DESIGN, FABRICATION AND EVALUATION OF A MANUALLY OPERATED HYDRAULIC OIL EXTRACTOR FOR GROUNDNUT

M. TECH THESIS

BY

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CERTIFICATION

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DEDICATION

This project work is dedicated to God Almighty the giver of life and wisdom.

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ABSTRACT

Functional processing of agricultural produce requires easily operated equipment. A manually operated hydraulic press was developed for extracting oil from decorticated groundnut seeds. It is made up of a piston, cylinder, collector, hydraulic jack and frame. The total weight of the press is 32.7 kg with height and breath of 72.4 and 30.9 cm respectively. The pressing by a 3 ton hydraulic jack. The components of the machine were fabricated using locally available materials such as mild and stainless steel, which are sourced from the local market. The extractor unit was tested using press cage with pore sizes of 3, 4 and 5 mm and cage diameter of 5.2, 7.9 and 10 cm. Whole and ground groundnut seeds were used for the machine testing. The Kampala variety (*Sam nut-10*) of groundnut was used for the evaluation of the machine performance. Oil yield, extraction efficiency and machine capacity of the machine were evaluated. The physco-chemical properties of the groundnut oil extracted were determined.

Results obtained showed that pore size of 3 mm gave the least oil yields of 21.2 and 23.6 %, for whole and ground seed at cage diameters of 7.9 cm. the pore size 4 mm gave an oil yield of 23.0 and 26.9 % while that of 5 mm gave 23.0 and 26.2 %; for whole and ground seed respectively with no significant difference. Similar trend was observed for the extraction efficiency and machine capacity where the values increased sharply as pore size increased from 3 to 4 mm but decreased with a further increase from 4 to 5 mm.

The increase in cage diameter from 7.9 to 10 cm resulted in a decrease in oil yields from 23.02 and 26.87 % to 21.74 and 24.08; for whole and ground sample respectively. Maximum extraction efficiency of 79.02 and 84.22 % was recorded for diameter 5.2 cm at pore size of 4 mm for whole and ground seed respectively, while cage diameter of 10 cm gave the lowest value of 39.80 and 44.09 % for whole and ground seeds respectively. The highest machine capacity of 0.978; 1.084 kg/hr (whole and ground seeds respectively) was obtained at cage diameter of 10 cm. Analysis of variance showed that cage diameter made a significant effect ($P \leq 0.05$) on all the parameters evaluated. For all pore size and cage diameter except cage diameter of 7.9 cm, material type (whole and ground seed) do not have significance effect on oil yield, extraction efficiency and machine capacity.

Regression analysis was conducted using stepwise regression Models of the form

$Y = ax^2 + bx + c$ were best fitted to predict the oil yield (Y_1), extraction efficiency(Y_2) and machine capacity (Y_3) with pore size (X_1) cage diameter and (X_2) as the independent variables.

The combined effect of pore size and cage diameter for oil yield, extraction efficiency and machine capacity showed that, pore size has a positive relationship with the machine performance and negative relationship cage diameter. While machine capacity accounts for 29 % of the variation observed in machine capacity for whole seed and 37 % for ground seed.

CHAPTER ONE

INTRODUCTION

Oil can be extracted from many raw materials, but not all extractable oils are edible. Some contain poisons and unpleasant flavors (Frank, 1998). Edible oils are derived from animals and plants. Those from plant sources are of important interest in various food industries. Edible oils from plants are classified as vegetable oils. They provide characteristic flavors and textures to foods as integral diet components (Odoemelam, 2005). The largest sources of vegetable oils are annual plants, which include soybeans, corn, cottonseed, groundnut, sunflower, rapeseed, melon and sesame seed (Frank, 1998; O'Brien 1998). Other sources accre oil-bearing perennial plants include olive, coconut, shear, cashew and palm (Atiku *et. al*., 2004). In Nigeria, the major sources of edible oils are groundnut, also called peanut (*Arachis hypogaea L.*) and oil palm (*Elaeis guineensis*). Groundnut, an oil bearing seed, is a major raw material for several industries in Nigeria, especially in the food processing and poultry sectors. It is grown mainly in Kano, Anambra, Plateau, Taraba, Sokoto, Bauchi, and Benue States. These oils are used mainly as cooking oils and for the production of soap, margarine, and cosmetics (Ong *et al*., 1995).

There is a universal demand for vegetable oil due to its increasing domestic and industrial uses. As an unprocessed commodity, it was a major foreign exchange-earning cash crop in Nigeria in 1950s and 1960s. Peanuts are among the oldest oil crops in Nigeria and are mostly consumed as snack, after roasting or in fried form and vegetable oil (Bansal *et al*., 1993; Jambaunathan *et al*., 1993). The residue (cake) left after the extraction of its oil is used for making groundnut cakes and animal feed (Akubuilo, 1978; Olorunisola, 1999). Vegetable oil has made an important contribution to the diet in many countries, serving as good source of protein, lipid and fatty acids for human nutrition including the repair of worn out tissues, new cells formation as well as a useful source of energy (Gaydou *et al*., 1983; Grosso and Guzman, 1995; Grosso *et al*., 1999). Oil content of vegetable oil-bearing materials varies between 3 and 70 % of the total weight of the seed, nut, kernel or fruit (Bachman, 2004). The rate of vegetable oil consumption is increasing compared with animal fat due to its health implication (Akinoso, 2006).

The industry is thus challenged to produce high quality oil products at reduced prices. Oil is usually extracted from oil-bearing seed by mechanical or solvent expression methods.

Mechanical expression by hydraulic or screw press is common in modern palm oil production. However, hydraulic press is commonly used by small scale processors because it is less capital-intensive in terms of initial and maintenance costs (Adeeko and Ajibola, 1990; Owolarafe *et al,* 2002). Hydraulic presses are available in different versions, but their efficiency seldom exceeds 70% (Badmus, 1991). Several attempts have been made toward improving the efficiency of the hydraulic press in Nigeria. Most of them have focused on optimization of process variables such as applied pressure, pressing temperature, and moisture conditioning of the fed samples (Fasina and Ajibola, 1989, Adeeko and Ajibola, 1990). And, recently cage diameter and cage wall pore size (Owolarafe *et al,* 2007). Improvement in the mechanical extraction equipment and techniques through proper conditioning can raise oil recovery from 73% to 80% for rapeseed and groundnut (peanut) and from 60% to 65% for cotton seeds (Pathak *et al.*, 1988)

1.1 Justification of the research

Manual operated equipment are very easy to operate in a remote, local area without any technicality or expensive power source. They are cheaper hence affordable to farmers in the local area. This will then make it readily available for small scale use.

1.2 Objectives of the Research

The objectives of this work are to;

(i) design and fabricate a manually operated hydraulic oil press,

(ii) evaluate the performance of the machine and

(iii) study the effect of the extractor parameters on the quality of oil produced

CHAPTER TWO
LITERATURE REVIEW

2.1 Economic Importance and Uses of Groundnut

Groundnut is one of the most widespread and potentially most important food legumes in the world (Morden *et al.*, 1982). The groundnut has been identified as one of the leguminous species with the greatest potential for both food and industrial purposes in the tropical regions of Africa (FAO, 1989).

All part of groundnut plant can be easily utilized. The vine with leave makes excellent high protein hay for ruminant livestock. The shells or pods can be used as feed for livestock, burned for fuel, made into particle-board and many other uses (Gerhard et al., 1989). The seeds can be used directly for food or crushed to produce oil and a high protein meal. Also, the whole seeds may also be boiling, broiled fried, salted, used for candies, or eaten raw. The seeds can be grinded to groundnut butter (FAO, 1989).

Peanuts have a variety of industrial end uses. Paint, varnish, lubricating oil, leather dressings, furniture polish, insecticides, are made from peanut oil. Soap is made from saponified oil, and many cosmetics contain peanut oil and its derivatives. The protein portion of the oil is used in the manufacture of some textile fibers.

Peanut shells are put to use in the manufacture of plastic, wall board, abrasives, and fuel. They are also used to make cellulose (used in rayon and paper) and mucilage (glue). Peanut plant tops are used to make hay. The protein cake (oil cake meal) residue from oil processing is used as animal feed and as a soil fertilizer. Peanut can also be used like other legumes and grains to make a lactose free milk-like beverage. Groundnut butter has been combined with different flavoring and other components to make ice cream like products (Mcwatters and Cherry, 1982).

Like other oilseed, groundnut seed deteriorate in storage. Although loss of viability is of little consequence in seed to be processed, the effect on seed oil and its constituent is important. Major loss of oil quality in terms of color, free fatty acids, iodine and other valves in oil from seed kept in unsuitable or prolonged storage is usually experienced. The reason given for this deterioration is high moisture content, relative humidity and fungi infection. Therefore, rapid movement from producer to processing plant is essential if full benefit is to be obtained from oil seed production (Singh *et al.*, 1984).

2.2 Pre-pressing Operation

The extraction of oil from oil bearing seeds involves some or a number of post harvest procedures, depending on the type of seed to be processed and the scale of operations. These include shelling, cleaning, decortication, size reduction and conditioning. These processes are as important as they can have strong effects on oil quality (List *et al*, 1981).

2.2.1 Seed Cleaning

Seed is cleaned to remove trash, dirt, sand and metal pieces, before it is weighed and subjected to further processing. This is to ensure accurate control of oil and cake yield. The presence of sand in the processed seed can result in high wear on critical components of the machines used. Using clean oil seed will increase the time that the expellers can be used before replacement parts are needed. Efficient removal of foreign material from seed will also increase the pressing efficiency during oil extraction (Okunade, 1995). Cleaning also involves the passing of the oil seeds through a magnetic separator to remove iron and steel objects and separate seeds from foreign particles.

2.2.2 Shelling/ Decorticating/ Dehulling

Shelling is the removal of the outer shell of the oilseed. After raw material has been cleaned, it may be necessary to remove its outer seed coat. There are a couple of reasons for doing this. The seed coat does not contain oil, so including it makes extraction less efficient. Also, the next step will be grinding to reduce particle size, and any tough seed coats interfere with this process. Some seeds, such as peanuts, can be shelled by hand. Some others, such as sunflower seeds, are usually hulled with machines. This is usually done to provide high quality edible oil and to reduce the fibre content of the meal. Some seeds such as palm kernel cannot be processed unless they are shelled. However, some seeds such as groundnut and sunflower can be processed without decorticating, but to ensure maximum oil extraction, a proportion of the hull is removed by decorticating it before the oil extraction process (Head *et al*, 1993a).

2.2.3 Size Reduction and Flaking

The oil in an oil-bearing seed is trapped inside the seed cell walls. Reddy and Bohle, (1993) reported that efficient extraction of oil from oil seeds requires reduction of the oilseed size to effect the flow of oil. Othmar and Agarwall (1955) reported that the inability to extract oil from a whole soybean grain and a half soybean grain clearly indicated that cell walls must be broken by flaking operations to allow the oil to be removed from the otherwise impervious cells. During flaking or seed size reduction, the oil cell walls of the seed is broken down or weakened to the point where the oil is available to be expelled.

Adeeko and Ajibola (1990) showed that oil yields from coarsely ground groundnuts were higher than those from finely ground samples. This is because FFA formation in a seed starts with the destruction of cells (Ohlsan, 1976). And, the acid formation in a seed is also limited to the cells broken during size reduction. This affects the quality and quantity of oil produced. Since the purpose of size reduction is to expose a greater area of the oil bearing cells, it is recommended that size reduction in oil seeds for oil extraction purpose should be limited to 50-70% of the seed. The size and hardness of the nut will determine the number of stages for the flaking operation. Without adequate flaking, the oil yield would be reduced. The first step in full expression of oil seeds is to thoroughly and completely roll oil seed meals, to uniformly rupture the greatest number of oil cells and to provide homogenous flake. Flaking soybean prior to expression give a higher oil yield than grinding (Khan and Hanna, 1984).

2.2.4 Conditioning

The preparation of oil bearing raw material prior to extraction is in all case very important as it transform the raw material into a stage that will give a high yield of good quality oil and meal. Oilseed generally contains high quality of protein with its oil trapped within the cell walls. Some parameters are used to effect the transformation, which subsequently ease the flow of oil from the seed. The parameter when manipulated brings about changes in the seed which will result in the regulation of the protein, thereby making the mass more permeable to oil flow and the coalescence of small droplets of oil present in the seed into large drops with reduced viscosity, such that it can flow easily from the seed. These parameters are oil point and oil point pressure, moisture content, temperature (heating) and pressure. Fasina and Ajibola, (1989a) studied oil expression from canophor nut and concluded that the amount of heat treatment given to samples, the moisture content after heating and the applied pressure were the most significant factors affecting the yield of oil expressed mechanically. Sukumaran and Singh (1983) indicated that moisture content, temperature, period of pre-heating and the applied pressure were some of the parameters that significantly affect oil expression.

2.3 Parameters affecting Oil Extraction

There are various factors that affect the efficiency of oil extracted Such factors includes heat treatment and conditioning, Oil point and oil point pressure, moisture content, applied pressure, pressing time, pore size, diameter of cage, processing condition and so on (Owolarafe *et al*, 2007, Fasina and Ajibola, 1989b, Sukumaran and Singh, 1983)

2.3.1 Heat Treatment and Conditioning

Tunde-Akintunde *et al* (2001) reported that when a large surface area is exposed to heat there will be moisture adjustment, protein coagulation, and reduction of viscosity of oil, which causes rupturing of the oil bearing cells leading to very low oil point pressure. Also, a high temperature roasting and long roasting time may have negative effects on quality of oil expressed and the cake residue. Peterson *et al* (1982) expressed oil from oil seeds using expeller incorporated with pre-heater auger that supplies heat to the oilseeds, he found that oil expression efficiency increased with increasing oilseeds heat to the oilseeds temperature and that the best condition for oil seed expression ranged from 77°C to 105°C.

Khan and Hanna (1984) experimented on soybean oil expression at different temperature, ranging between 22 to 60°C preheat temperature, indicated that changes in temperature significantly affects the oil yield. Fasina and Ajibola, (1989a) made a comparison of oil yield from roasted and unroasted samples of conophor nut and showed that the oil yields obtained from unroasted and sample were lower than those from roasted samples indicating the necessity for adequate heat treatment. It has been reported that heat conditioning of low oil content sunflower increases oil yield from 17.4 to 19.61 per 100 kg seed (Head *et al*, 1993b). Heat treatment from the forgoing is important in oilseed processing.

2.3.2 Oil Point and Oil Point Pressure

Oil-point pressure is the pressure at which oil exclude from interior of the seed to fill inter-particle void and wet their surfaces (Ajibola *et al.*, 2002 and Sukumaran and Singh, 1989). The effective pressure to be applied to an oil seed for the oil bearing cells to start discharging their contents is determined by first identifying its oil point pressure. (Ogunsina *et al.*, 2008). In mechanical oil expression, before oil can be release from the press mass, it must first come out of the interior of the individual seed to their surfaces and fill the inter-particle voids; when the inter –particle voids are filled, there is a build up of pore pressure leading to the development of pressure gradient in the voids. As a result oil flows through the porous median and is finally expressed through the porous retaining envelope (Okunade, 1995). Ogunsina *et al.* (2008) showed that the oil point pressure reduces with increase in heating temperature and heating time at all moisture levels. This is due to loss in moisture during heating of oil bearing cells creating a void which serves as migratory space for the contents of the oil bearing cells as heating continues (Adeeko and Ajibola, 1990).

