same and, over years of product development, first on the basis of trial and error but now by research programmes, have developed the most effective and economical methods of producing a wide range of foods to suit every taste and pocket. In order to achieve this, a wide range of additives to perform a number of tasks in the process, right from cleaning and refining of the raw materials, preserving them in optimal condition throughout, further processing are required. Additions of other ingredients to ensure that the products appear attractive to the consumer are also involved. It is therefore advised to review the use of additives in the food supply, knowing that they are essential to food preparation, quality and preservation.

Anon (2006), revealed that the primary aim of the food-manufacturing industry is to provide a wide range of safe, wholesome, nutritious and attractive products at affordable prices all year round in order to meet consumer requirements for quality, convenience and variety. It would be impossible to do this without the use of food additives. They are essential in the battery of tools used by the food manufacturers to convert agricultural raw materials into products that are safe, stable, of consistent quality and readily prepared and consumed. Different types of additives are used for different purposes, though many individual additives perform more than one function.

2.2 Definitions of Food Additives

Food additives are defined in European legislation as "any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food, whether or not it has nutritive value, the intentional addition to a food for a technological purpose in the manufacture, processing, preparation, treatment, packaging, transport or storage. Food additives are used either to facilitate or complement a wide variety of production methods in the modern food supply. Their two most basic functions are that they either make food safer by preserving it from bacteria and preventing oxidation and other chemical changes, or they make food look or taste better or feel more pleasing in the mouth (Feingold, 1975).

According to Dean (2002), the use of additives in food preservation is, one of the oldest traditions. The use of food additives is not new. Preserving food is an age-old necessity. Many of the techniques that are now taken for granted, such as the use of saltpetre as curing agent, or vinegar (acetic acid) as additives. They would have been the mainstay for ensuring a longer-term supply of precious perishable foods. Canning, refrigeration and freezing, are relatively new. Salt, though not an additive by the modern definition, but is very essential.

Additives or processing aids can be defined as "any substance not consumed as a food ingredient by itself, intentionally used in the processing of raw materials, foods or their ingredients, to fulfill a certain technological purpose during treatment or processing, and which may result in the unintentional but technically unavoidable presence of residues of the substance or its derivatives in the final product, provided that these residues do not produce any health risk and do not have any technological effect on the finished product." Additives should include any of the following categories such as preservatives, antioxidants, emulsifiers, stabilisers, thickeners, flavour enhancers etc. In developed countries, where more detailed legislation are in place and there are laid down criteria for additives usage, the technological need must be demonstrated that their presence presents no hazard to the consumer; and that they do not mislead the consumer. The use of additives may be considered only where there is demonstrable benefit to the consumer, namely to preserve the nutritional quality of the food; to provide necessary ingredients or constituents for foods manufactured for groups of consumers with special dietary needs, or to enhance the keeping quality or stability of a food or to improve its organoleptic properties, provided that, in doing so, it does not deceive the consumer; and to assist in manufacture, processing, preparation, treatment, packing, transport or storage of food, and that the additive is not used to disguise the effects of the use of faulty raw materials or of undesirable (including unhygienic) practices or techniques during the course of any of these activities (McKendry, 1973).

2.2.1 Additives as Preservatives

A food additive must fall within a category or categories listed below:

Colours

Antioxidants

Preservatives

Emulsifiers

Thickeners

Gelling agents

Stabilisers

Flavour enhancers acids

Acidity regulators

Anti-caking agents

Modified starch

Sweeteners

Raising agents

Anti-foaming agents

Glazing agents (Kendrick, 2005).

Stich and Court (2006), deduced the following on additives: Additives as Preservatives are probably the single most important class of additives, as they play important roles in the safety of the food supply. Despite this fact, any chemical used to counteract the perishability of food raw materials has often become perceived as suspect, and any food containing a preservative has been considered inferior or unsafe. Yet the use of chemical preservatives, such as sulphur dioxide and sulphites, is a continuation of the age-long practices of using salt, spices to preserve perishable foods in the days before refrigeration and modern processing techniques. All food raw materials are subject to biochemical processes and microbiological action, which limit their keeping qualities. Preservatives are used to extend the shelf-life of certain products and ensure their safety throughout that extended period. Most importantly, they retard bacterial degradation, which can lead to the production of toxins and cause food poisoning. Thus they offer a clear consumer benefit in keeping food safe over the shelf-life of the product, which itself may be extended by their uses and thus meet the demands of modern lifestyles, including infrequent bulk shopping expeditions. The continued perception of preservatives as undesirable, to which the many labels indicating "no artificial preservatives" testify, is therefore an unfortunate consumer misapprehension.

2.2.2 Additives as Antioxidants

Antioxidants reduce the oxidative deterioration that leads to rancidity, loss of flavour, colour and nutritive value of foodstuffs. Fats, oils, flavouring substances, vitamins and colours can all oxidize spontaneously with oxygen when exposed to air. The rate of deterioration can vary considerably and is influenced by the presence of natural antioxidants and other components, availability of oxygen, and sensitivity of the substance to oxidation, temperature and light, for example. Oxidation can be avoided, or retarded, by a number of means, such as replacing air by inert packaging gases, removal of oxygen with glucose oxidant, incorporation of ultra-violent (UV)-absorbing substances in transparent packaging materials, cooling and use of sequestering agents. These may not be possible in all cases, or sufficient for an adequate shelf-life for some foods. Thus, antioxidants are used to retard oxidative deterioration and extend shelf-life. Some antioxidants actually remove oxygen by self-oxidation, e.g. ascorbic acid, while others interfere with mechanism of oxidation, e.g. garlic acid, esters. All have specific properties, making them more effective in some applications than in others. Often a combination of two or more antioxidants is more effective than any one used simply because of their synergistic effects. The presence of sequestering agents, such as citric acid, may also have a synergistic effect, by reducing the availability of metallic ions that may catalyse oxidation reactions. The use of the powerful synthetic antioxidants and the garlic acid esters is very restricted. Foods antioxidants cannot restore, they can only retard the oxidation process. As oxidation is a chain reaction process, it needs to be retarded as early as possible. The most effective use of antioxidants is therefore in the fats and oils used in the manufacturing process.

2.2.3 Additives as Emulsifiers and Stabilizers

The purpose of emulsifiers and stabilisers is to facilitate the mixing together of ingredients that normally would not mix such as fat and water. This mixing of the aqueous and lipid phases is then maintained by stabilisers. These additives are essential in the production of mayonnaise, chocolate products and fat spreads, for example. The manufacture of fat spreads (reduced-fat substitutes for butter and margarine), has made a significant contribution to consumer choice and dietary change, and would not be possible without the use of emulsifiers and stabilisers. Other reduced- and low-fat versions of a number of products are similarly dependent on this technology. Anyone who has ever made an emulsified sauce, such as mayonnaise or hollandaise, will appreciate the benefits of this technology. In addition to this function, the term stabiliser is also used for substances that can stabilise, retain or intensify an existing colour of a foodstuff and substances that increase the binding capacity of the food to produce reconstituted food (Emerton, 2008).

