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## **DEVELOPMENT AND EVALUATION OF A DOUBLE PEDAL OPERATED PISTON PUMP**

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### **ABSTRACT**

A study was undertaken to design and construct a low-lift double pedal, double cylinder operated pump for use in small irrigation project areas. The double pedal pump was operated by one adult man power. The pump discharge rate, speed, maximum lift, discharge length, suction head and efficiency were determined. The average discharges of the pump ranged from 10.1 to 1.6 litres per minute were noted against heads of 0.35 to 2.1m. It was observed that the discharge rate depends on effort applied by operator and suction head. Efficiency of the pump was 57 percent against a head of 0.35 m. The double pedal pump can be constructed using local materials and skill. It would be suitable to irrigate small plots like vegetables and seed beds with less physical effort.

**Keywords:** Pedal pump, Suction head, Discharge rate, Efficiency, Discharge length, Irrigation

### **1. INTRODUCTION**

Scarcity of water resources is one of the main challenges in the world and it is considered as one of the limiting factors for economic development especially for agriculture. With the supply

of irrigation water, most of the agricultural lands can be brought under cultivation of high yielding crops. The productivity of the land now producing food under natural condition can be increased considerably by the application of supplemental irrigation (Islam *et al.*, 2007).

Irrigation system is aimed at increasing and improving agricultural yield, particularly in moisture-deficient environments. It plays a vital role as a leading input because the productivity of other inputs such as improved seed and fertilizers largely depend on the availability of ensured water supply in the fields.

In Africa, where the majority of farmers are still smallholders with one to three hectares (ha), small-scale private irrigation schemes (SPRI) are likely to bring higher returns per hectare than government-led schemes (Takeshima *et al.*, 2010). SPRI benefits farmers in a variety of ways. It usually leads to higher profitability of various crops (Yaro, 2004). It also benefits farmers (including female farmers) by producing more food crops in the “slack” period of rain fed agriculture (Ogunjimi and Adekalu, 2002). SPRI enables households to irrigate garden vegetables, water livestock, and undertake microenterprises (Westby *et al.* 2005).

In Nigeria different manually operated water pumps for low lift irrigation are used especially in the north where proper mechanization are employed including irrigation application. The pedal pump seems to be an appropriate irrigation technology in rural areas, where labours are abundant and most of the farmers are poor (Iqbal, 2010). Such kind of irrigation technologies are operated and maintained by farmers themselves from their own capital for producing crop in the small fragmented lands. The average small farm sizes spreading over a number of scattered plots are unsuitable to irrigate with a large size of stream (Islam *et al.*, 2007).

The socio-economic condition of Nigerian farmer does not permit large scale irrigation investment. Hence, introduction of pedal pumps for the irrigation of small scale farms can play a vital role for increasing food grain production in Nigeria. Capital intensive technology like deep tubewells and shallow tubewells are beyond the purchasing capacity of the poor farmers. However, they can afford labour intensive technologies such as pedal pumps, hand pumps, rower pumps, treadle pumps and many more due to their lower cost.

The current success of manually operated pumps can be explained in terms of factors like appropriate design, low cost, effective marketing, and high cash returns (Orr *et al.*, 1991). Some researchers (Obijiaku, 2011; Sermaraji, 2014) had focused their endeavour on the development of low lift labour-intensive devices and had succeeded in developing pumps such as treadle pump, rower pump, wheel pump, diaphragm pump, blower pump and many more. But these pumps still are not popular in the country due to their low efficiencies and discharges, short service lives, high friction losses and many other mechanical troubles.

According to survey report (Faruk and Pramanik, 1995) many users of these devices complained about their health troubles and desired to get a better technology requiring less manual power and mechanical troubles. High initial maintenance cost, non-availability of spare parts, requirements of large irrigable land and similar other restrictions make the poor illiterate farmers reluctant to use deep tubewells and shallow tubewells. But double pedal pumps can be locally produced at low-cost with all the spare parts available in the country. Thus, the objective of this study was to design, develop and test a double pedal piston pump with a relatively high discharge rate and improved ergonomics for safe operation.