2.3.3 Moisture Content

Addition of water during conditioning of raw material (oilseeds) enhances the rupture of the cell wall and the liberation of oil. Fasina and Ajibola, (1989b) in their experiment on melon seed found that oil yield during oil expression increases with increase in moisture content. The highest oil yield of 41% was obtained at an expression pressure of 15Mpa, when conditioned from initial moisture content of 9% to 12% (wet basis). This yield corresponds to an expression efficiency of 80%.

In the mechanical expression of oil from conophor nut, Fasina and Ajibola, (1989a) obtained a trend in which the oil yield increase with increase in moisture content up to level of 10% and a further increase in the moisture content led to a decrease in oil yield. Reddy and Bohle (1993) in the mechanical expression of oil from mustard seeds showed that increasing the moisture content of the seeds from 8 to 16% resulted in a dramatic drop in total oil recovery from 54.7% to 4.4%. Sukumaran and Singh (1983) found that with increase in moisture content, pressure required to release oil from the oil containing cellular structure of rapeseed also increased.

The effect of moisture level on oil yield can be related to mucilage development on oil cells (Vaughan, 1970). It is believed that at moisture level above the optimum range, there is swelling of the mucilage which in turn produces a cushioning effect on the seed. The swelled up mucilage can be an impediment to oil flow during expression while the cushioning effect on the seed reduces the rupturing of the particles and internal tissues during pressure application.

Singh *et al* (1984) worked with sunflower seeds and developed a relationship between moisture content of seeds and the efficiency of expressing oil from seed and concluded that moisture content of sunflower seeds is the most significant factor affecting the expression of oil from the seed. A moisture content of 6% (wet basis) was found by the group to be optimum for expression of oil from peanut and sunflower seeds.

2.3.4 Applied Pressure

Pressure is applied to oilseed to release trapped oil from the cellular structure of the oil seed. Fasina and Ajibola (1989b) reported that applied pressure is one of the important factors affecting the yield of oil expressed mechanically. Ward (1976) stated that increasing the pressure applied on oil sample during screw press tend to eventually seal the capillaries through which oil is exposed, thereby hindering the flow of oil from the sample.

Sukumaran *et al* (1985) studied the influence of internal pressure on the performance of screw expeller in oil expression from oil seeds (peanut) and observed that decrease in internal pressure initially led to a higher oil extraction rate when the pressure was dropped 20% of the maximum of 45Mpa. The oil extraction rate showed a further increase and then a decrease. He also observed that the meal oil content showed a continuously increasing trend with decreasing screw pressure for up to a pressure drop of approximately 40% of the maximum. Adeeko and Ajibola (1990) also reported that oil yield increased with pressure increase of up to 20 Mpa applied for 10 minutes beyond which the yield either leveled up or decreased.

Adeeko and Ajibola (1990) in their experiments on oil production from groundnut found that oil yield increased with increasing pressure for the greater part of the process. Kormend (1984) showed that in expressing apple juice, the pressing time required for any percentage yield of fruit is proportional to the square of the initial thickness of the material.

2.3.5 Pressing Time

Khan and Hanna (1984) studied the effect of duration of pressing on oil yield. They expressed oil at duration of 4 - 6 minutes from soybean. They concluded that increase in pressing time, increases the oil yield in certain limits. Prolonged time did not significantly affect the resultant oil yield and should therefore be terminated at a maximum of 10 minutes of pressing to save time and maximize energy consumption in order to reduce cost of production.

2.3.6 Pore Size and Diameter of Cage

Owolarafe *et al* (2007) reported that pore size and cage diameter of hydraulic press are one of the important factors affecting the efficiency of oil extraction. Oil yield was observed to increase with increase in pore size from 4 to 6 mm. but decreases as pore size increases from 6 to 10 mm. This was attributed to the fact that the larger the pore the less restriction to flow. Similarly the cage diameter of the press enhances the release of oil from oil bearing seeds (Owolarafe *et al.*, 2007). They reported that oil yield increases with increase in cage diameter from 80 to 120 mm and stated that with increase in cage diameter there is more material in the cage and hence more oil is expected. However, increasing the cage diameter from 120 to 150 mm reduce the quantity of oil obtained. Singh and Singh (1991) also reported similar findings for rapeseed.

2.3.7 Processing Condition

Vegetable oil constitutes a major component of daily diet consumption and its being considered on the basis of functionality, economy, and acceptability (Anyasor *et al.*, 2009). High iodine value denotes higher degree of unsaturation of the oil caused by the extraction of oxidation and degree of heat treatment during oil processing (Kirk and Sawyer, 1991). Increase in oil yield with sterilization time is expected since sterilization is a heat rendering and moisture absorption process which achieves the objectives of lowering the viscosity of oil as well as coagulation of protein. This tends to facilitate oil flow (Babatunde *et al.*, 1988). According to study carried out by Owolarafe, *et al.*, (2008) on the quality of crude palm oil expressed at different processing conditions, solid impurities at sterilization time of

30 mins are generally high. This impurity reduces as the time was increased to 60 min and again increases as sterilization time exceeds 90 mins. Oil containing high percentage solid impurity generally results in heavy sludge and loss of oil to the sludge (Owolarafe, 1999). He reported that solid impurity increase with pressure. At higher pressure, there is the tendency that more of the fine fibers are forced out of the mash causing the oil to look like slurry.

2.4 Oil Extraction Methods

Generally oilseeds extraction can be classified into:

(1) Traditional method namely aqueous extraction and hand pressing method

(2) Solvent extraction method

(3) Mechanical oil expression

2.4.1 Traditional Methods

The method employed depends on the oilseeds being processed. In Nigeria, oilseeds are processed traditionally through the use of aqueous extraction and hand pressing techniques. This involves the use of hot water flotation. It is probably the simplest and is applicable to almost all oilseeds. It is still been used in many rural areas in the developing countries. The hot water flotation involves placing the pre-prepared material (ground oilseed) in boiling water and simmered for several hours. On removing from the fire and cooling, the oil floats to the surface and is skimmed off. The skimmed oil is then heated in a pan to drive off the last traces of water. This helps in improving the storage quality of the oil. This method has generally low extraction efficiency and problems often occur with the formation of oil-water emulsion, which makes the final separation difficult (Adeyemo, 2000). All the processes are carried out manually. Figure 2.1 shows a flowchart of the process. The grinding is usually done either on stone or by pounding inside mortar. The press requires high human energy is time consuming and of maximum efficiency of 20% depending on the oil bearing seed and skill of people involved in the processing. According to Adeeko, (1988) low yield and poor quality of oil are usually obtained. According to Sharma (1977) major loss of oil quality is in terms of colour, free fatty acids, Iodine and other chemical values in oil from seed are due to unsuitable or prolonged storage. The reasons given to this deterioration are high moisture content, relative humidity and temperature and fungal infection.

Semi modernized method involves the use of manually operated presses. The process comprises of traditional and modern techniques. Some of the processes can be achieved by the use of machines, shelling by the use of mechanical sheller; grinding by the use of hammer mill or plate grinders. Kathry and Keith (1995) estimated the efficiency to be as high as 65%. However, high human power is required to operate the press.

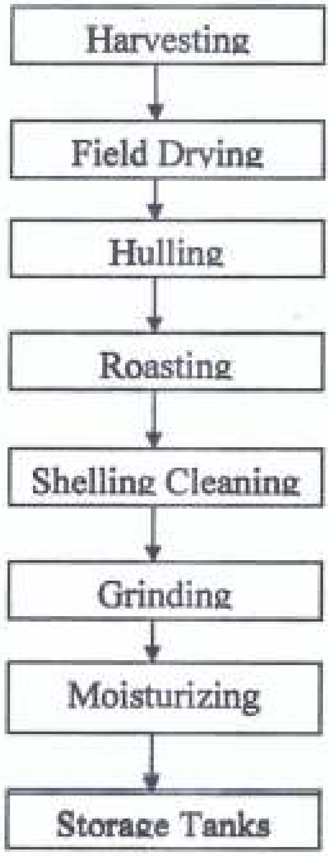

Figure 2.1: Flowchart for Aqueous Extraction/ Hand Pressing Process of Oilseed Extraction

Sources: Adeyemo, 2000.

2.4.2 Solvent Extraction

This is the extraction of oil from cellular structure of oil-bearing seed. The operational principle involves preparation of seed by cracking them into chips. These chips are warmed and passed through smooth flaking rolls. The flaking rolls flatten the chips into paper-thin, flat flakes. The thin flakes can then be treated with solvent, which dissolves or washes the oil out of them. Solvents that boil at fairly low temperatures (65°C) are used so that the solvent can be readily removed from both the oil and the flakes. Solvent extraction recovers almost all the oil, leaving only one percent or less oil in the flakes. Like pressing, solvent extraction can be done with equipment that processes the oilseed in batches, or with equipment that processes it continuously. A continuous extractor is not considered economically practical unless it processes at least 200 tons per day (Nathan, 1985). Batch solvent extraction is likely to be the appropriate method if you plan to process less than 200 tons of seed per day, but enough to yield oil in commercial quantities. A batch solvent extraction plant can be as simple as an enclosed steel tank with a false bottom made of screen or metal slats. The flakes are dropped into the tank, where they lie on the false bottom (Nathan, 1985).

The tank inlet is closed, and solvent is pumped in to flood the bed of flaked oilseed. The solvent is allowed to contact the seed for 10 to 20 minutes; then the drain valve at the bottom (under the false bottom) is opened to complete the extraction. After the final extract has been fully drained, steam is introduced into the bottom of the extractor. This evaporates the solvent out of the flakes. This combination of steam and solvent is piped as vapor into a condenser that contains water-cooled tubes. The solvent is lighter than water, so it is readily freed of water by standing in a tank from which water is decanted, or overflowed. The flakes now are nearly solvent free, but are wet from the steam treatment. They are conveyed out of the extractor to a steam-heated dryer to reduce the moisture to about 12 percent for best storage quality.

Most of the washes or miscallas are saved and reused on a later batch. However, fresh, oil-free solvent must be used for the final wash of a batch. And, the first oiliest miscella is pumped to a steam-heated, tubular evaporator, which boils most of the solvent out of the mixture, recovering solvent for reuse. The oil then goes to a vacuum stripper, where it is heated to about 100'C and steamed as it passes down through a series of steel baffles or a column of stoneware rings or saddles. The purpose is to expose every portion of the oil to steam, which is needed to remove the last 5 to 10 percent of the solvent from the oil.

Continuous extractors use conveyors inside vapor-tight housings. The conveyor may be an endless metal mesh belt or a series of sieve-bottom buckets attached to a traveling chain. Flaked seeds are conveyed continuously into the extractor through a vapor lock or seal which prevents solvent vapors from escaping out of the extractor into the flake conveyor (Nathan, 1985). The flakes are sprayed or wet with miscella as they enter the extractor, and receive several washes with successively more dilute (less oily) miscella. These miscellas drain down through the flakes and through the sieve bottom or belt into pans, which drain into pumps. The pumps transfer the miscella to the next state, from less oily to more oily flakes. In this continuous countercurrent, the oldest solvent miscella (the solvent miscella with the highest oil content), contacts the fresh incoming flakes. The final wash uses oil-free hexane. The flakes are then drained (10 to 15 minutes), and dropped from the belt or the basket into a spent-flake hopper. From here a mass-flow conveyor lifts the still solvent-wet flakes (containing 35 percent moisture) and delivers them into a desolventizer-toaster. This is a steam-jacketed vessel, usually a vertical set of kettles with gates that allow the flakes to fall from one kettle into the next below while being treated with direct steam. The lower kettles act as dryers to bring the moisture content down to proper levels. Air is drawn to cool the dried hot flakes, either in the lower part of the same vessel or in a separate meal cooler. As in the batch extractor system, the solvent vapors flow to a condenser with water-cooled tubes and the liquid solvent is separated from the water by decanting.

Extraction efficiencies using solvent extraction is well over 98% as estimated by Bargale (1997). Fasina (1988) reported the disadvantages of solvent extraction to include the following:

(1) it is relatively expensive than other methods

(2) there is high possibility of fire and explosion hazards

(3) there is risk of undissolved chemicals remaining in the cake

(4) low oil content meal tends to be dusty causing nasal problem to the attendant

(5) it requires high skilled labour.

2.4.3 Mechanical Oil Expression

This is a modern method of oil extraction it is largely used in oilseed processing industries in Nigeria. Pre-pressing conditions such as cleaning, dehulling, size reduction and heating are factors influencing the yield and oil extracted (Khan & Hanna, 1984). This involves the use of machines and equipment in the extraction of oil. It involves the basic principles of subjecting the pre-prepared material to press thereby pressing out the oil. These devices are either powered (animal or machine) or manually operated. These helps to remove drudgery production quality and quantity and encourage more economic activities as it will encourage increase in crop production. These oil extraction devices include oil expellers, and oil plate presses.

Oilseed expellers produce oil and oil cake from oilseeds continuously, unlike the presses which operates on a batch systems. Expellers use a horizontally rotating metal screw which feeds oil bearing raw material into a barrel shaped outer casing with perforated walls. Raw material is continuously fed to the expeller which grinds and presses the oil out as it passes through the machine. Pressure is exerted on the raw material by restricting the gap at the end of the cage. This rupture the oil cells in the raw material and oil flows through the perforations in the casing and is collected in a trough.

Small-scale expellers can be manually operated or power driven. However, most of them are power driven, typically requiring about 3 HP and are able to process between 8 and 45 kg per hour of raw material depending upon the type. The various types of mechanical oil expeller include:

2.4.3.1 Ghani

Ghani originated in India where it is primarily used to extract oil from mustard, sesame seeds and sunflower seeds, in some cases. It can be used for coconut and groundnut. It consist of a wooden mortar and wood or stone pestle device which grinds oil seeds into fine particles and extracts the oil from it (Weiss, 1983). Traditionally, ghanis are powered by bullocks harnessed to a long lever arranged to turn the pestle inside the mortar. A batch of oil seed is load into the mortar. The pestle grinds the oil seed inside. After the seed has been ground, a certain amount of water is added. The water combines with the ground oil seeds, releasing the oil, which is expelled by the kneading action of the pestle through a hole in the bottom of the mortar. The oil is collected in a container. After the operator is satisfied that a good yield of oil has been extracted, the ghanis is brought to a halt and the oil cake is removed. Normally, two bullocks are needed to drive the ghanis, depending on the size of mortar and the type of seeds, an animal powered ghanis, can process about 10 kg of seeds every two hours. Electrically powered ghanis are fast replacing bullock-driven ghanis because bullocks are becoming increasingly costly to maintain. In the electrically powered ghanis, either the pestle or the mortar is held stationary relative to the others. Ghani's has oil extraction efficiency of about 60% and has a low running cost. Pre-grinding equipment is not required for smaller oil seeds such as groundnut, rapeseed, sesame and sunflower seeds. It is also suitable for use by small groups in villages. Figures 2.2 and 2.3 shows animal and electrically operated Ghanis respectively.

2.4.3.2 Screw Presses

The operate principles is such that the substance from which the oil is to be extracted is pressed slowly and with maximum pressure by a plunger (Round Steel plate) forced down by a screw, into a cylinder with a large number of small holes. A screw which is rotated inside the tube forces oil out of the compressed mass to escape through an enclosed screen that runs parallel to the screw and along the tube-wall while the spent cake is extruded through the end of the tube (Gikuru and Lamech, 2007). The capacity of a screw press depends upon the cage size. An example of a screw press is a bridge press the bridge press, which is usually referred to as spindle press, has the press plate mounted at the base of a screw rod which runs in a nut set, mounted in the cage of the frame that surrounds the cage. The screw rod which is turned by a single cross-head bar providing two levers, has thrust bearing incorporated into it which allows the screwed rod rotate easily against the pressure plate. Thompson and Peterson (1982) used a small screw press to express sunflower seed and found out that oil extraction efficiency was about 70%. Figure 2.4 and 2.5 shows manually operated and power operated oil expeller respectively.