2.2.4 Additives as Colour

Colours are used to enhance the visual properties of foods. Their use is particularly controversial, because colour is perceived by some as a means of deceiving the consumer about the nature of the food.

Colours and sweeteners are very specific, well-defined classes of additives, because of the nature of their function. There are other categories namely thickeners, acids, acidity regulators, anticaking agents, anti-foaming agents, bulking agents, carriers, glazing agents, humectants, raising agents and sequestrates (Eugenia, 2008)

2.2.5 Additives as Flavour Enhancers

Flavour enhancers are substances that have no pronounced flavour or taste of their own but which bring out and improve the flavours in the foods to which they are added (Court, 2006). Although salt has a distinctive taste of its own and is not classed as a food additive, it is in fact the most widely used flavour enhancer. Some sweeteners have also been found to have flavour-enhancing properties and have been authorised for use as such. For example, neohesperidine can enhance the flavour of meat products and margarine. Although flavour enhancers are categorised as additives, flavourings are technologically different and regulated separately, even though they are often considered by users to be the same thing. Flavourings are defined as imparting odour and/or taste to foods and are generally used in the form of mixtures of a number of flavouring preparations and defined chemical substances. These do not include edible substances and products intended to be consumed as such, or substances that have exclusively a sweet, sour or salty taste, such as ordinary food ingredients such as sugar, lemon juice, vinegar or salt.

According to Stich (2006), there are three distinct classes of flavouring substances: natural, artificial and complex mixture of individual. Most flavourings are developed from substances naturally present in foods. Protection is ensured and additives are not use to deceive, since their usage is essential in food.

2.3 Effect of Pepper and Onion as Additives on Groundnut Oil Expression

According to Chukwu and Bature (2010), the effect of pepper and onion on the yield of oil expressed from groundnut paste, was investigated and the following results were deduced. the oil expressed from groundnut with pepper as an additive has the highest average yield compared to those obtained using onion as the additive or without additives. Oil yields obtained when pepper was added at low and high levels were 31ml and 35ml per 100g of groundnut respectively. When onion was added at low and high levels, the yields were 26.6ml and 20.3ml per 100g of groundnut respectively. While the yield with no additive was 22.3mi per 100g of groundnut. The results suggested the suitability of pepper as an additive to increase oil yield from groundnut. Optimum conditions for maximum yield of oil from 100g of groundnut paste were recommended.

2.4 Method of Oil Extraction

According to UNIFEM (1987), oil extraction methods are classified into two major groups. Such includes mechanical and solvent extractions. Ward (1985) discovered other method of oil extraction which is bio-chemical extraction. Biochemical method involves high pressure carbon dioxide and enzymes extraction.

2.4.1 Mechanical Extraction

Methods involved in the extraction process of groundnut include industrial and local methods. Industrially, oil extraction is carried out either mechanically involving the use of hydraulic press and screw press. Mechanical extraction method involves the application of pressure to the oil bearing tissues to squeeze out the oil. This is accomplished by hydraulic press and screw press (Kochhar, 1987).

2.4.2 Hydraulic Press

In hydraulic press, pressure is exerted by a hydraulic device between two plates with a cylinder that have perforated holes all over. Ward (1985) concluded that the method is inefficient as regards the amount of oil removed from the seeds. According to Ajibola *et al.* (1989) and Asiedu (1989), hydraulic press removes 76–85 percent of total oil content from the seeds while the residual cake usually contains 7 percent oil.

Asiedu (1989), revealed that the pressed cake from screw press normally contains 5 percent oil. The screw press has the advantage of being simple and inexpensive compared to solvent extraction. However, the higher power consumption, wear and tear of the machine results in high operating costs. The oil produced from the mechanical methods particularly oil expeller plant is suitable for local consumption without further refining compared to solvent extracted oil.

2.4.3 Screw Press

Screw press was developed to supplement the effort of hydraulic press. The press can be used in batch or continuous process (Ward, 1985). According to Appelqvist (1992), screw press has five essential elements, the main worm shaft, the drainage barrel, choke mechanism the motor transmission, thrust bearing and cooling system. The capacity of the screw press depends on the size of the drainage barrel, an average being 15kg per batch (Brennan, 1989). Asiedu (1989) reported that the screw press removes about 85-95 percent of total oil content and the resulting cake contains 5 percent oil. Although, screw press is more efficient than hydraulic press, it has the disadvantages of higher power consumption, wear and tear of the machine, resulting in high working costs (Appelqvist, 1992).

2.4.4 Traditional / Local Method

Traditionally, groundnut oil is extracted by the use of hand, grinding stone or mortar and pestle to produce paste. Small quantity of hot water is added at interval of time as the paste is agitated. The oil rich paste becomes thickened as stirring continues. The process continued until as much of the oil – water mixture as possible has been extracted. Oil –rich paste left is kneaded and pressed by hand to remove the oil. The oil-water mixture is heated to remove the water in it, while the cake can be rolled and fried and sold as snacks. Traditional method of extracting oil is labour intensive and yield is low compared to mechanical methods (UNIFEM, 1987).

In some localities in Nigeria, most especially Bida and its surrounding local governments in Niger State, some natural products such as onion, pepper, ginger, sorghum floor and potash, are added to the groundnut during extraction. Traditional extraction of groundnut oil is the most common and versatile method. The method of production of groundnut oil and its products (fried cake) is an important source of income for women in most areas in Nigeria and particularly in Niger State. At household levels, the process takes between 2 - 4 hours excluding time spent on other activities such as cooling and packaging. The production rate as well as yield is very low as low as 0.317li/kg.

2.4.5 Solvent Extraction

Khan and Haruna (1983) described this method as the most efficient method of removing oil from oil seeds. According to Salunkhe and Desai (1986), the method can be classified into batch or continuous process. The method involves mixing a petroleum based solvents with pre-pressed material in a close chamber. Oil is then separated from the solvent by direct heating and indirect steam injection, the solvent being recovered for use through the desolventizer (Ward, 1985). The solvent used in oil extraction includes, Hexane, Benzene, Carbonsulphide, Petroleum ether, acetone, (Bernardini, 1985).

Kochhar (1981), reported that about 99 percent oil is removed through this method and the cake obtained contains 1 percent oil or less compared to 5 -7 percent in mechanical pressing. The method is expensive and complex in operation. It is not a common method industrially used in Nigeria because it poses some difficulties, such as discoloration of the oil, cost of the equipment, solvent effect, risk of fire and explosion when highly inflammable solvents like trichloroethylene of high temperature are used.

2.4.6 High Pressure Carbon dioxide and Enzyme Extraction.

Ward (1985), discovered the use Biochemical extraction involving high pressure carbon dioxide and enzyme extraction as other methods of extracting oil from oil seeds.

In the use of high pressure carbon dioxide extraction, the seed are mixed with high pressure carbon dioxide (liquid that dissolves in oil). When pressure is released, the carbon dioxide becomes a gas and the oil is left behind.

Enzyme extraction is used by large scale vegetable oil industries. The process produces many high value products. Seeds are cooked and ground in water, enzymes are added to digest the solid material from the seed. Oil is then extracted from the remaining stuff by the use of a liquid – liquid centrifuge.