## 2. MATERIALS AND METHODS

### 2.1 Design Considerations

For efficient design of the double pedal pump, factors such as workability, safety of the operators, ease of maintenance, and minimal cost of machine by ensuring that construction materials are sourced locally were considered.

### 2.2 Design calculations

#### Area of piston (A)

The area of piston was determined using equation 1.

$$A = \frac{\pi d^2}{4} \quad (1)$$

Where,

$d = \text{diameter of piston}$

#### Volume of Cylinder (V)

$$V = \frac{\pi d^2 h}{4} \quad (2)$$

Where,

$d = \text{diameter of cylinder}$

$h = \text{height of cylinder}$

#### Pump discharge

$$Q = \frac{\text{Volume of water collected L/min}}{\text{time spent}} \quad (3)$$

### **Pump speed**

$$P_s = \frac{\text{number of stroke}}{\text{times spent}}, \text{in stroke/min} \quad (4)$$

### **Pump efficiency**

$$E_p = \frac{\text{actual volume}}{\text{theoretical volume}} \times \frac{100}{1} \quad (5)$$

## **2.3 Description of the Developed Pedal Pump**

The pedal pump consists of frame, cylinders, pistons seal, lever, non-returning valve, spring and pedals. Fig. 1 gives the developed pedal pump.

### **Frame**

The two design factors considered in determining the material required for the frame are weight and strength. The frame was constructed with 25 mm by 25 mm mild steel angle iron. The frame provides firm support for the entire assembly. Based on anthropometric considerations, the overall dimension of the frame was chosen as 580 mm x 500 mm x 900 mm.

### **Cylinders**

The cylinder is a chamber where water is collected temporarily from the inlet pipe after suction before going out through outlet. Cylinders from internal combustion engine of Peugeot 504 were used. The internal and external diameters of the cylinder were about 88 mm and 93 mm respectively.

### **Pistons**

The piston which has a length of 71 mm and diameter of 87 mm was sealed with a circular rubber seal and glued to the surface of the piston. The piston reciprocates in the cylinder to

create a partial vacuum and suction pressure where the water is sucked in at higher pressure and expelled through the outlet pipe.

### **The Manifold System**

The manifold which comprises of pipe, valve, nipple, elbow, non-returning valve was created at the lower part of the pump and also at the side which helps in the suction and delivery of water.

### **Pedals**

The pedals were made of angle iron connected with a rod, which was used to move the piston. Operator forces the pedal downward with his foot which in turn causes the piston to move downward. The size of the pedal was 410 mm x100 mm and was found to be comfortable to place a foot on it.

### **Principle of Operation**

The pump is easy and requires minimal energy to operate. During the upward movement of the piston, a negative pressure [vacuum] is created in the cylinder, which opens the non-returning valve and water enters the pump chamber of the cylinder. High pressure generated in the pump chamber as the piston moves downward closes the non-returning valve. This pressure is due to compression of water which in turn opens the valves and water flows from the suction to delivery side of the cylinder. Water which accumulated in the cylinder discharges as the process is repeated.