Figure 2.2 Animal Powered Ghani

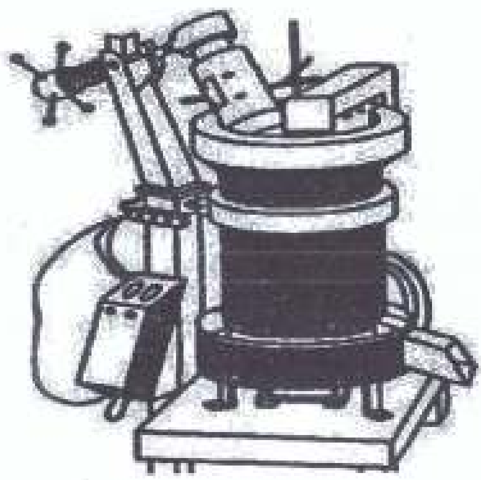

Figure 2.3: Electrically Powered Ghani

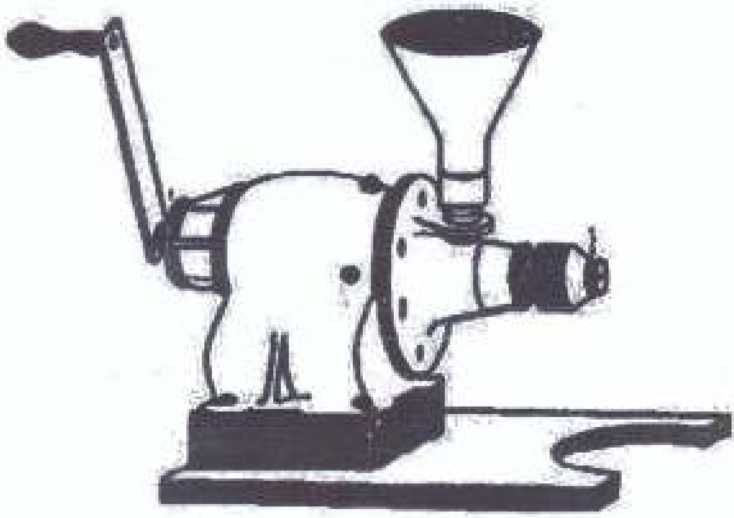

Figure 2.4 manually operated oil expeller

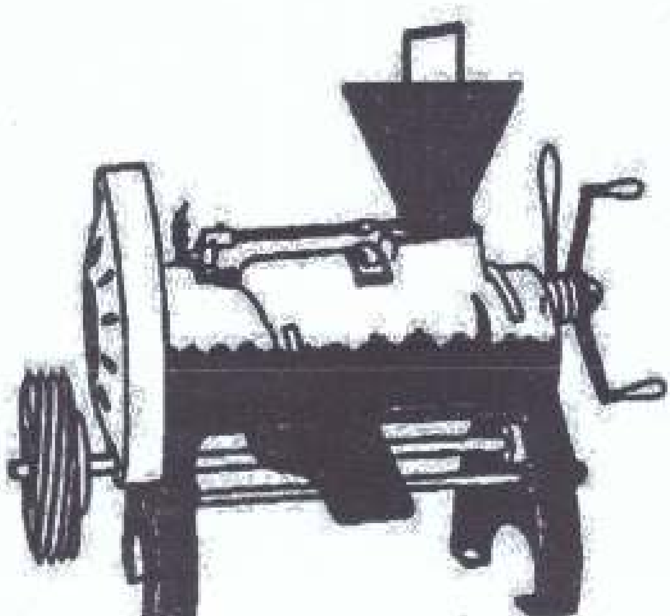

Figure 2.5: Power Operated Oil Expeller

2.4.3.3 Hydraulic Press

Hydraulic press can be manually or power operated. The principle of operation of this machine involves the application of direct and high hydraulic pressure for a considerable amount of time and the oil allowed to slowly permeate from the mass of compressed kernels or ground product (Gikuru and Lamech, 2007). Pressure is exerted by an hydraulic device such as a lorry jack. They require a heavy rigid frame structure. These presses usually generates greater pressure than a screw press while in use, the hydraulic fluid, which may be toxic must not come in contact with the food stuff. Figure 2.6 shows manually operated hydraulic press.

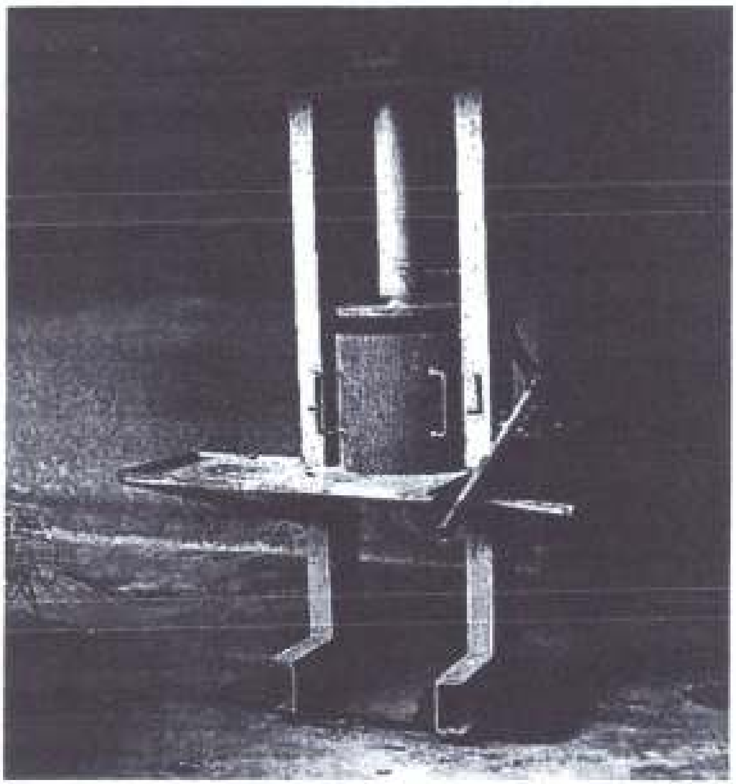

Figure 2.6: Manual Hydraulic Press (FAO, 2002)

2.4.3.4 Ram Press

The ram press technology for oil expression has received a lot of attention in the last decade. The technology is based on manually operated mechanical presses, which employ a slider-crank mechanism in two different configurations. The original machine was designed by Karl Bielengber in 1985 (ATI, 1985). However, there are other designs either based on the original bielengberg ram press or using different type of mechanisms, such as that of RAM 32 oil expression machine. (Uziak and Loukanov, 2007). The ram press technology requires that the seeds be preprocessed and the expressed oil be refined. The ram press is a manually operated mechanical press capable of pressing a range of oil-seeds including sunflower, sesame and groundnuts, as well as seeds from pumpkin, rape, watermelon, mustard, and Jatroffa curcas (Bielenberg, 1996; Eliah, 1997). The capacity of the press is 14 litres of oil for an eight- hour shift, which approximately amounts to pressing a 55 kg of seeds. Maintenance is limited to simple routine cleaning and general checks (Uziak and Loukanov, 2007).

2.4.4 Combination of Screw Press and Solvent Extraction

Screw press and solvent extraction are often used together in factories owned by multinational companies. The process involves subjecting the cake from screw press to solvent extraction. The process is considered as the most efficient method of extracting oil. Most of the oil in the residue after the first processing using screws press is dissolved in the solvent used during solvent extraction (Nathan, 1985).

2.5 Physical Properties of Oil

The physical properties of oil are of considerable commercial importance. These include the color, specific gravity, viscosity and refractive index. Pale and bright colors are desirable in oil attractiveness and are easier and less expensive to refine than for dark oils. The variety of seed, environment during growth maturation, storage and method of processing the seed may have effect on the oil color.

Color can be defined as a psychological interpretation of a physiological response by the eye and brain to the physical stimulus of light radiation at different wavelength. Color is a quality attribute which together with flavor and texture plays an important role in lipid acceptability. Lipids are made up of chemical compounds and one of the more interesting groups is the pigments. These pigments may change in color during the processing of oil as a result of a change in physical state, or of chemical reaction with metals, metallic salts, acids, alkali, oxygen etc. They also vary in stability, in rate of reaction, and in the nature of the products formed from them. The most acceptable color of refined oil is bright yellow.

Specific gravity is a very important particularly in design of tanks, piping and pressing equipment for oil-bearing material. Specific gravity is related to the purity of oil. Specific gravity of fatty acid tends to be higher, the greater its saturation, the lower its molecular weight (Adeeko, 1988). Viscosity which is the measure of internal friction is also a very important property. Oils owe their relatively high viscosity to the long chain structure of their glycerides molecules. Viscosity decreases slightly with increase in degree of unsaturation (Adeeko, 1988). It is employed by analytical chemist in establishing, identifying or detecting adulteration in fatty oils because most oil except center oil have viscosity that do not differ too much from average. Viscosity is important in design of pumps, piping and other equipment used for processing oil (Abramovic and Klofutar, 1998).

2.7 Chemical Properties of Oil

The chemical properties of oil are those chemical characteristics that are necessary for the confirmation of the identity and edibility of the oil. The identity characteristic includes free fatty acids, peroxide value, iodine value, and saponfication value.

2.7.1 Free Fatty Acid

The free fatty acid (FFA) of an oil or fat is half its acid value. It is the fatty acid present in oil following hydrolysis by lipase and which has not been neutralized (Onyeike and Oguike, 2003). It is the number of milligrams of potassium hydroxide (KOH) requires to neutralize the (FFA) in one gram of fat or oil. The concentration of FFA in crude oil is influenced by many factors including agronomic and those arising from handling and processing of the oilseeds (Adeeko, 1988). The FFA content of an oil increases with the ripeness of the seed. Also, storage of oilseeds at high moisture content promotes heating and mould growth leading to an increase in the FFA level. The glyceride in the oil can be attacked by lipase enzyme causing the decomposition of the oil. According to Demian (1990), acid values are used to measure the extent to which glyceride in the oil has been decomposed by lipase and other actions such as light and heat.

In the presence of heat and light the decomposition is accelerated. The extent of this decomposition is measured by their acid value. As rancidity is usually accompanied by free fatty acid formation, the determination of acid value is often used as a general indication of the condition and edibility of oils (Kirk and Sawyer, 1991).

2.7.2 Peroxide Value

This is a measure of active oxygen in 100 g of fat or oil. It is expressed as milliequivalents of peroxide value and used as a measure of stability or for following the course of the rancidity of an oil because, it is intermediate product formed in the autoxidation of oil (Adeeko, 1988). It is also useful in evaluation of the effectiveness of antioxidant compounds on the keeping quality of fats and fat product. During storage, peroxide formation is slow at first during an induction period which may vary from a few weeks to several months according to the particular oil or fat, temperature etc. (Jambunathan *et al.*, 1993).

Fresh oils usually have peroxide values well below 10 meq/kg. A rancid taste often begins to be noticeable when the peroxide value is between 20 and 40 meq/kg, which however depends on the particular type of the oil or fat. Volumetric determination of peroxide value depends on the reaction of potassium iodine in acid solution with the bound oxygen. This is followed by titration of the liberated iodine with sodium thiosulphate. Acetic acid–chloroform mixture is usually used as solvent (Pearson, 1981).

2.7.3 Iodine Value

The iodine value of oil is define as the weight of iodine absorbed by the sample (Onyeike and Oguike, 2003). The iodine value of glyceride is related to its unsaturation. The higher the iodine value, the greater the unsaturation and the liquidity.

There are three types of fatty acids which may be classified as follows:

(i) Saturated fatty acids in which there is single bond in the carbon chain e.g. stearic acid, lauric acid.

(ii) Unsaturated fatty acids in which there is one double bond in the carbon chain e.g. oleic acid.

(iii) Poly-unsaturated fatty acids (PUTA) in which there are two or more double bonds in the carbon chain e.g. Linoleic acids Linolenic acid.

The degree of unsaturation is the measure of double bonds present in fatty acids. It is important in determining its properties. All natural lipids contain both saturated and unsaturated fatty acids (combine with glycerol), but the greater the proportion of the latter the lower the melting point of the lipid. Lipids which are high in unsaturated fatty acid are therefore lipid at room temperature while those rich in saturated fatty acid are solid at room temperature.

The degree of unsaturation of oil is measured by its iodine value. When iodine is added to a triglycerol formed from unsaturated fatty acids, it reacts with the double bonds in the molecule, and the degree of unsaturation may be calculated from the amount of iodine absorbed. One molecule of iodine is used to saturate each bond. The amount of iodine needed to saturate the oil is constant for particular oil or fat, but the exact figure obtained depend on the particular technique employed.

Iodine value is often the most useful figure of identifying an oil or at least placing it into a particular groups. The greater the degree of unsaturation (i.e. the higher the iodine value), the greater is the liability of the oil or fat to go rancid by oxidation. Iodine value is usually determined by wijs' method (Pearson, 1981).

2.7.4 Saponification Value

The saponification value of an oil or fat is defined as the number of milligram of potassium hydroxide required to neutralize the fatty acids resulting from the complete hydrolysis of 1g of the sample. Saponification is a chemical reaction between a fatty acid and alkali to form soap (Onyeike and Oguike, 2003).

Denniston *et al*., (2004) reported that high saponification value indicated the presence of greater number of ester bonds, suggesting that the fat molecules were intact. The esters of the fatty acids of lower molecular weight require the most alkali for saponification, so that the saponification value is inversely, proportional to the mean of the molecular weight of the fatty acids in the glycerides present.

2.7.5 Refractive Index

The refractive index of oil is a physical attribute of lipids, measured by the angle through which a beam of light is bent when passing through a thin film of melted fat. The index of each lipid falls within a range and can be used as a characteristic of the lipid in checking purity or searching for components of a mixture. It is temperature dependant and is usually measured at 40°C, a temperature at which all lipids are liquid. A correction factor can be used if it is not possible to work at a selected temperature for which reference data are available (Ihekoronye and Ngoddy, 1985). Refractive index is the ratio of the velocity of light in a vacuum to velocity of light in the medium being measured. The presence of free fatty acid in an oil sample might cause the refractive index and specific gravity to be lower than expected. Increase in the chain length of the acid causes an increase in refractive index. Increasing the temperature of an organic liquid causes the refractive index to decrease.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Machine Description and Operational Principles

Figure 3.1 and 3.2 show the isometric drawing and picture of the hydraulic oil extractor. It is made up of piston, cylinder, collector, hydraulic jack, and the frame. The piston is a short cylindrical element. It is located at the center underneath the cross bar of the frame. It compresses and crushes the seed inside the cylinder as the cylinder is moved upward towards it. The piston is made of stainless steel with 7.90 cm external diameter, 3 mm thickness and 16 cm length. The other end of the piston is attached to a mild steel flange of 12 cm external diameter.

The cylindrical cage, acts as the compressing chamber. Seed is metered into it and then crushed by the piston. The whole oil extraction process takes place in the cylinder. It is of 7.90 cm internal diameter and 15.06 cm high and 3 mm thick. Stainless steel was used for constructing the cylinder. The cylinder is designed to sit inside the collector. The collector holds the expressed oil and allows the oil to flow through a tap for subsequent collection. The collector is 12 cm in diameter and the collector channel is 7.5 x 2.6 cm stainless steel tube.