The table below shows the efficiencies and percentage oil yield from the cake of various extraction methods.

Table 2.1: Efficiency of the Methods of Oil Extraction

Methods of Extraction	% of oil removed	% of oil in the cake
Hydraulic Press	75 - 85	7
Screw Press	85 - 95	5
Solvent Extraction	>99	1 or less
Local Extraction	31.7	>7

Source: Extracted from Ajibola and Asiedu (1989), UNIFEM (1987).

2.5 Factors Affecting the Rate of Oil Extraction.

There are several factors that affect the rate of oil extraction from oil seeds and nuts. Several research works have been conducted to investigate these factors at optimal value levels. These factors include:

2.5.1 Moisture Content

Moisture content is significant in oil extraction processes. Singh *et al.* (1984) discovered that for optimum expression of oil from groundnut and sunflower, 6 percent moisture content wet basis is significant. Weiss (1983) reported that for oil seed with high percentage of oil content such as groundnut and coconut, moisture content (wet basis) of between 2 – 6 percent is most suitable for optimum expression of oil.

Bonginwar *et al.* (1977) found that the percentage of oil removed decreases when moisture content of groundnut is above 6 percent. The higher the moisture contents of groundnut, the lower the yield. Bhuchar *et al.* (1979) concluded that the optimal extraction of oil from groundnut is attained at about 2 percent moisture content.

2.5.2 Applied Pressure

Koo (1984) and Pominiski *et al* (1970) reported the significant of applied pressure in extraction of oil from groundnut and other related seeds and concluded that oil yield is directly proportional to the square root of the pressure and that the amount of oil expressed is optimum at an expression pressure of 15Mpa and above. Adeeko and Ajibola (1990) carried out expression on groundnut and reported that oil yield increases with pressure up to 20Mpa beyond which the yield decreased.

Adekola (1992), reported that increase in oil yield was recorded for increase in applied pressure and discovered that the yield reduces between the pressure of 20 and 25 Mpa on coconut oil extraction. Peri *et al* (1995), concluded that the extraction on olive paste at optimum yield was attained under the maximum pressure of 81 x 10^5Mpa.

2.5.3 Extraction Time

Dedio and Dorrell (1972) observed that expression of oil from flax seed at 4.5 percent moisture content takes 7 minutes of pressing time for optimum extraction of oil. According to Adekola (1992), oil yield from coconut is depended on expression duration, and 10 minutes was found to be optimal for high oil yield.

2.5.4 Temperature

Khan and Haruna (1983) reported the importance of temperature in extraction of oil from soyabean and concluded that an increase in temperature up to 65°C is suitable for optimal expression of soyabean oil.

Adeeko and Ajibola (1990) found that the rate of oil extraction is greatly increased by an increase in temperature. Local pressing is done at an average temperature of 90^0C +5^0C. Peri *et al* (1995) discovered that oil extraction from olive paste was attained optimum yield at 40^0C. According to Weiss (1993), during hydraulic pressing of cottonseed, temperature of 75^0C and 91^0C was observed in pan and 107^0C and 120^0C was suitable in the base of the pan.

2.5.5 Particle Size

Particle size is significant in oil extraction from groundnuts because the size of particles influences the rate of extraction. The smaller the size, the greater is the interfacial area between the solid and liquid solvent and therefore the higher the rate of transfer of materials. Adeeko and Ajibola (1990) discovered that oil yield from finely ground sample were higher than coarse groundnut paste.

2.5.6 Quality Assessment of Groundnut Oil.

The term 'quality' has different meanings to those who are concerned with the handling, storage, processing and utilization of agricultural produce, even though all are interested in produce of good quality. For example food handling agencies will want dry, insect- free, undamaged produce which will store well; millers will want good quality which will yield a high percentage of finished produce; and consumers will be concerned with flavour, appearance or cooking quality of the produce (Proctor, 1994).

Quality assessment may be either subjective or objective depending on the mode of assessment. Subjective assessment is made usually by human sensory organs of feel, sight, taste and smell judgment while objective evaluation makes use of instruments to measure the parameters. Quality assessment serves the purpose of ensuring the safety of goods eaten by consumers, or the quality of other goods in a condition that will ensure suitability for their intended utility. It also provides the basis for comparison and hence uniformity within and between countries. The quality assessment of every solids or liquids food includes physical, chemical and microbiological examination. Fresh food have distinctive natural odour, generally accepted as an indicator of good quality, processed foods are often spoilt by presence of undesirable flavour, odour, taste and colour caused by either microbial action or chemical action (Peter, 1997). The quality assessments considered are colour, taste, odour and texture of the groundnut oil.

Colour is probably the most important appearance characteristics of food. For the taste and odour; it is the combined perception of substance detected by the senses of taste and smell is often called "taste" (Peter, 1997).

Texture is the attribute of a substance resulting from combination of physical properties and perceived by the senses of touch (including mouth feel). From the above, texture is clearly defined as sensory attribute, measured directly by sensory means. A glossary of textural terms as proposed by Proctor (1994), relating to the structure of the material like size, shape such as powdery, gritty, mealy and term relating to mouth feel characteristics as juicy, greasy, creamy are mostly used.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 List of Materials and Equipment

Groundnut seeds

Grinded Potash

Sorghum Floor

Transparent rubber container

Stainless Pan

Filter and funnel

3.1.1 Equipment

Cosmo Digital weighing balance

Standard oven

Hydraulic power press

Measuring Cylinder

Stop watch.

3.1.2 Seed Source

Matured groundnut seeds ('variety: runner') which is characterized by its red skin and small sized seeds called "Ekochi" (see Plate I) were obtained from a market in Bida, Niger State and used for the experiment. The experiment was carried out in quality control assessment laboratory of Agricultural Engineering Department, The Federal Polytechnic, Bida.