The frame is the basic structure upon which all other components parts rest. Though, consideration is given to light weight of the frame, strength and stability was paramount so that other components could be adequately supported. The joints are made rigid, stable and able to bear the pressure. The height is 72.46 cm to accommodate the total length of the cylinder, the jack and the spindle, as well as the piston.

The hydraulic jack handle is primed to exert pressure on the system, thereby crushing the seed. It uses a fluid which enables it to exert pressure. This fluid that is incompressible is forced into a cylinder by a pump plunger. Oil is used since it is self lubricating and stable. When the plunger pulls back, it draws oil out of the reservoir through a suction check valve into the pump chamber. When the plunger moves forward, it pushes the oil through a discharge check valve into the jack cylinder. The suction valve ball is within the chamber and opens with each draw of the plunger. The discharge valve ball is outside the chamber and opens when the oil is pushed into the cylinder. At this point the suction ball within the chamber is forced shut and oil pressure builds in the cylinder. The total length of the jack is 39 cm and the base is 10 x 7 cm.

The basic principle of operation of this machine includes the application of direct hydraulic pressure which allows the product to be under pressure for a considerable amount of time while the oil slowly permeate from the mass of compressed kernels (Gikuru and Lamech, 2007)

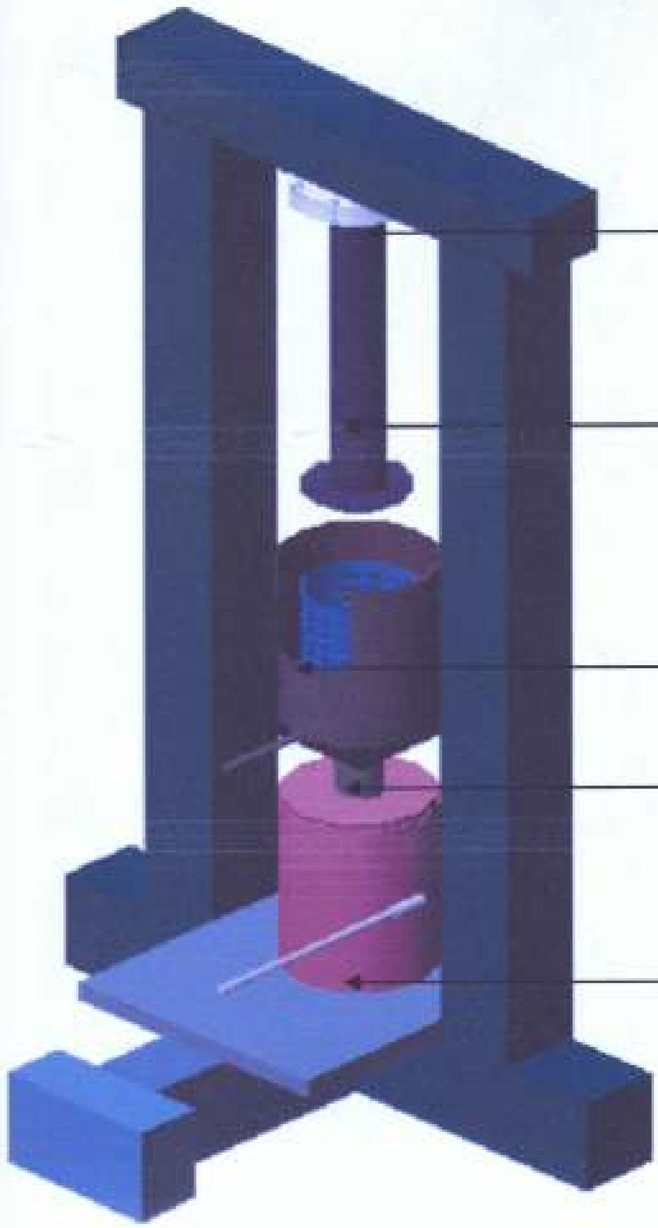

Plate 3.1: Isometric View of the Hydraulic Extractor

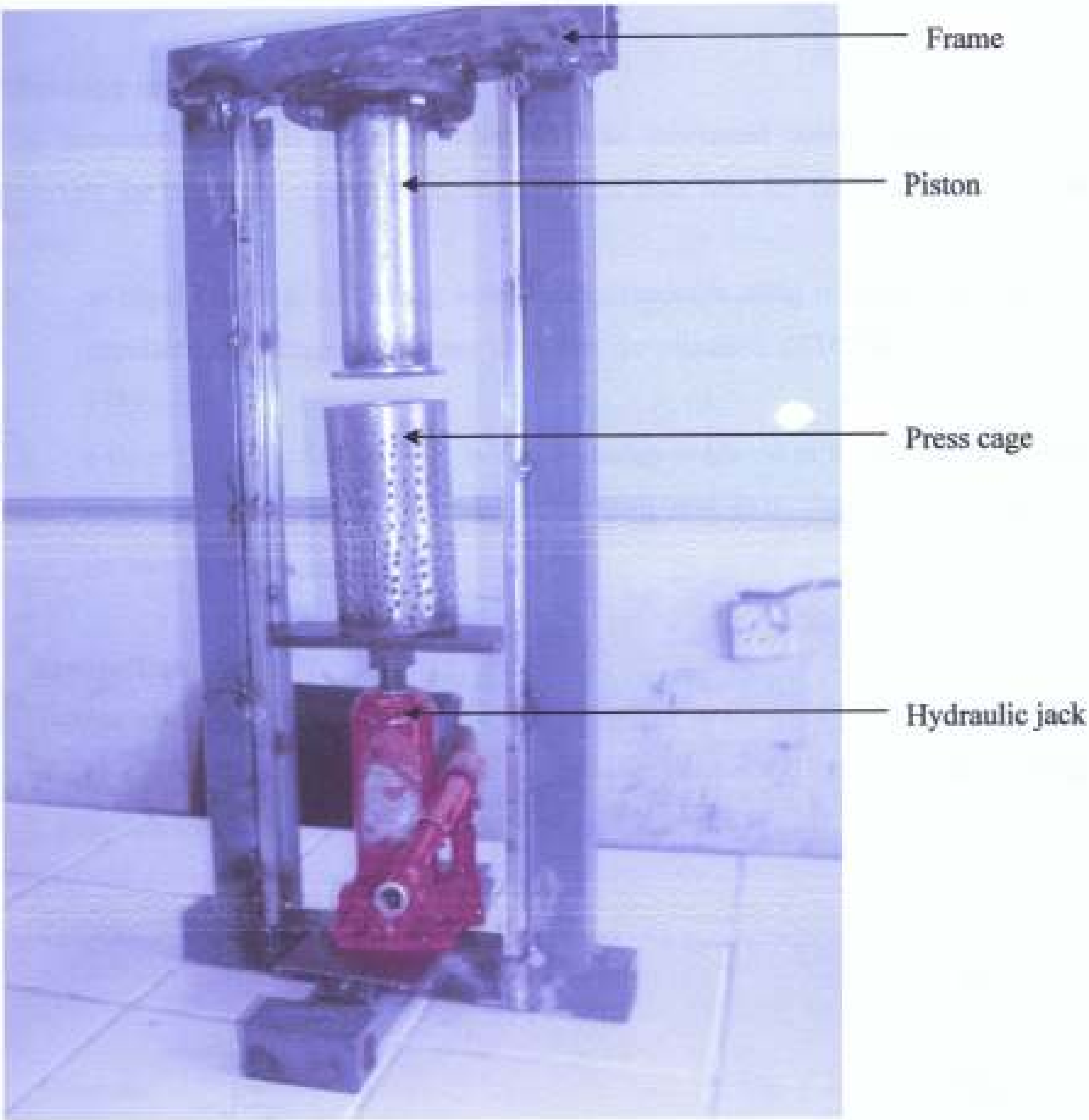

Plate 3.2: Picture of the assembly Hydraulic Oil Extractor (without Cage casing)

3.2 Design parameters

The extractor which is manually operated was fabricated using locally available materials for home and on farm use. Some design data used for the machine are listed below:

(i) to expel oil from oil bearing seeds like groundnuts using manually operated oil expeller, a pressure of between 10-60bar is required. (STORK, 1960; Asiedu, 1989).

(ii) a three (3) ton hydraulic jack which is readily available in the market was used to supply the pressure needed for crushing and extracting the oil from the groundnut seeds.

3.3 Design Calculation

3.3.1 Design of Cylinder Diameter

Using a three (3) ton hydraulic jack, the cylinder diameter (D) was estimated using eqn 3.2, derivable from eqn 3.1

$$\text{Pressure} = \frac{Force}{Area} = \frac{4F}{\pi D^2} \qquad 3.1$$

$$\text{Diameter} = \sqrt{\frac{4F}{\pi P}} \qquad 3.2$$

Where F = force (N),

P = Pressure (N/m^2)

Force required = 3000 kg X 9.81 m/s^2

Force = 29430 N

D= Diameter = 7.9 cm

3.3.2 Design of Cylinder Height

The cylinder was sized to accommodate 450 g of groundnut seed. This led to the estimation of the volume from the density of the groundnut seed. Using density equation in eqn 3.3, the volume was obtained (eqn 3.4). The result was equated with volume equation (eqn 3.5) to obtain the height of the cylinder.

$$\text{Density of groundnut (Kampala)} = \frac{Mass}{Volume} \qquad 3.3$$

Density = 0.610g/cm^3

$$\text{Volume} = \frac{Mass}{Density} \qquad 3.4$$

$$\frac{450\ g}{0.610\ g/cm} = 737.71\ cm^3$$

$$\text{Volume of the cylinder} = 737.71\ cm^3 = \frac{\pi d^2 h}{4} \qquad 3.5$$

Height = *15.06 cm*

3.3.3 Estimation of the Frame Dimensions

Total height of the cylinder	= 15.06 cm
Total length of the hydraulic jack	= 39.05cm
Total length of piston	= 16.33 cm
Clearance range	= 2.0 cm
Total height of frame	= 72.46 cm

The width of the press is equal to 30.988 cm this is to accommodate the diameter of the press cylinder, the collector, and a clearance range. The total weight of the press including the jack was found to be 32.7 kg using a spring balance.

3.4 Fabrication Procedure

The manually operated oil extractor was constructed using available material. The components are either made from mild or stainless steel. Construction of the machine entails the fabrication of individual parts and the assembling of the parts to form the machine. Some components of the machine were purchased while others were fabricated. The fabrication of these components was carried out in stages, under different operations, using different types of equipment and machine tool. The procedures used at each stage are as explained.

3.4.1 Stage 1: The Cylinder

The cylinder was fabricated using a 3 mm thick steel pipe. The steel pipe was cut into a cylinder 15.06 cm high and 7.90 cm internal diameter. The body of the cylinder was perforated using drill to make holes, to allow for easy flow of the extracted oil.

3.4.2 Stage 2: The Piston

This was made of stainless steel plate 8.2 cm external diameter and 2.7 cm external diameter x 16 cm length stainless steel tubes and a flange of 12 cm external diameter, 8 mm thick with a 2.7 cm hole at the center, made of mild steel. The fabrication procedure of the piston is described below:

(a) Both ends of the tube were faced.

(b) The tube was welded in the center of 8.2 cm steel disk

(c) The welded steel plates were then mounted on lathe machine and turned the disk to fit the inside diameter of the cylinder. This will be 7.9 cm external diameter.

(d) The other end of the tube was fitted to the center of the galvanized disk and welded.

(e) A 10 mm internal diameter hole was made on the galvanized disk at four places.

3.4.3 Stage 3: Frame

This is made of mild steel and a stainless steel u- channel. 5.05 cm x 5.05cm x 140 cm long tubing for the upright, 5.05 cm x 5.05 cm x 31.00 cm mild steel pipe for the top cross member, 1 cm x 60 cm long u – channel. The fabrication procedure of the frame is described below:

(a) A two equal piece of 70 cm x 5.05 x 5.05 cm was made and then faced.

(b) The two piece were welded to the cross member and the base member together on the upright tube.

(c) A 1 cm x 2 mm x 60 cm u- channel was then welded on the upright tube.

(d) All edges were grinded to remove any burrs.

3.5 Assembly of Machine

The machine has a main frame on which all the components are assembled. The step by step assembling of the fabricated parts on the main frame is as detailed below:

(a) the connector bar for the collector ring was fixed on the main frame, to allow free longitudinal movement.

(b) the piston connector rod was welded in a fixed position at the top cross bar of the frame.

(c) the cage cylinder was placed inside the collector.

(d) the powering unit (hydraulic jack) was placed below the collector ring on the base of the frame. The machine is ready for use. Fig 3.3 shows the complete assembly of the machine

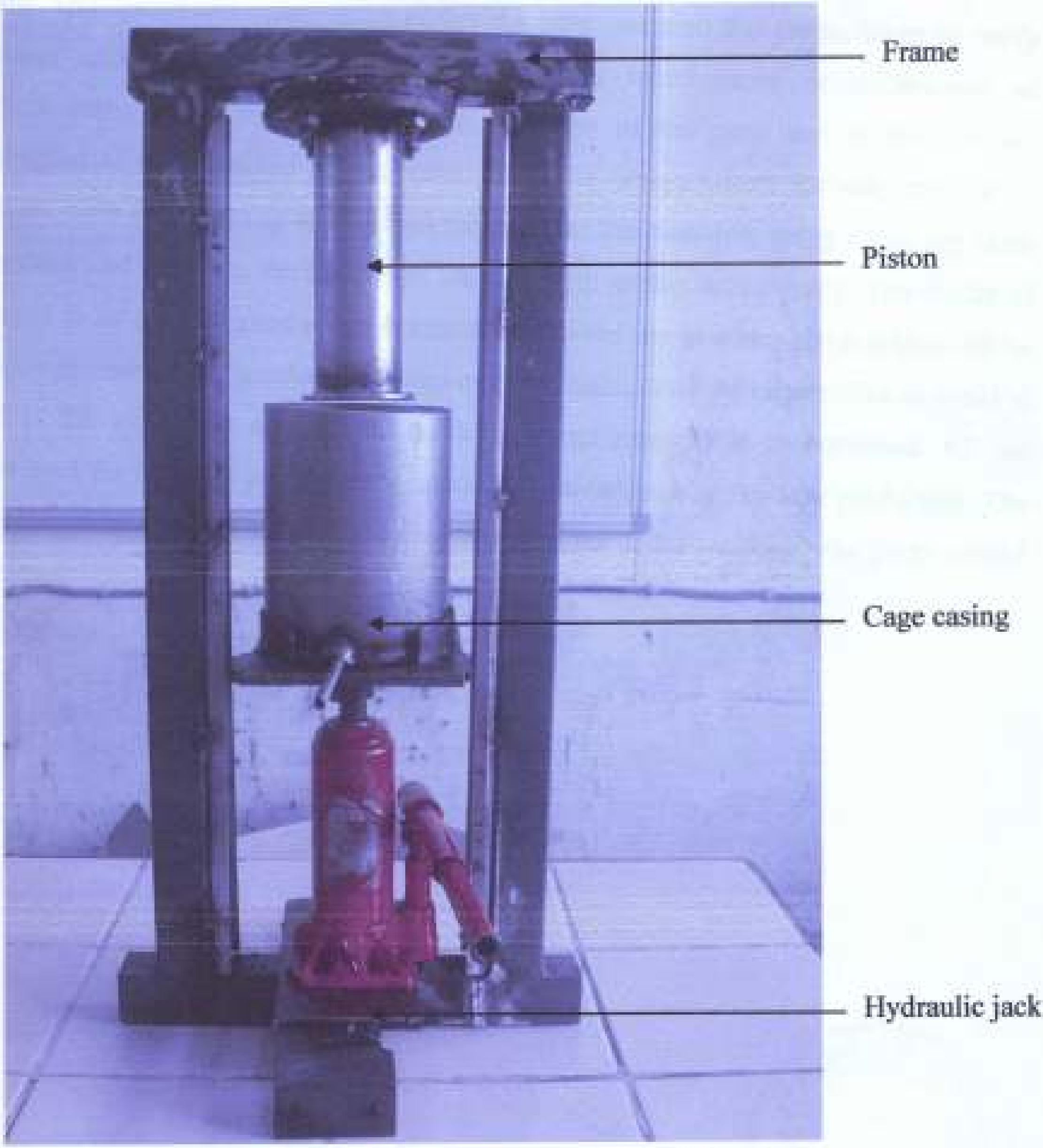

Plate 3.3: Picture of the Assembly Hydraulic Oil Extractor with the Cage Casing and Discharge Chute

3.6 Machine Maintenance

The ease of maintenance of a machine is an important factor to be considered in the machine operation. The design and construction of this machine ensured that the parts can be easily dismounted and reassembled. This allows for easy maintenance or replacement of component parts. Also, this will eliminate corrosion of the parts and in turn prevent contamination of the extracted oil and cake. Since the design allows for easy removal of component parts for cleaning as required, wipe clean the machine, using clean dry cloth after washing and lubricate the spindle of the jack with grease occasionally. The choice of the material to be used for production is important and the use to which the machine will be put and the overall cost of production of the machine influenced the choice. The material to be used in the extraction area of the machine is not susceptible to corrosion. All the materials used for machine production were easily sourced locally to ease production. The cost of production material selected for the constructions of the machine was given careful consideration.