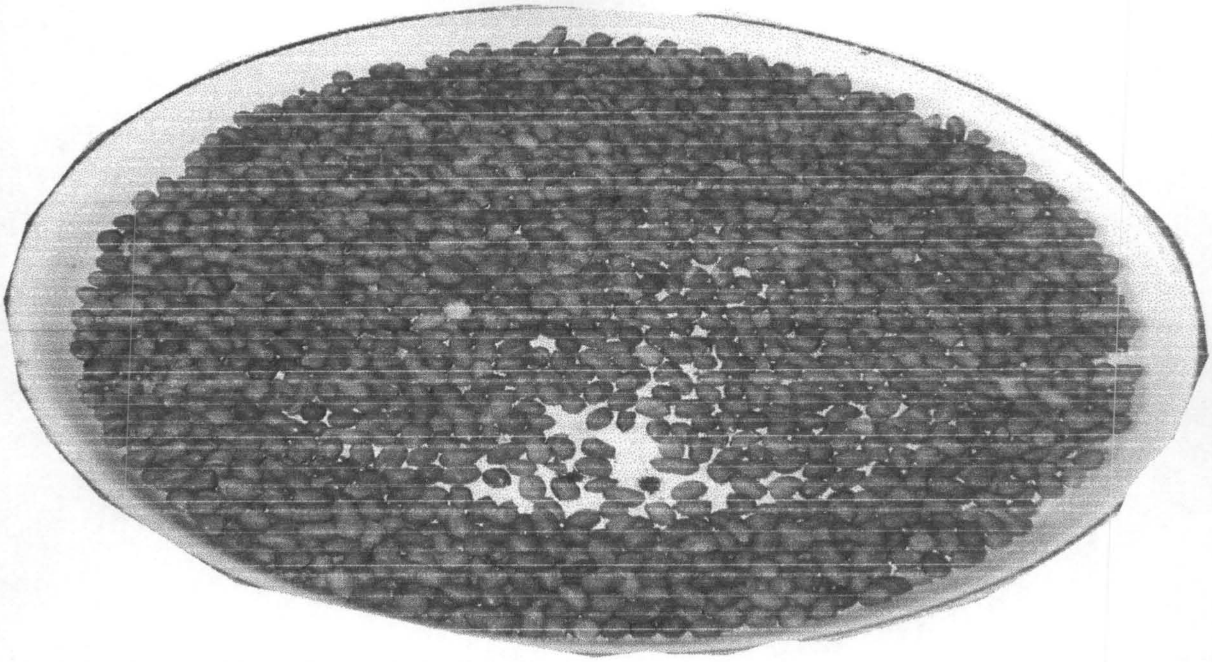

Plate I: Shelled Groudnut (*Arachis hypogaea*)

3.1.3 Additives

Additives that were used in this work were potash and sorghum floor (see plate II and III). Potash is ground into powder; the quantity needed for each test was weighed out from the prepared sample of potash, mixed with the quantity of water and salt to be used for the extraction of groundnut oil. Out of Sorghum floor sample prepared, required quantity according to factor levels were weighed for the experiment

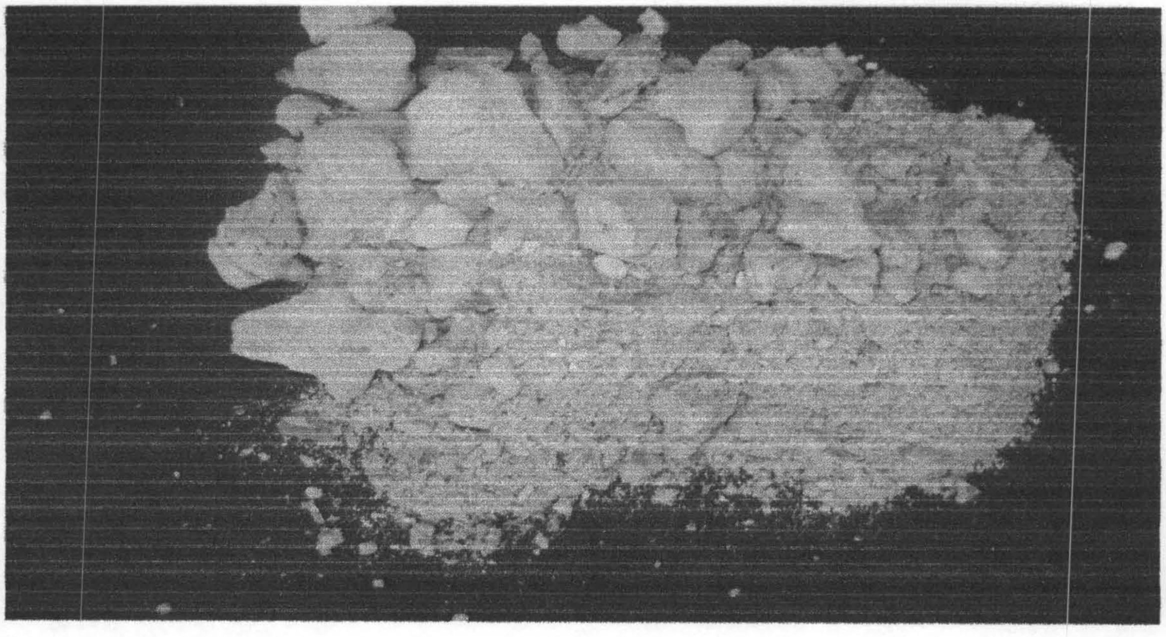

Plate II: Potash as an Additive

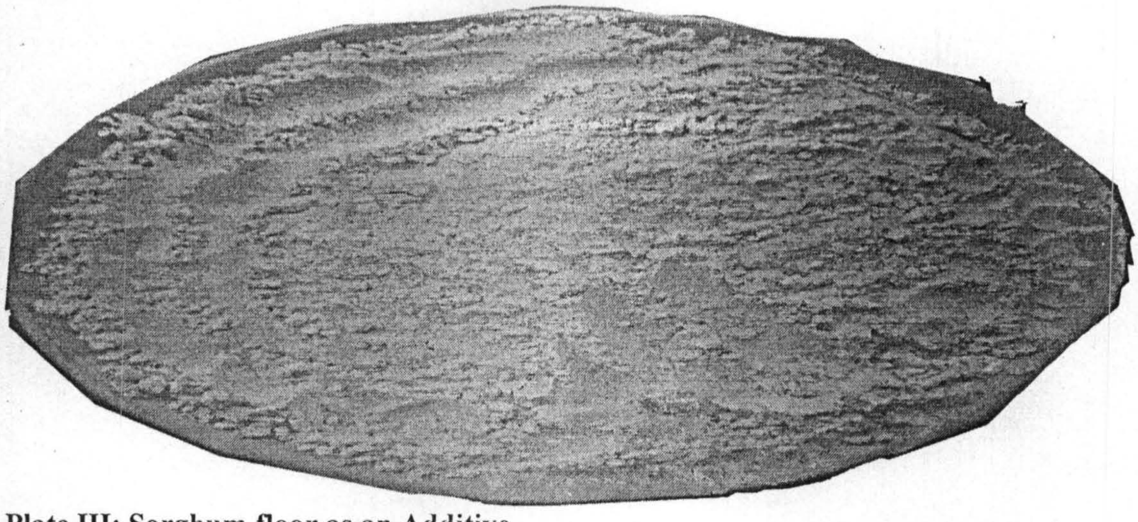

Plate III: Sorghum floor as an Additive

3.1.4. Groundnut Processing (Sample Preparation)

The seeds were manually cleaned by separating the broken nuts, stones, metal, sand, chaff and other extraneous materials from the bulk of the material. This was necessary to avoid products of low quality. The seeds were dried in the sun for two to five days to ensure that the seeds were dry enough up to 12% (wet basis) to enhance maximum oil yield. Groundnut seeds sample for the experiment was slightly roasted for 20-30 minutes at approximately 140–200^{0}C with wooden fire roaster, allowed to cool for skinning process. Skinning was achieved by using grinding machine (increase in clearance between the grinding stones) then winnowed. The winnowed sample was prepared for size reduction i.e. milled into paste. For the experimental test, 4Kg of groundnut was used for each treatment with addition of 1.4Litres of water and 0.080Kg of salt with known weight of additives (potash and sorghum floor) at different levels were added. The test sample variables were temperature (25^{0}C), moisture contents (10%), applied hydraulic pressure (1,500KN/m^2) and expression time was 15mins (Ajibola and Fasina, 1989; NSPRI, 2002). Each sample was mixed and introduced into the press. Oil obtained was drained and collected; allowed to settle and filtered before measurement using a graduated cylinder. Each test was in four replicates.

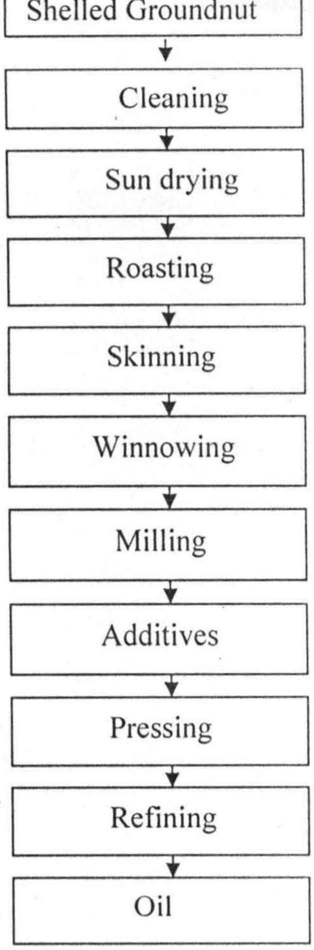

Fig. 3.1: Flow Chart for the Processing Groundnuts into Oil.

3.1.5 Moisture Content Determination

The pre-extraction moisture content of the groundnut sample was first of all determined using oven drying method as described by ASAE S269.4 (1998) standard. The procedure is expressed as follows:

Empty clean and dried container was weighed and the weigh was recorded as Xg.

Weight of container + sample = Yg

Weight of sample = (weight of container + sample weight) – weight of container.

$$= Yg - Xg$$

Oven was set at 103^0C and allowed to standardized in attaining the temperature. It was allowed to heat up for about 15 minutes before the materials were placed in it.

The sample was brought out at interval of 30 minutes, covered with lid and allowed to cool using natural current of air then weighed using cosmo digital weighing balance This procedure is repeated until constant weight is attained.

Moisture content was calculated using the expression

$$M.C_{wb} = \frac{W_i - W_f}{W_i} \times 100\%$$

$M.C_{wb}$ = Moisture content wet basis (%)

W_i = Initial weight of the sample (kg)

W_f = Final weight of sample (kg)

3.1.6 The Choice of Oil Extraction

The mechanical extraction method was chosen for the experiment. The extraction of oil from milled sample of known groundnut weight was carried out using hydraulic powered press, Guaranteed by Ogawa Seiki Company Ltd, Tokyo, Japan. The hydraulic power press of model 526, capacity of 2.5×10^4 MPa pressure gauge. It consists of a rectangular platform, which serves as a base for the frame, a mild steel pressing ram with iron springs attached at both ends, press lever for lowering the pressing ram, pressure gauge returning lever for lifting the pressing ram and a pressing cylinder that holds the sample. The cylinder has holes all over, where oil oozes out and drained. The pressure was monitored and read by means of a dial gauge installed in the machine, a stop watch was used for the purpose of timing. (See Plate IV). Mechanical extraction of oil from oilseeds is one of the methods that are presently used in the removal of oil from oil–bearing materials. This method offers the possibility of using the cake residue. It has relatively low initial and operational costs and produces uncontaminated oil.

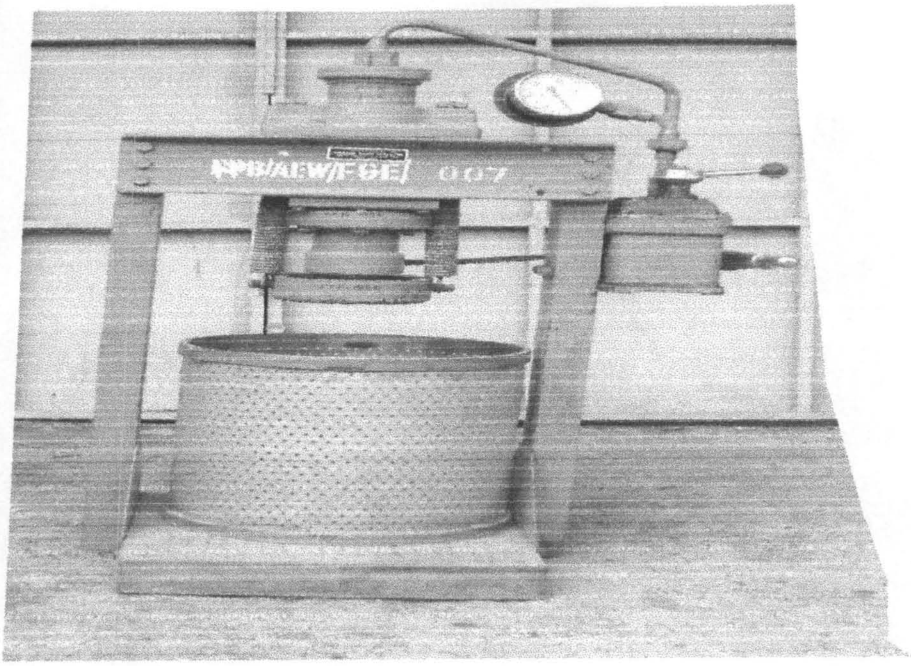

Plate IV: Hydraulic Powered Press

3.1.7 Physical Determination of Colour, Taste, Odour and Texture of Groundnut Oil.

The assessment was done by six (6) assessors. Sample of unheated groundnut oil was tasted with mouth, seen, hand felt (touch and rubbed between the fingers to fill its size and shape). Little sampled groundnut oil was heated to 40 – 60^{0}C the vapour was sniffed, observed to see if there would be change in colour of the oil after heating. .

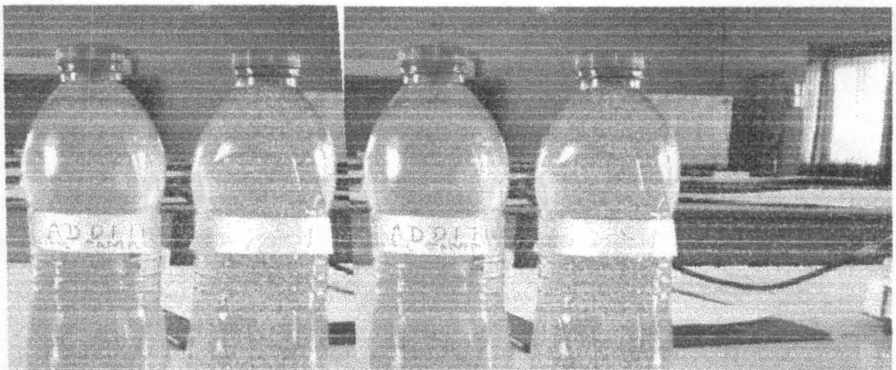

Plate V: Groundnut Oil after Extraction (Unheated)

3.1.8 Experimental Design

The experimental design used for the analysis was 2^2 factorial experiment in completely randomized design. Statistical software (*SPSS 15.0*) was employed for these analysis and results are shown in Table 4.1 and 4.2 respectively. The sample variables were temperature (25^0C), moisture content (10%), hydraulic pressure (1500KN/m^2) and extraction time (15mins). All these values were selected based on literature. The inputs variables applied were potash at high or positive level (0.0030Kg), potash at low or negative level (0.0020Kg) while sorghum floor at high or positive level (0.10Kg), sorghum at low or negative level(0.05Kg). The levels of inputs variables were selected and coded as positive (+) or high level and negative (-) or low levels.