3.7 Machine Costing

The cost of producing the oil extractor is provided in table 3.1.

Table 3.1: Machine Costing

S/N	Component Item	Material Specifications	Unit Cost	Quantity	Total Cost
1	Cylinder	8.23 cm x 7.9 cm x 16cm steel pipe	₦1666.6	3	₦5,000
		10.33 cm x 10 cm x 16cm steel pipe	₦1000	1	₦1000
		5.5 cm x 5.2 cm x 16cm steel pipe	₦1000	1	₦1000
2	Piston	15 cm x 3 mm thick disk steel plate	₦500	3	₦1500
		5.5 cm x 5.2 cm x 16cm steel pipe	₦1250	2	₦2500
		4.13 x 3.8 x 16 cm steel pipe	₦1000	1	₦1000
		15 cm x 8 mm thick mild steel disk plate	₦200	4	₦800
3	Collector	15.33 x 15cm x 16cm steel pipe	₦1500	1	₦1500
		8.5 mm x 7.5mm x 6cm steel pipe	₦300	1	₦300
4	Frame	5.2 x 5.2 x 160cm mild steel pipe	₦2000	1	₦2000
5	Jack	3 ton jack	₦2500	1	₦2500
6	Miscellaneous	Muslin cloth	₦100	4	₦400
7	Cost Of Labor	Driller ,Cutter and Welder	-	-	₦16000
8	Transportation		-	-	₦4000
Total					₦39,500

3.8 Machine Testing and Evaluation

Two machine parameters namely: the diameter and pore size of the cylinder were varied. Cylinder diameters of 5.2, 7.9 and 10 cm, and pore size of 3, 4 and 5 mm were used. The machine was tested and evaluated by determining its oil yield, extraction efficiency and machine capacity for both whole and ground groundnut. Groundnut seeds, Kampala variety (*Sam-nut 10*) used were obtained from the local market. The groundnuts were shelled, cleaned and roasted lightly at a temperature of 70°c for 20 minutes The red skins were removed by rubbing individual kernels against each other by hand (Asiedu, 1989).

3.8.1 Moisture Content Determination

The initial moisture content of the seed was 12 % wet basis. They were conditioned to desired moisture levels of 8.5 % wet basis by oven drying at 60°C for 6hour. This was estimated by drying 5 g of the sample in an oven at 105°C for six hours and then repeating the same until a constant weight was achieved. The analysis was carried out in triplicates. The loss in weight during drying in percentage was taken to be the percentage moisture content. This was calculated as expressed in equation 3.6 (AOAC, 1984).

$$\text{Moisture content (\%)} = \frac{\textit{Loss in weight}}{\textit{Weight of sample}} x \frac{100}{1}$$

$$\frac{W_2 - W_3}{W_2 - W_1} \quad x \quad \frac{100}{1} \qquad 3.6$$

Where

W_1 = weight of empty Petri dish

W_2 = weight of Petri dish and sample before drying

W_3 = weight of Petri dish and sample after drying

3.8.2 Oil Content Determination

Oil content of the seed was found to be 54.63 %. This was determined using method described by AOAC (1984). Five grams (5 g) of the groundnut sample were transferred into a thimble using filter paper. The cleaned weighed distillation flask containing ether was connected to the soxhlet apparatus and the mouth of the thimble was clocked with cotton wool to avoid spillage of sample particle back to the flask. The extraction was carried out using petroleum ether which was kept gentle boiling for approximately 8 hours. The Erlen meyer flask was then removed and dried in the oven, cooled in the dessicator and weighed. The percentage fat was thus calculated using equation 3.7 below.

$$\text{Oil content} = \frac{Weight\ of\ oil\ extracted}{Weight\ of\ sample} x \frac{100}{1} \qquad 3.7$$

Two treatment conditions of the groundnut seed were examined namely: the whole groundnut seed and ground groundnut seed. The grinding was achieved by using the laboratory specified blender to size reduce the groundnut. 450 g of the prepared groundnut was measured into the press cylinder lined with muslin cloth and subjected to pressing in the designed press for duration of 10 minutes as reported by Gikuru and Lamech, (2007). Prior to this the sample was heated to a temperature of 70°C to facilitate the rupturing of the groundnut seed as reported by Tunde-Akintunde *et al* (2001). All experiments were conducted in triplicates.

3.8.3. Oil Yield Determination.

The oil yield was determined according to method described by Owolarafe *et al* (2009) as the percentage weight of oil recovered from the total weight of groundnut used. This is given below as:

$$\text{Oil yield (\%)} = \frac{wg - wp}{wg} x\, 100 \qquad 3.8$$

Where wg = weight of groundnut before extraction of oil

wp = weight of pressed cake after extraction of oil.

3.8.4 Oil Extraction Efficiency Determination

Subsequently, the extraction efficiency of the machine was determined as the ratio of oil yield (%) to oil content of the groundnut seed (Owolarafe *et al*, 2009). The extraction efficiency is thus given below as:

Extraction efficiency $= \frac{Oil\ yield}{Oil\ content} x\,100$ 3.9

3.8.5 Machine Capacity Determination

Machine capacity was estimated using equation 3.8 by adopting the method described by Adewumi (2007). This is the measure of the mass of the oil the machine could handle per unit time. If M_o is the mass of oil produced and T_t, the time taken to produce M_o. Machine capacity C_m is given by the relationship:

Machine capacity (C_m) $= \frac{M_o}{T_t} kg/hr.$ 3.10

3.9 Physical and Chemical Properties of Oil Extracted

The following quality tests were carried out in triplicates on the groundnut oil extracted:

3.9.1 Melting Point

Frozen oil sample in a capillary tube was heated slowly in a water bath and the temperature at which the oil starts melt was taken as the melting point (Ihekoronye and Ngoddy, 1985).

3.9.2 Smoking Point

Enough oil to cover the bulb of a thermometer was poured into a 50 cm^3 conical flask covered with a rubber stopper with two holes on it (one for the thermometer and the other to let in air into the flask). The flask was heated until the oil just started to smoke (sp), and at that point temperature was taken. (Mondy, 1980).

3.9.3 Flash Point

Oil sample used for the determination of the smoking point was heated further at higher temperature of which the smoke evolving was very dense. This was recorded as the flash point (Mondy, 1980).

3.9.4 Acid Value

Acid value was determined by titre metric method of AOAC (1984). 5g of the oil sample was weighed and 75ml of hot neutral alcohol was added with a few drops of phenolphthalein. The mixture was shaken vigorously and titrated with 0.1M NaOH solution with constant shaking until the pink coloration remains permanent acid value was calculated using the formula. The acid value was estimated by multiplying the volume of NaOH by a factor of 5.6 and then divided by the total weight of oil used.

$$\text{Acid Value} = \frac{V \ x \ 5.6}{Weight \ of \ sample} \qquad 3.11$$

Where V = titration end point value.

3.9.5 Iodine Value

Iodine value was determined using the titre metric method of AOAC (1984). This was calculated by the volume of 0.1M sodium thisulphate used multiplied by factor of 1.269 divided by weight of oil used. 2 g of oil sample was weighed into a dry glass stopper bottle of 250 ml capacity and 10ml of carbon tetrachloride was added to the oil. About 20 ml of wij's solution was then added and allowed to stand in the dark for 30 min. 15 ml of (10%) potassium iodine and 100 ml of water was added and then titrated with 0.1M sodium thisulphate solution using starch as indicated just before the end point. A blank was also prepared alongside the oil sample. Iodine value was calculated from the formula:

$$\text{Iodine value (wij's)} = \frac{(V_2 - V_1) \ x \ 1.269}{Weight \ of \ sample \ (g)} \qquad 3.12$$

Where: V_2 = titre value for blank, V_1 = titre value for sample (s)

3.9.6 Peroxide Value

Peroxide value was evaluated using method specified by AOAC (1984). 2 g oil sample was weighed into a tube and 1g of powered potassium iodide with 20 ml of solvent mixture (glacial acetic Acid and chloroform) was added. This was then placed in boiling water for 30 s. The content was poured into a flask containing 20 ml of 5% iodide solution. The tube was then washed with 25 ml of distilled water and titrated with 0.002 N Sodium thiosulphate solution using starch as indicator. A blank was prepared alongside the oil samples. Peroxide was obtained using the formula:

Peroxide value

$$= \frac{2(V_1 - V_2)\ m\ Eq / kg}{Weight\ of\ sample\ (g)} \qquad 3.13$$

Where: V_2 = Blank titre value, V_1 = sample (s) titre value.

3.9.7 Saponification Value

The saponification value was determined using the titre metric method of AOAC (1984). 2 g of oil sample was weighed into a conical flask and 25 ml of alcoholic potassium hydroxide was added. Solution was heated in boiling water for 1 hour 1ml of 1% phenolphthalein was added and titrated with 0.5 N HCI. A blank was prepared alongside the oil sample. The value was calculated by the formula:

$$\text{Saponification value} = \frac{56.1N\ (A - B)}{Weight\ of\ oil\ used\ (2g)} \qquad 3.14$$

Where N = Normality of HCl acid used, A = Volume of H_2SO_4, for blank, ml, B = Volume of H_2SO_4, for sample, ml, 56.1 = Equivalent weight of potassium hydroxide.

3.9.8 Suspended Particle

Suspended particle was determined using the method described by ISO (2000) 50 ml of the homogenized sample was dissolved in 200 ml of n-hexane petroleum ether. The mixture was then filter through a filter paper. Another 100ml of the solvent is used to wash the residue. The procedure was repeated empty there was no trace of oil in the residues.

The filter paper with the residues was then transfer to the ocean operated at 103^0C for all the solvent present to evaporate. The percentage suspended particle was evaluated using equation (11).

$$\text{Suspended particle} = \frac{Weight\ of\ residue\ (g)\ x\ 1000 / L}{Volume\ of\ sample\ used\ (ml)} \qquad 3.15$$

3.10.1 Statistical Analysis.

All determinations were performed in triplicate, analyzed statistically using Analysis of Variance procedures at $p < 0.05$. Duncan's multiple-range test (DMRT) was used to differentiate between the mean values. Also regression model was developed to predict machine performance, with the aid of Microsoft SPSS 10 package, Excel Microsoft office.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Studies were conducted on the effects of material type, pore size and cage diameter of machine performance indices, the physico-chemical properties of the oil as reported below.

4.1 EFFECT OF PORE SIZE ON OIL YIELD FOR WHOLE AND GROUND GROUNDNUTS

Appendices I shows the results of the effects of pore size on oil yield, extraction efficiency and machine capacity for whole and grounded groundnut seed. Appendices II shows the effect of material type on oil yield, extraction efficiency and machine capacity at different pore size.

The oil yield was observed for whole and ground seeds respectively to vary with the pore size, the pore size of 3 mm yielded the least with 21.25; 23.61 %, while 4 mm and 5 mm yielded 23.02; 26.87 % and 23.08; 26.15 % respectively. However, statistical analysis of the result obtained shows that there is no significant difference in oil yield at $P \leq 0.05$ for all pore size. It was observed from Appendices II that the material type (whole and ground) has no significant effect with any of the pore size evaluated except at pore size of 4 mm. therefore for pore size of 4 mm; ground groundnut had high oil yield value.

The relationship is also graphically presented in Fig. 4.1 and it is evident from the figure as shown, that an increase in pore size from 3 to 4 mm resulted in an increase in oil yield for whole and ground Groundnut seed. Further increase in pore size for the material types (whole and ground seed) however resulted in a slight decrease in oil yield. The result of this finding is however in agreement with the finding of Owolarafe *et al* (2007) on crude palm oil yield. The regression equations for the variables are presented mathematically in equations 4.1 and 4.2 for whole and ground seed respectively.

$Y_1 = -0.0085x^2_1 + 0.0775x + 0.0568$ 4.1

$Y_2 = -0.0199x^2_1 + 0.1719x - 0.1005$ 4.2

Where, Y_1 = oil yield for whole groundnut, Y_2 = oil yield for ground groundnut, X_1 = pore size

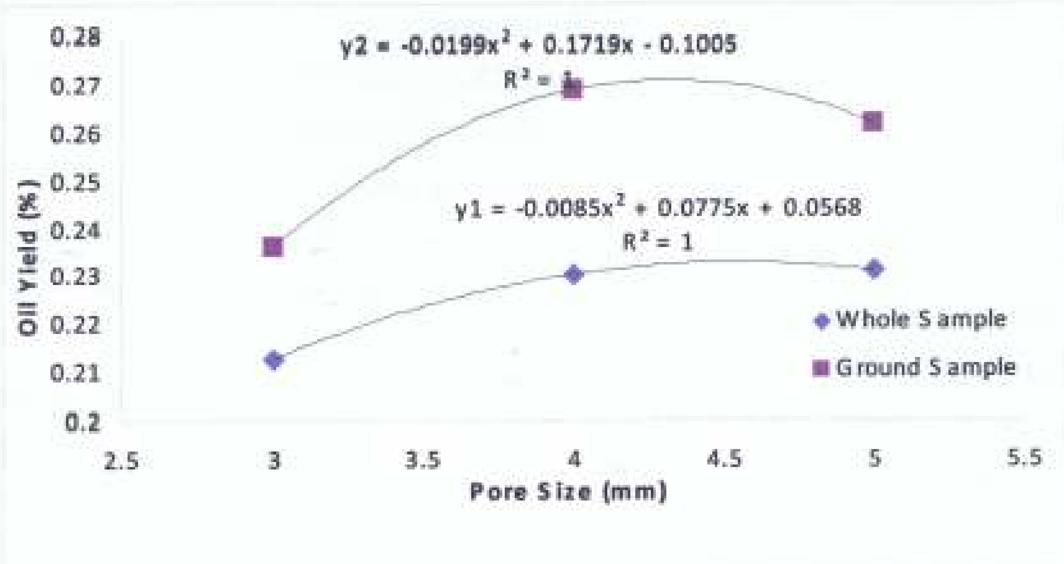

Fig. 4.1: Effect of Pore Size on Oil Yield for whole and ground groundnut

4.2 Effect of Pore Size on Extraction Efficiency for Whole and Ground Groundnut

The result of the means extraction efficiency at different press pore size both for whole and ground sample of groundnut considered are shown below in Appendices I. The extraction efficiency was observed to vary with the pore size as the pore size of 4 mm for ground groundnut resulted in the highest extraction efficiency with 49.19 % compared to 3 and 5 mm which has 38.89; 43.21 and 42.24; 47.87 % for whole and ground seeds respectively.