Table 3.1: Factors and Coded Value

Level of Factors	Code	Input Variables (Kg)	
		X_1	X_2
Potash (-), Sorghum floor (-)	X_1-, X_2-	0.0020	0.05
Potash (+), Sorghum floor (-)	X_1+, X_2-	0.0030	0.05
Potash (-), Sorghum floor (+)	X_1-, X_2+	0.0020	0.10
Potash (+), Sorghum floor (+)	X_1+, X_2+	0.0030	0.10

Table 3.2 shows how treatment combinations between main effects and interactions are formed

Table 3.2: Layout of Treatment Combinations in 2^2 Factorial Design.

RUNS	MAIN EFFECT			REPLICATION			
	X_1	X_2	X_{12}	1	2	3	4
1	-	-	+				
2	+	-	-				
3	-	+	-				
4	+	+	+				

X_1 = Potash, X_2 = Sorghum Floor, Negative or low level(-), Positive or High level.(+)

A Total number of 4 runs of the experiments were conducted and replicated four times having 16 runs of experiment. 4Kg of groundnut was used for every experimental sample.

Additives used are of positive and negative levels. Potash levels are (+) = 0.0030Kg, (-) = 0.0020Kg, while sorghum floor levels are (+) = 0.10Kg, (-) = 0.05Kg.

CHAPTER FOUR

4.0. RESULTS

4.1 Presentation of Results

Table 4.1 Shows the average yields of groundnut oil obtained using potash and sorghum floor as additives at various levels. The results, showed the quantity of additives per unit weight of groundnut to be added for maximum yield, it also show that there were differences in yields of groundnut oil when additives were added at various levels.

Table 4.1: Average Yield of Groundnut Oil obtained Using Additives at Various Levels.

Treatment	Additive Levels (kg)		Oil Yield (Cl)				
			1	2	3	4	Mean ± SD
Control	C*	0	37.5	40	37.5	35	37.5 ± 2.05
Potash	X_1+	0.0030	80	75	70	75	75 ± 4.09
	X_1-	0.0020	72	64	60	58	63.5 ± 6.19
Sorghum floor	X_2+	0.10	48	65	57	60	57.5 ± 7.14
	X_2-	0.05	56	60	52	40	52 ± 8.64
PS(+,+)	X_1+, X_2+	0.0030, 0.10	169	138	170	143	155 ± 16.9
PS(-,-)	X_1-, X_2-	0.0020, 0.05	155	110	140	110	128.8 ± 22.5
PS(+,-)	X_1+, X_2-	0.0030, 0.05	164	121	166	129	145 ± 23.6
PS(-,+)	X_1-, X_2+	0.0020, 0.10	148	071	140	066	106.3 ± 43.8

C* = Control Experiment, X_1 = Potash, X_2 = Sorghum Floor. Negative or low level (-), Positive or High level (+), PS (combination of X_1, X_2)

4.2. Statistical Analysis

Statistical software (SPSS 15.0) was employed for this analysis mean, standard deviation and the summary of the ANOVA was shown in Table 4.2 and those in Appendix 1II. Analysis was based on the data provided on Table 4.1 above.

Table 4.2. Summary of Analysis of Variance (ANOVA)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	$F_{calculated}$	Sig.
potash	4225.000	1	4225.000	5.199	.042
sorghum	156.250	1	156.250	.192	.669
potash * sorghum	1056.250	1	1056.250	1.300	.276
Error	9751.500	12	812.625		
Total	301414.000	16			

Level of Significance = 0.05

Criteria region: f > 4.75

F = 5.199 = MS Potash / MS Error

Assumption test: Was the combinations of Additives effective?

Potash was the only result that shows significant variation among means. With this data, sorghum floor and combinations of sorghum floor and potash appear not to be effective because it was not significant ($\alpha = 0.05$).

Table 4.3 shows the results of quality assessment of groundnut oil using sensory parameters of human being. The unheated and heated oil were compared, observed and result was recorded, using six (6) assessors. The results were used to determine if additives has effect on colour, taste, odour and texture of oil extracted from groundnut.

Table 4.3: Sensory Parameter of Groundnut oil.

Additive Levels (Kg)		Colour		Taste		Odour		Texture	
		U	H	U	H	U	H	U	H
C*	0	Yellow	Light-yellow	Tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_1+	0.0030	White-fume yellow	Yellow	Tasteless	Tasteless	Not offensive	Not offecnsiv	Smooth	Smooth
X_1-	0.0020	White-fume yellow	Yellow	Tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_2+	0.10	Light yellow	Yellow	Tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_2-	0.05	Light yellow	Yellow	Tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_1+, X_2+	0.0030, 0.10	White-fume yellow	Light yellow-brown	Creamy, tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_1-, X_2-	0.0020, 0.05	White-fume yellow	Light yellow-brown	Creamy, tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_1+, X_2-	0.0030, 0.05	White-fume yellow	Light yellow-brown	Creamy, tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth
X_1-, X_2+	0.0020, 0.10	White-fume yellow	Light yellow-brown	Creamy, tasteless	Tasteless	Not offensive	Not offensive	Smooth	Smooth

U= Unheated, H = Heated

CHAPTER FIVE

5.0 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion of Results

The results obtained in Table 4.1 showed that oil extraction with potash and sorghum floor has highest average yield compared to when other additives such as onions, ginger, pepper were used. Research work has been carried out on effect of pepper and onion as additives on groundnut oil expression (Chukwu and Bature, 2010). The average yield of oil obtained when pepper was added at low and high levels ranges between 31Ml and 35Ml per 100g of groundnut respectively, while that of onion at low and high levels ranges between 26.6Ml and 20.3Ml per100g of groundnut respectively, and for the control experiment was 22.3Ml per 100g of groundnut. The values are extremely low compared to the oil yield shown in Table 4.1 using potash and sorghum floor as additives.

The large variation in oil yield as compared to past research work could be attributed to the type of additives selected and also to the choice of oil extraction method used.

5.1.1 Effects of Potash as Additive

The results in Table 4.1 obtained from the experiment when the following operational conditions are kept constant, moisture content of 10%, temperature of 25^0C applied pressure of $1,500KN/m^2$, expression time of 15 minutes show that there were significant differences in the average yield of groundnut oil extraction when additives are added. When 0.0020Kg (Low level) of potash was added to 4Kg of groundnut paste, the average yield was 63.5Cl; it was 75Cl for 0.0030Kg (High level) of potash, This shows that the oil yields from groundnut increased by 26.0, 37.5, indicating that oil yield is positively sensitive to increased quantities of potash added.

5.1.2 Effect of Sorghum floor as Additive

The result in Table 4.1 obtained from the analysis when moisture content, applied pressure, expression time and temperature were kept constant, 10%, 1.500KN/m^2, 15minutes and 25^{0}C respectively. The average yield when 0.05Kg (low level) of sorghum floor was added, the yield of oil was 52Cl and at 0.10Kg (high level), the yield of 57.5Cl of groundnut oil from 4Kg of groundnut paste. This indicates that oil yields from groundnut increased by 14.5, 20.0, showing that oil yields is positively sensitive to increased quantities of sorghum floor but not to the levels of potash.

5.1.3 Effect of Potash-Sorghum floor Combinations

The results in Table 4.2b (Appendix III) show the yield at the various levels of combinations of potash and sorghum floor. When potash and sorghum floor at their low levels were added to 4Kg of groundnut paste, the oil yield was 128.8Cl with standard deviation of 22.5. Potash and sorghum floor at their high levels yielded 155Cl with standard deviation of 16.9. For potash and sorghum at low and high level, the results of the oil yield was 106.3 with standard deviation of 43.8 and for potash and sorghum floor at high and low levels, the yield was 145cl with 23.0 standard deviation.

The result in Table 4.1 was further analyzed statistically. The analysis of variance (ANOVA) (Table 4.2 and in Appendix III). From the ANOVA table, F tabulated at 0.05 level of significance for degrees of freedom 1 and 12 is 4.75, for $\mathbf{F_{calculated}}$ = 5.199 = MS Potash / MS Error and the assumption tests was that, is additives effective? , secondly is the combinations of Additives effective?

From the results, Potash was the only result that shows significant increase in oil yield among means. Sorghum floor and combinations of sorghum and potash do not show any significant increase in oil yield ($\alpha = 0.05$).

5.1.4 Effect of Additives on Colour, Odour, Taste and Texture of Groundnut Oil.

From Table 4.3, the results indicated that additives of potash and sorghum floor have little or no effect on colour, odour, taste, and texture of groundnut oil. Both heated and unheated oil used for colour falls within the range of groundnut oil colour of clear, light yellow-brown. The odour was not offensive because it takes the peanut odour which is a natural odour of groundnut. The oil was tasteless and smooth in texture when rubbed between the fingers.

5.2 Conclusions

The following conclusions were made, based on the results of the analysis potash as an additive significantly influenced oil yield when added to groundnut. This implies that potash increase oil yield of groundnut cake. Secondly, the effect of sorghum floor is not significant and that of combination of potash and sorghum floor does not significantly increase oil yield.

In view of the above, potash has the best and highest yield and is effect was significant compared to sorghum floor, combination of potash and sorghum floor and the control experiment. The research established the suitability of potash as good additives to increase oil yield from groundnut.

The following were also deduced from the result obtained from the experiment, that increase in the oil yield extraction with additives has demonstrated the positive effect of using additive on the yield of groundnut oil extraction.

a. The addition of potash and sorghum floor has a positive effect on the yield of oil from groundnut paste. Higher oil yield is recorded when potash at low level and sorghum floor (X_2-), of (0.0020, 0.05Kg) level were added to 4Kg of groundnut with average oil yield of 38.0Cl. When 0.0020Kg (Low level) of potash was added to 4Kg of groundnut paste, the average yield was 63.5Cl; it was 75Cl for 0.0030Kg (High level) of potash, This shows that the oil yields from groundnut increased by 26.0, 37.5, indicating that oil yield is positively sensitive to increased quantities of potash added.

b. The average yield when 0.05Kg (low level) of sorghum floor was added, the yield of oil was 52Cl and at 0.10Kg (high level), the yield of 57.5Cl of groundnut oil from 4Kg of groundnut paste. This indicates that oil yields from groundnut increased by 14.5, 20.0, showing that oil yields is positively sensitive to increased quantities of sorghum floor but not to the levels of potash.

c. Combining potash and sorghum floor appear to offer beneficial effects in oil yield and residue after extraction. Potash increase quantity of oil yield while sorghum floor increase quantity of residue (fried cake).

d. Additives of potash and sorghm floor have no effect on colour, taste, odour and texture of groundnut oil.

5.3. Recommendations

This project work was based on some selected natural products (additives) to be added to groundnut to increase its poor oil yield. The additives are limited to potash and sorghum floor without a prior knowledge of their average oil yield and its significance effect, until after the research. I therefore recommend that further experiment should be carried out on the following areas:

1. Further test on the chemical composition of the oil extracted by the additives particularly those with high yield.
2. Experiment should be conducted on the shelf life of the extracted oil and its rancidity.
3. Studies should also look at the suitability of the residual cake for livestock and poultry feeds.
4. Finally, the result of studies of this nature should be made readily available to local processors so that the findings will not be for the purpose of academic excellence.

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APPENDIX I

RESULT OF THE ORAL INTERVIEW WITH THE GROUNDNUT PROCESSORS

S/No	Questions	Responses	% of respondent
1.	What crops do you make oil from?	Groundnut, melon, palm fruit,	20
		Groundnut, melon	50
		Groundnut, melon, coconut and palm kernel	10
		Groundnut, melon, Shea butter and palm fruit	20
2.	Which crop do you use most?	Groundnut	100
3.	Is the oil from groundnut good for cooking and frying?	Yes	100
4.	What type of groundnut do you use?	Ekochi (small sized red skin)	80
		Kampala (white and red)	20
5.	Which type gives the high yield of oil	Ekochi	90
		Kampala	10
6	How do you prepare groundnut for oil making	Cleaning, drying, roasting, skinning, mixing, pressing	100
7.	When do you roast and why?	After cleaning, for easy removal of skin to get more oil.	100
8.	Do you soak the groundnut in water before roasting?	Yes	10
		No	90
9.	How do you know that groundnut is dried for roasting	At the point when skin peels when robbed between palms.	90
		By breaking the nuts into two	10
10.	Do you add anything to the groundnut	Yes	90
		No	10
11.	What do you add?	Potash, sorghum floor, onion, pepper	10
		Potash and sorghum floor	40
		Potash, sorghum floor, pepper	40
		Nothing	10
12.	Why do you add these?	To extract more oil	10
		To improve taste and flavour	75
		Nil	5
13	Do you combine potash and sorghum floor?	Yes	90
		No	10
14	At what stage do you add potash and sorghum floor?	After milling	100
15	To what quantity of potash, sorghum floor did you add?	10kg of groundnut, 0.016kg of potash and 0.08kg of sorghum floor.	70
		10kg of groundnut, 0.024kg of potash and 0.192kg of sorghum floor.	30
16	How many bottles of oil do you get from the quantity added?	2 – 3 litres of oil	30
		4 – 5 litres of oil	70
17	What quantity of water and salt did you add to number 15	₦10 salt and 2.5 litres of water	80
		N 20 salt and 1.5 litres of water	20
18	How long does extraction time takes?	10 – 20mintes	20
		30 – 45mintes and above	80
19	What method do you use to extract oil	Hand pressing	70
		Mechanical extraction	30
20	When do you stop the extraction?	When oil cease coming ot from the paste.	50
		After spending 15 minutes of extraction	50

From the results of oral interview (Appendix I) administered to local processors, 80% of them use the small sized seeds characterized by red skin called "Ekochi" for optimum oil yield. The processors roast the seeds for easy skinning and dissolution rate of the oil in preparation for the extraction. The percentage of those that use additives is 85% while 70% reported that the additives are used for taste and flavour improvement. Only 10% used it for high oil yield and the remaining 5% said they were just using it. Quantity of sorghum floor and potash used are very minimal. 80 percent of the processors expressed oil over the period of 30-45minutes by hand pressing. 60% usually add 1.5-2.5 Litres of warm water during extraction, 90 percent obtained 4 – 4.5 Litres from 10Kg of groundnut. However, there has been no scientific investigation on the effect of these additives on the quantity and rate of oil extracted.