However, statistical analysis of the result obtained shows that the perceived difference observed for extraction efficiency are not significantly different from each other at $P \leq 0.05$. More so, it was observed from Appendices II that the material type (whole and ground) has no significant effect with any of the pore size evaluated except at pore size of 4 mm.

The relationship is also graphically presented below in Fig. 4.2 and it is evident from the figure as shown that, an increase in pore size from 3 to 4 mm resulted in an increase in extraction efficiency for whole and ground Groundnut. Further increase in pore size for the material types (whole and ground seed) however resulted in a slight decrease in extraction efficiency. The regression for the variable is presented mathematically equations 4.3 and 4.4 for whole and ground Groundnut seed respectively.

$$Y_4 = -0.0365x^2_1 + 0.3153x - 0.1853 \qquad \ldots\ldots\ldots\ldots\ldots\ldots 4.3$$

$$Y_3 = -0.0158x^2_1 + 0.1428x + 0.1024 \qquad \ldots\ldots\ldots\ldots\ldots\ldots 4.4$$

Where

Y_3 = extraction efficiency of whole groundnut

Y_4 = extraction efficiency of ground groundnut

X_1 = pore size

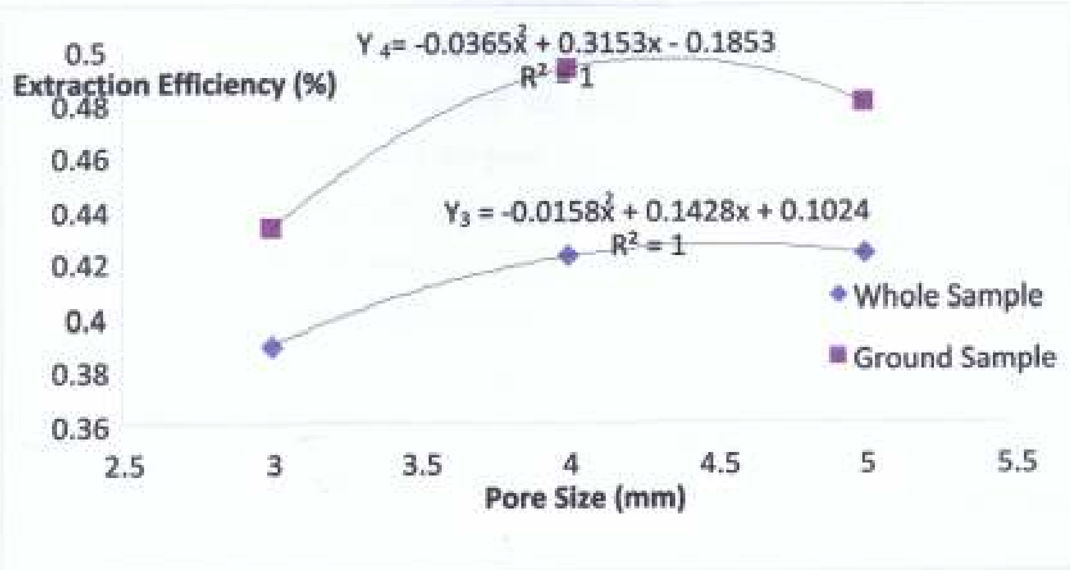

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Fig. 4.2: Effect of Pore Size on Extraction Efficiency for whole and ground groundnut

4.3 Effect of Pore Size on Machine Capacity for Whole and Ground Groundnut

The result of the means machine capacity at different press pore size both for whole and ground sample of groundnut considered are shown above in Appendices I. The machine capacity was observed to vary with the pore, where pore size of 4 mm for ground groundnut resulted in the highest machine capacity of 0.5645 kg/hr. followed by pore size 5 mm with 0.554; 0.628 kg/hr. while the least was attributed to pore size of 3 mm with 0.510; 0.5667 kg/hr. for whole and ground seed respectively.

However, statistical analysis of the result obtained shows that the perceived difference observed for machine capacity are not significantly different from each other at $P \leq 0.05$. More so, it was observed from Appendices II that the material type (whole and ground) had no significant effect on any of the pore sizes evaluated except at pore size of 4 mm. The relationship is also graphically presented below in Fig. 4.3 and it is evident from the figure as shown, that an increase in pore size from 3 to 4 mm resulted in an increase in machine capacity for whole and ground seed respectively. Further increase in pore size for the material types (whole and ground seed) however resulted in a slight decrease in machine capacity. The regression equations for the variable are presented mathematically in equations 4.5 and 4.6 for whole and ground seed respectively.

$Y_6 = -0.0476x^2_1 + 0.4118x_1 - 0.24$ 4.5

$Y_5 = -0.02x^2_1 + 0.182x_1 + 0.144$ 4.6

Where

Y_5 = machine capacity for whole groundnut

Y_6 = machine capacity for ground groundnut

X_1 = pore size

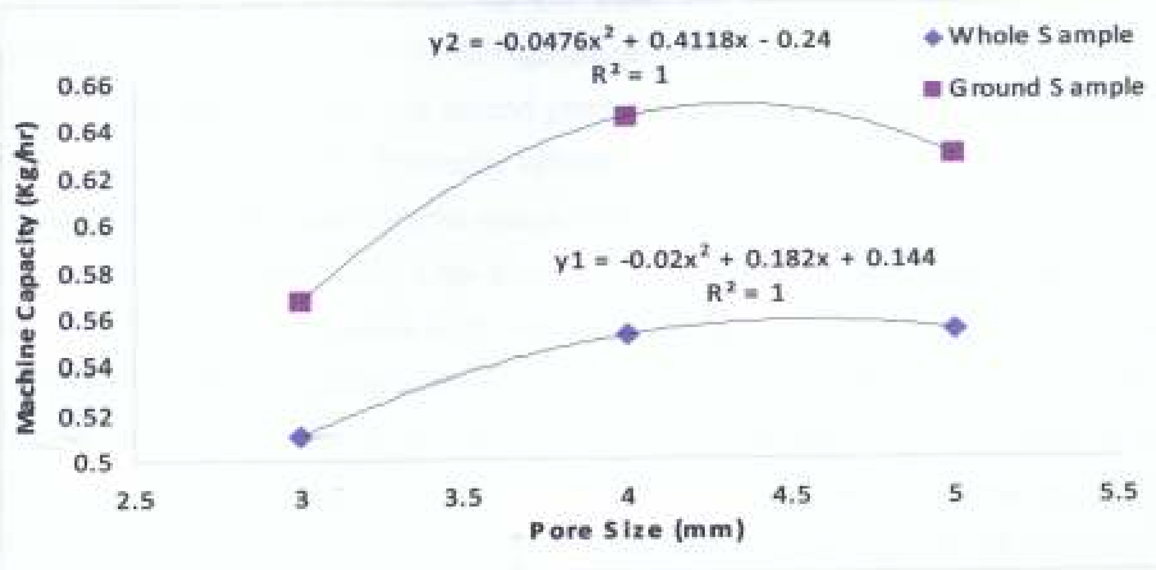

Fig.4.3 Effect of Pore Size on Machine Capacity for whole and ground groundnut

4.4 Effect of Cage Diameter on Oil Yield for Whole and Ground Groundnut

Appendices III shows the effects of cage diameter on oil yield, extraction efficiency and machine capacity for whole and ground groundnut seed. Appendices IV are the effect of material type on oil yield, extraction efficiency and machine capacity at different cage diameter. Altering the cage diameter was observed to have a significant effect on oil yield for 5.2, 7.9 and 10 cm respectively. Cage diameter 5.2 cm resulted in the highest oil yield: 43.17; 46.01 %, for whole and ground seeds respectively. Cage size of 7.9 had oil yield of 23.02; 26.87 % for whole and ground sample while cage diameter at 10 cm gave oil yield of 21.74; 24.08 respectively. There is however no significant difference in the oil yield of cage diameters of 7.9 and 10 cm. From appendices IV it could be deduced that the material type (whole and ground) has no significant effect on oil yield for cage diameters of 5.2 and 10 but had at cage diameter of 7.9 cm.

The relationship is graphically presented in Fig. 4.4. It is evident from the figure that oil yield decreases sharply as cage diameter was increased from 5.2 to 7.9 cm. for both whole and ground sample, further increase in cage diameter from 7.9 to 10 cm resulted in a reverse trend in oil yield as observed on the graph. The increase in oil yield with a decrease in cage diameter could be attributed to a decrease in surface area leading to an increase in pressure applied. This finding is however in contrast to the finding of Owolarafe *et al* (2007) on crude palm oil yield. The regression for the variable is presented mathematically in equations (4.7) and (4.8) for whole and ground seed respectively.

$$Y_1 = 0.014x_2^2 - 0.2617x_2 + 1.4063 \quad \ldots\ldots\ldots\ldots\ldots\ldots 4.7$$

$$Y_2 = 0.012x_2^2 - 0.2281x_2 + 1.3217 \quad \ldots\ldots\ldots\ldots\ldots\ldots 4.8$$

Where

Y_1 = oil yield for whole groundnut

Y_2 = oil yield for ground groundnut

X_2 = cage diameter

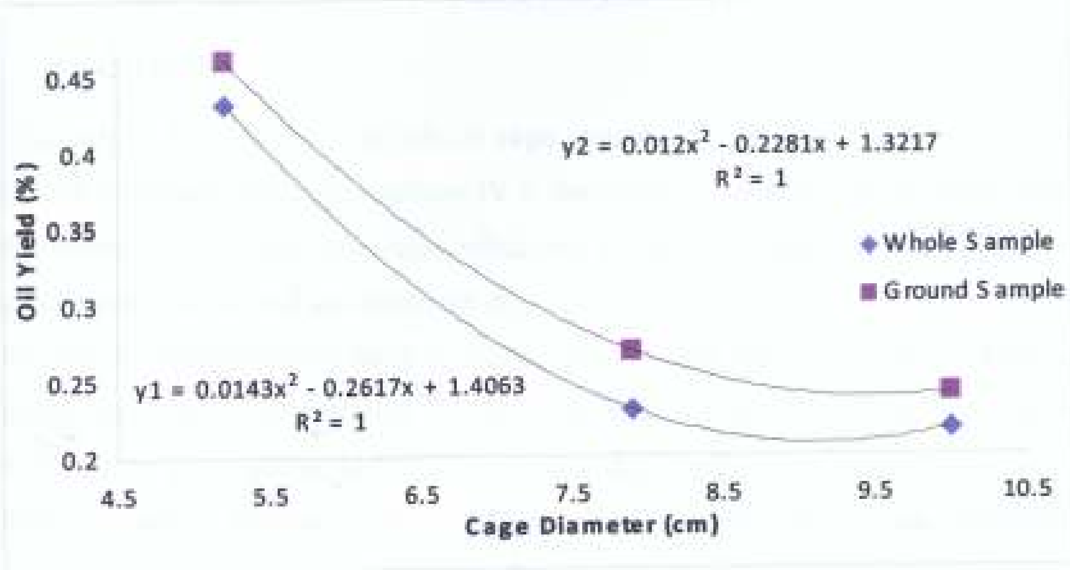

Fig.4.4: Effect of Cage Diameter on Oil Yield for whole and ground groundnut

4.5 Effect of Cage Diameter on Extraction Efficiency for Whole and Ground Groundnut

Appendices III shows the effects of cage diameter on extraction efficiency for whole and ground groundnut seed. Appendices IV is the effect of material type on extraction efficiency the results of the mean extraction efficiency at different cage diameter both for whole and ground seed considered are shown in Appendices III

Maximum extraction efficiency of 79.02; 84.22 % for whole and ground seed respectively was recorded for cage diameter 5.2 cm. Cage size 7.9 cm had oil yield of 42.14; 49.18 % while 10 cm gave 39.80; 44.09 % for whole and ground sample respectively.

These extraction efficiency values obtained for 5.2 cm are however an improvement on the 64 % reported by Ajibola (1989) for tenera palm kernel using hydraulic press and 70 % obtained by Bamgboye and Adejumo (2007) for sunflower using screw press. Also they are comparable to 94.7 % value obtained by Akinoso *et a*l (2006) for tenera palm oil using screw press.

Statistically there is a significant difference in the extraction efficiency between cage diameter 5.2 cm and, 7.9 and between 5.2 and 10 cm. however; there is no significant difference between 7.9 and 10 cm. From Appendices IV it could be deduced that the material type (whole and ground seed) has no significant effect on extraction efficiency for 5.2 and 10 cm but had at cage diameters 7.9 cm.

The relationship is graphically presented in Fig. 4.5 Extraction efficiency decreased sharply as cage diameter increased from 5.2 to 7.9 cm. for both whole and ground sample, further increase in cage diameter from 7.9 to 10 cm resulted in a reverse trend in extraction efficiency as observed on the graph. The regression equation for the variable presented mathematically in equations 4.9 and 4.10 for whole and ground seed respectively. Similar model equations where presented by (Akinoso *et al.*, 2002), in modeling of oil expression from palm kernel.

$Y_3 = 0.0261x^2_2 - 0.479x_2 + 2.5741$ 4.9

$Y_4 = 0.022x^2_2 - 0.4178x_2 + 2.4203$ 4.10

Where

Y_3 = Extraction Efficiency for whole groundnut

Y_4 = Extraction Efficiency for ground groundnut

X_2 = Cage diameter

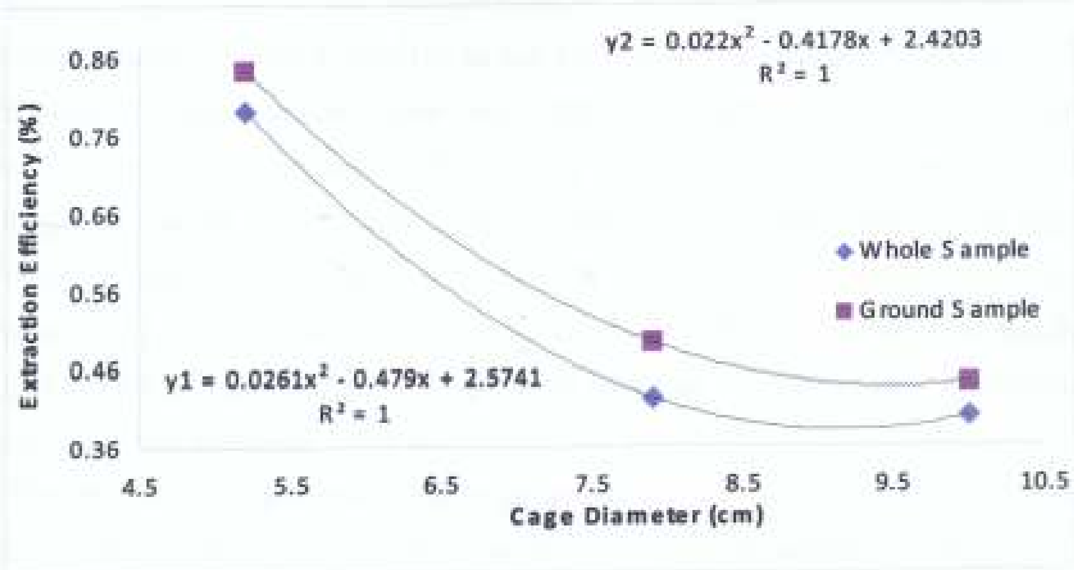

Fig.4.5 Effect of Cage Diameter on Extraction Efficiency for whole and ground Groundnut

4.6 Effect of Cage Diameter on Machine Capacity for Whole and Ground Groundnut

Appendices III shows the effect of cage diameter on machine capacity for whole and ground groundnut seed. Appendices IV gives the effect of material type on machine capacity at different cage diameter. The machine capacity was observed to vary with the cage diameter. Cage diameter of 10 cm resulted in the highest machine capacity of 0.978; 1.084 kg/hr. followed by cage diameter 5.2 cm with 0.648; 0.691 kg/hr. while the least was attributed to cage diameter of 7.9 cm with 0.552; 0.641 kg/hr. for whole and ground seed respectively.