APPENDIX II

The Value of Mean and Standard Deviation in Table 4.1

	X	*(X-37.5)*	*$(X-37.5)^2$*	*SD*
1	37.5	37.5 – 37.5	0	
	40	40 – 37.5	6.25	
	37.5	37.5 – 37.5	0	
	35	35-37.5	6.25	
			12.5/3= √4.2	
	M= 150/4= 37.5			**2.05**
2	**X**	**(X – 75)**	**$(X-75)^2$**	**SD**
	80	80 – 75	25	
	75	75 – 75	0	
	70	70 – 75	25	
	75	75 - 75	0	
			50/3 = √16.7	
	M = 300/4= 75			**4.09**
3	**X**	**(X- 63.5)**	**$(X-63.5)^2$**	**SD**
	72	72 – 63.5	72.25	
	64	64– 63.5	0.25	
	60	60 – 63.5	12.25	
	58	58 - 63.5	30.25	
			115/3 = √38.3	
	M = 254/4= 63.5			**6.19**
4	**X**	**(X- 57.5)**	**$(X-57.5)^2$**	**SD**
	48	48 - 57.5	90.25	
	65	65 - 57.5	56.25	
	57	57- 57.5	0.25	
	60	60- 57.5	6.25	
			153/3 = √51	
	M = 230/4= 57.5			**7.14**
5	**X**	**(X- 52)**	**$(X-52)^2$**	**SD**
	56	56 – 52	16	
	60	60 – 52	64	
	52	52 – 52	0	
	40	40 - 52	144	
			224/3 = √74.7	
	M = 208/4= 52			**8.64**
6	**X**	**(X- 155)**	**$(X-155)^2$**	**SD**
	169	169 – 155	196	
	138	138 – 155	289	
	170	170 – 155	225	
	143	143 - 155	144	

			854/3 = √286.7	
	M = 620/4= 155			**16.9**
7	**X**	**(X-128.8)**	**(X – 128.8)^2**	**SD**
	155	155 – 128.8	686.4	
	110	110 – 128.8	353.4	
	140	140 – 128.8	125.4	
	110	110 – 128.8	353.4	
			15186/3 = √506.2	
	M = 515/4= 128.8			**22.5**
8	**X**	**(X- 145)**	**(X – 145)^2**	**SD**
	164	164 - 145	361	
	121	121 - 145	576	
	166	166 - 145	441	
	129	129 - 145	256	
			1634/3 = √554.7	
	M = 580/4= 145			**23.6**
9	**X**	**(X- 106.3)**	**(X – 106.3)^2**	**SD**
	148	148 – 106.3	1738.9	
	071	071- 106.3	1246.1	
	140	140 – 106.3	1135.7	
	066	066 – 106.3	1624.1	
			5744.8/3 = √1914.9	
	M = 112.8/4= 106.3			**43.8**

APPENDIX III

Univariate Analysis of Variance

[DataSet0]

Table 4.2a:Between-Subjects Factors

Factor Levels		Value Label	N
Potash Additive	1	0.002	8
	2	0.003	8
sorghum Additive	1	0.05	8
	2	0.1	8

Univariate Analysis of Variance

Table 4.2b: Descriptive Statistics

Potash Additive	sorghum Additive	Mean	Std. Deviation	N
0.002	0.05	128.75	22.500	4
	0.1	106.25	43.760	4
	Total	117.50	34.384	8
0.003	0.05	145.00	23.338	4
	0.1	155.00	16.872	4
	Total	150.00	19.596	8
Total	0.05	136.88	22.931	8
	0.1	130.63	40.270	8
	Total	133.75	31.821	16

Table 4.2c: Tests of Between-Subjects Effects

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Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5437.500(a)	3	1812.500	2.230	.137	.358
Intercept	286225.000	1	286225.000	352.223	.000	.967
potash	4225.000	1	4225.000	5.199	.042	.302
sorghum	156.250	1	156.250	.192	.669	.016
potash * sorghum	1056.250	1	1056.250	1.300	.276	.098
Error	9751.500	12	812.625			
Total	301414.000	16				
Corrected Total	15189.000	15				

a R Squared = .358 (Adjusted R Squared = .197)

Estimated Marginal Means

1. Potash Additive

Table 4.2d: Estimates of Potash

	Mean	Std. Error	95% Confidence Interval	
Potash Additive	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.002	117.500	10.079	95.541	139.459
0.003	150.000	10.079	128.041	171.959

Table 4.2e: Pairwise Comparisons

		Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
(I) Potash Additive	(J) Potash Additive	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
0.002	0.003	-32.500(*)	14.253	.042	-63.555	-1.445
0.003	0.002	32.500(*)	14.253	.042	1.445	63.555

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 4.2f: Univariate Tests

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	4225.000	1	4225.000	5.199	.042	.302
Error	9751.500	12	812.625			

The F tests the effect of Potash Additive. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

2. Sorghum Additive

Table 4.2g: Estimates of Sorghum Floor

sorghum Additive	Mean	Std. Error	95% Confidence Interval	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.05	136.875	10.079	114.916	158.834
0.1	130.625	10.079	108.666	152.584

Table 4.2h: Pairwise Comparisons

		Mean Difference (I-J)	Std. Error	Sig.(a)	95% Confidence Interval for Difference(a)	
(I) sorghum Additive	(J) sorghum Additive	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bou
0.05	0.1	6.250	14.253	.669	-24.805	37.305
0.1	0.05	-6.250	14.253	.669	-37.305	24.805

Based on estimated marginal means

a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 4.2i: Univariate Tests

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	156.250	1	156.250	.192	.669	.016
Error	9751.500	12	812.625			

The F tests the effect of sorghum Additive. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Table 4.2j: Potash Additive * sorghum Additive

		Mean	Std. Error	95% Confidence Interval	
Potash Additive	sorghum Additive	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.002	0.05	128.750	14.253	97.695	159.805
	0.1	106.250	14.253	75.195	137.305
0.003	0.05	145.000	14.253	113.945	176.055
	0.1	155.000	14.253	123.945	186.055

Table 4.2k: Grand Mean

Mean	Std. Error	95% Confidence Interval	
Lower Bound	Upper Bound	Lower Bound	Upper Bound
133.750	7.127	118.222	149.278