Statistical analysis of the result obtained shows that the values obtained for cage diameter 10cm are significantly different from those of 5.2 and 7.9 cm while the later are not different from each other at $P \leq 0.05$. More so, it was observed from Appendices IV that the material type (whole and ground) has no significant effect on any of the cage diameters evaluated except at cage diameters of 7.9 cm.

The relationship is also graphically presented in Fig. 4.6 and it is evident from the figure as shown, that an increase in cage diameter from 5.2 to 7.9 cm resulted in a decrease in machine capacity for whole and ground seed respectively. Further increase in cage diameter for the material types (whole and ground seed) however resulted in a sharp increase in machine capacity for both whole and ground sample respectively. The decrease in the first instance with an increased cage diameter is not understood but the reverse trend could be attributed to more samples feed into the cage with larger diameter. The regression for the variable is presented mathematically in equations 4.9 and 4.10 for whole and ground seed respectively. Similar model equations where presented by (Akinoso *et al.*, 2002), in modeling of oil expression from palm kernel.

$Y_5 = -0.0476x_2^2 + 0.4118x_2 - 0.24$ 4.9

$Y_6 = -0.02x_2^2 + 0.182x_2 + 0.144$ 4.10

Where

Y_5 = machine capacity for whole groundnut

Y_6 = machine capacity for ground groundnut

X_2 = cage diameter

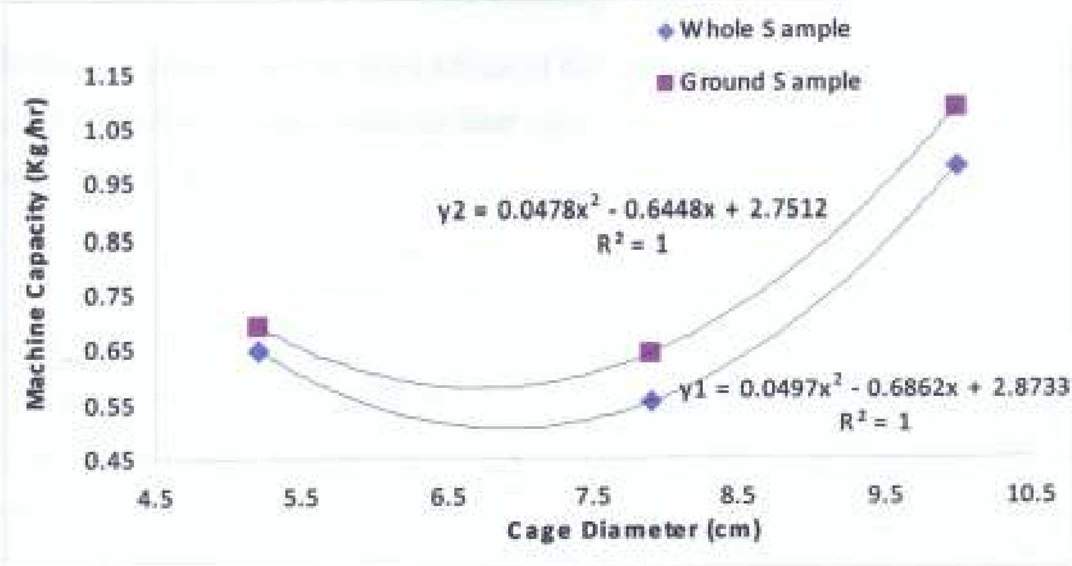

Fig.4.6 Effect of Cage Diameter on Machine Capacity for Whole and Ground Groundnut

4.7 Modeling the Combined Effect of Pore Size and Cage Diameter on Oil Yield, Extraction Efficiency and Machine Capacity.

In order to predict the combined effects of the variables (pore size and cage diameter) on oil yield, extraction efficiency and machine capacity, a stepwise regression model of the form in equation 4.11 was used.

$$Y = ax_1 + bx_2 + c \quad \text{....................4.11}$$

4.7.1 Oil Yield

The stepwise regression model was used to determine the effect of pore size (X_1) and cage diameter (X_2) on oil yield for whole seed (Y_1) and oil yield for ground seeds (Y_2). The model coefficients were found to be 0.00915 and -0.047 for whole seed and 0.013 and -0.048 for ground seed respectively. The oil yield can thus be evaluated from eqn. 4.12 and 4.3 for whole and ground seed respectively.

$$Y_1 = 0.596 + 0.0092x_1 - 0.047x_2 \quad \text{................4.12}$$

$$Y_2 = 0.618 + 0.013x_1 - 0.048x_2 \quad \text{................4.13}$$

Using this model, pore size and cage diameter account for over 75 % of the variation observed for in oil yield for whole seeds and 77 % for ground seeds with standard errors of 0.067 and 0.064 respectively. It has a very high predictive power.

The positive coefficient of pore size (X_1) shows that an increase in this variable would lead to an increase in oil yield (Y_1). Similarly the negative coefficient of the cage diameter (X_2) signifies that a reduction in this variable will result in an increase in oil yield (Y_2).

4.7.2 Extraction Efficiency

The stepwise regression model was equally used to determine the effect of pore size (X_1) and cage diameter (X_2) on extraction efficiency for whole seed (Y_3) and extraction efficiency for ground seeds (Y_4). The regression coefficients were found to be 0.017 and – 0.087 for whole seeds and 0.023 and -0.088 for ground seeds. The extraction efficiency can thus be evaluated from eqn. 4.14 and 4.15 for whole and ground seed respectively.

$Y_3 = 1.091 + 0.017x_1 - 0.087x_2$ 4.14

$Y_4 = 1.130 + 0.023x_1 - 0.088x_2$ 4.15

Using this model, pore size (X_1) and cage diameter (X_2) accounts for over 75 % of the variation observed in extraction efficiency (Y_2) for whole seed and 77 % for ground seed with standard errors of 0.123 and 0.117 respectively. It has a high predictive power.

The positive coefficient of pore size shows that an increase in this variable would lead to a better performance of the machine in terms of extraction efficiency while the negative coefficient of the cage diameter indicates that a reduction in these variables would increase the extraction efficiency of this machine.

4.7.3 Machine Capacity

The stepwise regression analysis was used to determine the effects of pore size (X_1) and cage diameter (X_2) on machine capacity for whole seed (Y_5) and machine capacity for ground groundnut seed (Y_6). These variables can be presented mathematically below in form of eqn.4.16 and4.17 for whole and ground seed respectively.

$Y_5 = 0.097 + 0.022x_1 + 0.060x_2$ 4.16

$Y_6 = 0.035 + 0.031x_1 + 0.07x_2$ 4.17

It can be deduced from the model, that using pore size and cage diameter to predict machine capacity accounts for 29 % of the variation observed in machine capacity for whole seed and 37 % for ground seed which is not suitable at 0.01 level of significance since their coefficients are not significantly different from zero (p- value > 0.01).

However, the positive coefficient of pore size (X_1) and cage diameter (X_2) shows that an increase in these variables would lead to an increase in machine capacity for (Y_5 and Y_6).

4.8 Effect of Pore Size and Cage Diameter on Physical and Chemical Properties of Oil

Table 4.5 and 4.6 shows the effect of pore size and cage diameter on the physico chemical properties of the oil.

It was observed that the pore size and cage diameter did not have any significant effect $P \leq 0.05$ on the physico chemical characteristic considered.

The oils produced were observed to be useful in industries that manufacture soap and cooking oil due to there relatively low acid values 5.68, 5.84 and 5.85, for 3, 4 and 5 mm pore size and 5.80, 5.84 and 5.20 for 5.2, 7.9 and 10 cm cage diameter respectively as compared to 21.0±1.0 obtained by Dosumu and Ochu (1995) from the seeds of *Piper guinease*.

The iodine values for varied pore size and cage diameter were mostly below 35. These values were lower than those reported by Pearson (1981) that is 80 – 100 g/100g as recorded for most edible oil. This indicates low degree of unsaturation and classified as non drying oil. A good drying oil should have iodine value 180 and above (Kyari, 2008).

The peroxide value obtained at different pore sizes and cage diameter ranges between 2.0 and 2.3 meq/kg, with pore size 3 and 5 mm ranking as the highest. These values were not far from cotton seed oil of 3.2 meq/kg reported by Popoola and Yangomodou (2006). The low value indicates that the oil can resist lipolytic hydrolysis and oxidation deterioration (Pearson, 1981).

The saponification value range of 191±0.52 to 193±2.92 is close to 187- 196 meqKOH/g reported by Pearson (1981). This property makes the oil useful in soap making. Also Denniston *et al*., (2004) reported that high saponification value indicated the presence of greater number of ester bonds, suggesting that the fat molecules were intact. Similarly the physical characteristics did not show significant variations in their compositions.

The melting point for pore size 3, 4 and 5 mm was observed to be around 27°C, while highest 28°C was recorded for cage diameter of 10 cm. A melting point can be used to identify a substance and to get an indication of its purity. The melting point (or freezing point) of a solid is the temperature at which the solid *exists in equilibrium* with its liquid state under an external pressure of one atmosphere.

The corresponding freezing points obtained were 19, 18 and 18°C for both pore size and cage diameter. This explains the fact that the oil is liquid at room temperature.

The smoking point for 3, 4 and 5 mm were observed to between 210 and 220°C same for cage diameter, and the corresponding flash point were 290°C respectively. This is an indication that the oil will be good for frying and will not dry out easily. Also the oil will not catch fire at the range of temperature used in frying.

The density for the pore size and cage diameter showed some variation ranging from 0.897 and 0.876, with cage diameter 10 cm ranking as the highest 0.897 This is one of the most important physical parameters that affect or specify oil quality. According to Etuk (2006) density is a useful aid in controlling hydrogenation and blending of fat. Ukpong (2006) also stated that the density of oil is an indicator or index of its total solid content.

The viscosity ranges between 0.5 and 0.60 with the highest 0.60, indicated for pore size 3 and 5 mm and cage diameter 5.2 and 7.9 cm respectively. Viscosity is a measure of the frictional force in a liquid (Sharma and Sharma, 2004). The degree of viscous drag depends on the density of the liquid implying that the denser a liquid, the higher its viscosity. This accounts for the measured relative values for the viscosities of the different oil.

The suspended particles were observed to vary significantly $P \leq 0.05$ between (2390 and 4236) for the various pore sizes and cage diameter. This was observed to decrease with increase in cage diameter and increase with decreasing pore size. The highest, 4158 mg/l, was obtained for 5 mm followed by 3168 mg/l for 4 mm while 3 mm gave the least. This could obviously be attributed to the fact that as the pore size gets bigger it becomes difficult for the sample to compact together and act like sieve to restrict particle flow into the oil. Also the decrease in suspended particle with increase in cage diameter could be as a result of applied pressure as explained by Owolarafe et al. (2008) on hydraulically expressed palm oil. That is with higher pressure, there is the tendency that more of the fine fibre may be forced out causing the oil to look like slurry.

Table 4.5: Effect of Pore Size on the Physical and Chemical Properties of Oil

Parameter	3 (mm)	4 (mm)	5 (mm)
Acid value	5.68±0.20[a]	5.84±0.20[a]	5.85±0.20[a]
Iodine value	34.7±1.6[a]	34.9±4.3[a]	35.6±8.0[a]
Peroxide value	2.3±0.00[a]	2.0±2.80[a]	2.3±0.01[a]
Saponification value	193±2.60[a]	192±2.75[a]	193±2.92[a]
Melting point	27±0.10[a]	27±0.33[a]	27±0.41[a]
Freezing point	19±0.22[a]	18±0.45[a]	18±0.43[a]
Smoking point	220±0.16[a]	220±0.08[a]	220±0.34[a]
Flash point	290± 0.00[a]	290± 0.5[a]	290±0.13[a]
Viscosity	0.60±0.01[a]	0.50±0.09[a]	0.60±0.05[a]
Density	0.876± 0.0[a]	0.876±0.1[a]	0.876±0.3[a]
Suspended particle	2390±1.6[c]	3168±073[b]	4158±0.3[a]

Values are means of triplicate reading ± SD. Mean with different superscript in the same roll are significantly different at P≤ 0.05.

Table 4.6: Effect of Cage Diameter on the Physical and Chemical Properties of Oil

Parameter	5.2 (cm)	7.9 (cm)	10 (cm)
Acid value	$5.80^{a} \pm 0.00$	$5.84^{a} \pm 0.20$	$5.20^{a} \pm 0.57$
Iodine value	$34.7^{a} \pm 8.0$	$34.9^{a} \pm 4.3$	$35.2^{a} \pm 8.0$
Peroxide value	$2.2^{a} \pm 1.40$	$2.0^{a} \pm 2.80$	$2.0^{a} \pm 0.30$
Saponification value	$192^{a} \pm 0.35$	$192^{a} \pm 2.75$	$192^{a} \pm 0.52$
Melting point	$27^{a} \pm 0.37$	$27^{a} \pm 0.33$	$28^{a} \pm 0.46$
Freezing point	$18^{a} \pm 0.42$	$18^{a} \pm 0.45$	$19^{a} \pm 0.21$
Smoking point	$220^{a} \pm 0.24$	$220^{a} \pm 0.32$	$210^{a} \pm 0.11$
Flash point	$290^{a} \pm 0.30$	$290^{a} \pm 0.50$	$298^{a} \pm 0.10$
Viscosity	$0.55^{a} \pm 0.15$	$0.50^{a} \pm 0.06$	$0.50^{a} \pm 0.16$
Density	$0.897^{a} \pm 0.2$	$0.886^{b} \pm 0.1$	$0.876^{c} \pm 0.1$
Suspended particle	$4236^{a} \pm 4.1$	$3168^{b} \pm 2.6$	$2840^{c} \pm 1.6$

Values are means of triplicate reading ± SD. Mean with different superscript in the same roll are significantly different at $P \leq 0.05$.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

A manually operated hydraulic press for extracting oil from decorticated groundnut seed has been developed and evaluated. The study revealed that machine performance was affected by material type, pore size and cage diameter. Optimum performance of hydraulic extractor in terms of oil yield, extraction efficiency and machine capacity was obtained at a pore size of 4 mm for ground seeds of groundnut.

Similarly an optimum performance of the hydraulic extractor in terms of oil yield, extraction efficiency and machine capacity was obtained at a cage diameter of 5.2 cm for ground seed of groundnut. In general, decreasing cage diameter resulted in an increased machine performance. Furthermore, the model developed was adequate at predicting the machine performance. A combination of pore size of 4 mm and cage diameter of 5.2 cm was found to be the optimum level to achieving maximum hydraulic press efficiency.

The groundnut oil produced was found to be of high quality and the physical and chemical properties were comparable to values obtained in the literature. However, the suspended particles were significant hence of concern.

5.2 RECOMMENDATION FOR FURTHER STUDY

Based on the conclusions made on this study, in other to fully exploit the possibility of improving the performance of oil extractor using hydraulic press it is recommended that further studies be carried out using cage diameter of 5.2 cm but varying the pore size.

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APPENDICE I

Table 4.1: Effect of Pore Size on Oil Yield, Extraction Efficiency and Machine Capacity For Whole and Ground Seed at cage size of 7.9 cm

Pore size (mm)	Oil Yield (%)		Extraction Efficiency (%)		Machine Capacity (kg/hr)	
	Whole	Ground	Whole	Ground	Whole	Ground
3	21.25^a±3.08	23.61^a±2.97	38.89^a±5.63	43.21^a±5.45	0.510^a±0.74	0.567^a±0.07
4	23.02^a±0.62	26.87^a±0.59	42.14^a±1.14	49.19^a±1.08	0.552^a±0.02	0.645^a±0.02
5	23.08^a±0.71	26.15^a±0.68	42.24^a±1.30	47.87^a±1.25	0.554^a±0.17	0.628^a±0.02

Values are means of triplicate reading ± SD. Mean with different superscript in the same column are significantly different at P≤0.05.

APPENDICE II

Table 4.2: Effect of Material Type on Oil Yield, Extraction Efficiency and Machine Capacity at Different Pore Size at Cage Size of 7.9 cm

Material Type	Oil Yield (%)			Extraction Efficiency (%)			Machine Capacity (kg/hr)		
	3	4	5	3	4	5	3	4	5
Whole	21.25^{a}	23.02^{b}	23.08^{a}	38.89^{a}	42.14^{b}	42.24^{a}	0.510^{a}	0.552^{b}	0.554^{a}
	± 3.08	± 0.62	± 0.71	± 5.63	± 1.14	± 1.30	± 0.74	± 0.02	± 0.17
Ground	23.61^{a}	26.87^{a}	26.15^{a}	43.21^{a}	49.19^{a}	47.87^{a}	0.567^{a}	0.645^{a}	0.628^{a}
	± 2.97	± 0.59	± 0.68	± 5.45	± 1.08	± 1.25	± 0.07	± 0.02	± 0.02

Values are means of triplicate reading ± SD. Mean with different superscript in the same column are significantly different at $P \leq 0.05$.

APPENDICE III

Table 4.3: Effect of Cage Diameter on Oil Yield, Extraction Efficiency and Machine Capacity Whole and Ground Seed at Pore Size of 4 mm

Cage diameter (cm)	Oil Yield (%)		Extraction Efficiency (%)		Machine Capacity (kg/hr)	
	Whole	Ground	Whole	Ground	Whole	Ground
5.2	43.17^{a} ±1.81	46.01^{a} ±1.72	79.02^{a} ±3.31	84.22^{a} ±3.15	0.648^{b} ±0.03	0.691^{b} ±0.03
7.9	23.02^{b} ±0.62	26.87^{b} ±0.59	42.14^{b} ±1.13	49.18^{b} ±1.08	0.552^{b} ±0.02	0.641^{b} ±0.01
10	21.74^{b} ±3.98	24.08^{b} ±3.86	39.80^{b} ±3.29	44.09^{b} ±3.08	0.978^{a} ±0.17	1.084^{a} ±0.17

Values are means of triplicate reading ± SD. Mean with different superscript in the same column are significantly different at $P \leq 0.05$.

APPENDICE IV

Table 4.4. Effect of Material Type on Oil Yield, Extraction Efficiency and Machine Capacity for Whole and Ground Seed. at Pore Size of 4 mm

Material Type	Oil Yield (%)			Extraction Efficiency (%)			Machine Capacity (kg/hr)		
	5.2	7.9	10	5.2	7.9	10	5.2	7.9	10
Whole	43.17^{a} ± 1.81	23.02^{b} ± 0.62	21.74^{a} ± 3.98	79.02^{a} ± 3.31	42.14^{b} ± 1.13	39.80^{a} ± 3.29	0.648^{a} ± 0.03	0.552^{b} ± 0.02	0.978^{a} ± 0.17
Ground	46.01^{a} ± 1.73	26.87^{a} ± 0.59	24.08^{a} ± 3.86	84.22^{a} ± 3.15	49.18^{a} ± 1.08	44.09^{a} ± 3.08	0.691^{a} ± 0.03	0.641^{a} ± 0.01	1.084^{a} ± 0.17

Values are means of triplicate reading ± SD. Mean with different superscript in the same column are significantly different at $P \leq 0.05$.

APPENDICE V
STATISTICAL ANALYSIS

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OIL YIELD	Between Groups	650.794	2	325.397	45.369	.001
	Within Groups	35.861	5	7.172		
	Total	686.655	7			
CAKE YIELD	Between Groups	650.794	2	325.397	45.369	.001
	Within Groups	35.861	5	7.172		
	Total	686.655	7			
MACHINE EFFICIENCY	Between Groups	2180.702	2	1090.351	45.416	.001
	Within Groups	120.041	5	24.008		
	Total	2300.742	7			
MACHINE CAPACITY	Between Groups	.293	2	.147	11.165	.014
	Within Groups	6.561E-02	5	1.312E-02		
	Total	.359	7			

Post Hoc Tests

Homogeneous Subsets

OIL YIELD

Duncan

	N	Subset for alpha = .05	
SAMPLE		1	2
10 (cm)	3	21.7400	
7.9 (cm)	3	23.0200	
5.2 (cm)	2		43.1700
Sig.		.611	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571. b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

CAKE YIELD

Duncan

SAMPLE	N	Subset for alpha = .05 1	2
5.2 (cm)	2	56.8300	
7.9 (cm)	3		76.9800
10 (cm)	3		78.2600
Sig.		1.000	.611

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571.
b The group sizes are unequal.
The harmonic mean of the group sizes is used.
Type I error levels are not guaranteed.

MACHINE EFFICIENCY

Duncan

SAMPLE	N	Subset for alpha = .05 1	2
10 (cm)	3	39.7967	
7.9 (cm)	3	42.1400	
5.2 (cm)	2		79.0250
Sig.		.611	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 2.571. b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Report

SAMPLE		OIL YIELD	CAKE YIELD	MACHINE EFFICIENCY	MACHINE CAPACITY
3 (mm)	Mean	21.2467	78.7533	38.8900	.5100
	Std. Deviation	3.0752	3.0752	5.6296	7.363E-02
	Std. Error of Mean	1.7755	1.7755	3.2503	4.251E-02
4 (mm)	Mean	23.0200	76.9800	42.1400	.5523
	Std. Deviation	.6222	.6222	1.1390	1.504E-02
	Std. Error of Mean	.3592	.3592	.6576	8.686E-03
5 (mm)	Mean	23.0767	76.9233	42.2433	.5537
	Std. Deviation	.7122	.7122	1.3032	1.716E-02
	Std. Error of Mean	.4112	.4112	.7524	9.905E-03
Total	Mean	22.4478	77.5522	41.0911	.5387
	Std. Deviation	1.8439	1.8439	3.3763	4.414E-02
	Std. Error of Mean	.6146	.6146	1.1254	1.471E-02

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
OIL YIELD	Between Groups	6.497	2	3.248	.941	.441
	Within Groups	20.703	6	3.450		
	Total	27.199	8			
CAKE YIELD	Between Groups	6.497	2	3.248	.941	.441
	Within Groups	20.703	6	3.450		
	Total	27.199	8			
MACHINE EFFICIENCY	Between Groups	21.818	2	10.909	.943	.440
	Within Groups	69.376	6	11.563		
	Total	91.194	8			
MACHINE CAPACITY	Between Groups	3.701E-03	2	1.850E-03	.934	.443
	Within Groups	1.188E-02	6	1.981E-03		
	Total	1.558E-02	8			

Post Hoc Tests

Homogeneous Subsets

OIL YIELD
Duncan

SAMPLE	N	Subset for alpha = .05
		1
3 (mm)	3	21.2467
4 (mm)	3	23.0200
5 (mm)	3	23.0767
Sig.		.287

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CAKE YIELD

Duncan

SAMPLE	N	Subset for alpha = .05
		1
5 (mm)	3	76.9233
4 (mm)	3	76.9800
3 (mm)	3	78.7533
Sig.		.287

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

MACHINE EFFICIENCY

Duncan

SAMPLE	N	Subset for alpha = .05
		1
3 (mm)	3	38.8900
4 (mm)	3	42.1400
5 (mm)	3	42.2433
Sig.		.287

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

MACHINE CAPACITY

Duncan

SAMPLE	N	Subset for alpha = .05
		1
3 (mm)	3	.5100
4 (mm)	3	.5523
5 (mm)	3	.5537
Sig.		.289

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Report

SAMPLE		OIL YIELD	CAKE YIELD	MACHINE EFFICIENCY	MACHINE CAPACITY
3 (mm)	Mean	23.6067	76.3933	43.2133	.5667
	Std. Deviation	2.9799	2.9799	5.4541	7.111E-02
	Std. Error of Mean	1.7204	1.7204	3.1489	4.106E-02
4 (mm)	Mean	26.8700	73.1300	49.1867	.6447
	Std. Deviation	.5923	.5923	1.0839	1.457E-02
	Std. Error of Mean	.3420	.3420	.6258	8.413E-03
5 (mm)	Mean	26.1533	73.8467	47.8733	.6277
	Std. Deviation	.6870	.6870	1.2574	1.617E-02
	Std. Error of Mean	.3967	.3967	.7260	9.333E-03
Total	Mean	25.5433	74.4567	46.7578	.6130
	Std. Deviation	2.1521	2.1521	3.9390	5.142E-02
	Std. Error of Mean	.7174	.7174	1.3130	1.714E-02

APPENDICE VI

REGRESSION ANALYSIS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.86309
R Square	0.744925
Adjusted R Square	0.48985
Standard Error	0.066993
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.026214	0.013107	2.920412	0.255075
Residual	2	0.008976	0.004488		
Total	4	0.03519			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.596137	0.245285	2.430384	0.135678	-0.45924	1.651514
Pore Size	0.00915	0.047371	0.193154	0.864676	-0.19467	0.212973
Cage Diameter	-0.04733	0.019646	-2.40905	0.137617	-0.13186	0.037202

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*
1	0.249691	-0.03719	-0.78508
2	0.386628	0.045072	0.951459
3	0.258841	-0.02864	-0.6046
4	0.15945	0.05795	1.223305
5	0.267991	-0.03719	-0.78508

PROBABILITY OUTPUT

Percentile	*Y*
10	0.2125
30	0.2174
50	0.2302
70	0.2308
90	0.4317

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.86296
R Square	0.7447
Adjusted R Square	0.489401
Standard Error	0.122684
Observations	5

ANOVA

	df	SS	MS	F	Significance F
Regression	2	0.087809	0.043904	2.916968	0.2553
Residual	2	0.030103	0.015051		
Total	4	0.117912			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	1.091093	0.449188	2.429035	0.1358	-0.84161	3.02379
Pore Size	0.01675	0.086751	0.193082	0.864725	-0.35651	0.39000
Cage Diameter	-0.08662	0.035978	-2.40762	0.137747	-0.24142	0.06817

RESIDUAL OUTPUT

Observation	Predicted Y	Residuals	Standard Residuals
1	0.457035	-0.06814	-0.78542
2	0.707663	0.082537	0.951429
3	0.473785	-0.05239	-0.60386
4	0.291881	0.106119	1.223265
5	0.490535	-0.06814	-0.78542

PROBABILITY OUTPU

Percentile	Y
10	0.388
30	0.39
50	0.421
70	0.422
90	0.790

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.538256
R Square	0.28972
Adjusted R Square	-0.42056
Standard Error	0.227703
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.042298	0.021149	0.407895	0.71028
Residual	2	0.103698	0.051849		
Total	4	0.145995			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.096571	0.833699	0.115834	0.918366	-3.49054	3.68368
Pore Size	0.022	0.16101	0.136637	0.903831	-0.67077	0.71477
Cage Diameter	0.059618	0.066775	0.892816	0.466166	-0.22769	0.3469

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*
1	0.633554	-0.12355	-0.76737
2	0.494585	0.153415	0.952825
3	0.655554	-0.10355	-0.64315
4	0.780752	0.197248	1.225061
5	0.677554	-0.12355	-0.76737

PROBABILITY OUTPU

Percentile	*Y*
10	0.5
30	0.55
50	0.55
70	0.64
90	0.97

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.878032
R Square	0.77094
Adjusted R Square	0.54188
Standard Error	0.063734
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.027343	0.013671	3.365672	0.22906
Residual	2	0.008124	0.004062		
Total	4	0.035467			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.617674	0.233351	2.646975	0.117992	-0.38635	1.621701
Pore Size	0.0127	0.045067	0.281805	0.804576	-0.18121	0.206606
Cage Diameter	-0.0482	0.01869	-2.57913	0.123166	-0.12862	0.032213

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*
1	0.274955	-0.03886	-0.86218
2	0.417809	0.042291	0.938423
3	0.287655	-0.01896	-0.42061
4	0.186425	0.054375	1.206544
5	0.300355	-0.03886	-0.86218

PROBABILITY OUTPUT

Percentile	*Y*
10	0.236
30	0.240
50	0.261
70	0.268
90	0.460

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.877862
R Square	0.770642
Adjusted R Square	0.541284
Standard Error	0.116735
Observations	5

ANOVA

	df	SS	MS	F	Significance F
Regression	2	0.091574	0.045787	3.359994	0.229358
Residual	2	0.027254	0.013627		
Total	4	0.118828			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%
Intercept	1.130254	0.427407	2.644445	0.11818	-0.70873
Pore Size	0.0233	0.082544	0.282273	0.804264	-0.33186
Cage Diameter	-0.08822	0.034233	-2.57688	0.123343	-0.23551

RESIDUAL OUTPUT

Observation	Predicted Y	Residuals	Standard Residuals
1	0.503254	-0.07115	-0.86201
2	0.764735	0.077465	0.938465
3	0.526554	-0.03475	-0.42104
4	0.341302	0.099598	1.206598
5	0.549854	-0.07115	-0.86201

PROBABILIT

Percentile
10
30
50
70
90

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.606714
R Square	0.368102
Adjusted R Square	-0.2638
Standard Error	0.232791
Observations	5

ANOVA

	df	SS	MS	F	Significance F
Regression	2	0.063137	0.031568	0.582535	0.631898
Residual	2	0.108383	0.054192		
Total	4	0.17152			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0.034852	0.852326	0.04089	0.971098	-3.63241	3.70211
Pore Size	0.03065	0.164608	0.1862	0.869463	-0.6776	0.73890
Cage Diameter	0.072582	0.068267	1.063202	0.399081	-0.22115	0.36631

RESIDUAL OUTPUT

Observation	Predicted Y	Residuals	Standard Residuals
1	0.7002	-0.1335	-0.81102
2	0.534878	0.156122	0.948446
3	0.73085	-0.08985	-0.54584
4	0.883272	0.200728	1.21943
5	0.7615	-0.1335	-0.81102

PROBABILITY OUTPU

Percentile	Y
10	0.566
30	0.62
50	0.64
70	0.69
90	1.08