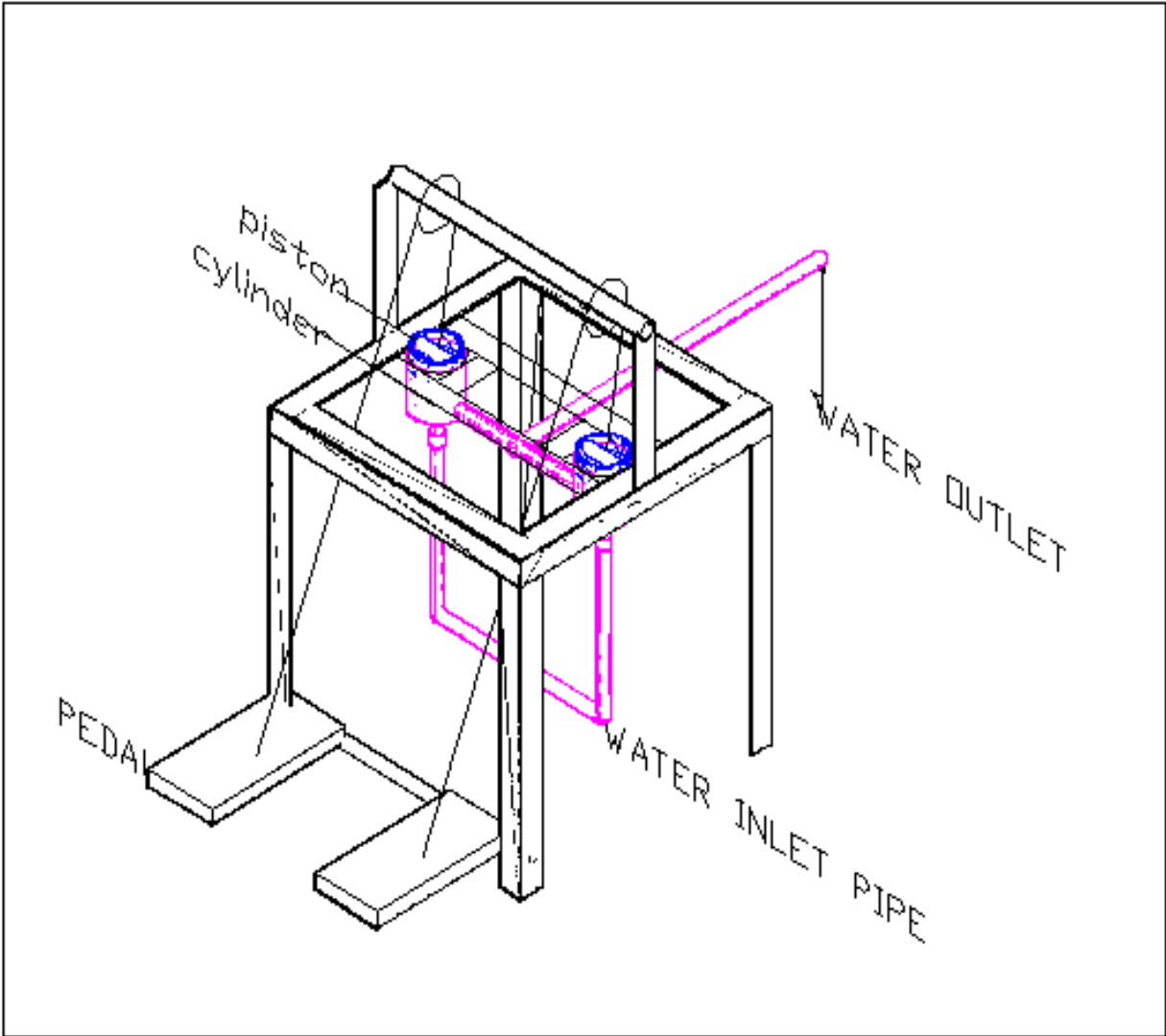


Fig. 1: Isometric View of the Double Pedal Pump

### 3. Experimental Procedure

The pedal pump was tested at soil and water Engineering laboratory, Agricultural and Bioresources Engineering Department, Michael Okpara University of Agriculture, Umudike.

The pump was tested at different suction head and was operated manually by an average sized man under the normal operating conditions. The pump was set up on a plat form over a bucket of cross sectional area of 0.07m<sup>2</sup> and height of 1m. The depth of water in bucket was varied by reducing the water level. The number of strokes that an operator was capable to give in one minute was termed as stroke per minute (spm). For each operation, one litre of water was collected using a measuring cylinder. Each test was carried out in three replications and in each case the operation period, number of stroke and volume of water were measured. The discharge rate in litre per minute was determined.

#### Pump Performance

The performance of the pedal pump was evaluated based on the following parameters:

##### i Pump Speed

During the operation of the pump, the number of strokes were counted for a known time. The time was recorded using a digital stop watch. Pump speed was calculated using equation 6.

$$Pump\ speed = \frac{number\ of\ strokes}{time\ (min)} \quad (6)$$

##### ii Pump Efficiency

The efficiency of pump was calculated from the following equation:

$$E_p = \frac{\text{actual volume}}{\text{theoretical volume}} \times \frac{100}{1} \quad (7)$$

Where; theoretical volume = stroke x cross sectional area of the pump

$$\text{Actual volume} = \frac{\text{volume of water collected in litres per minute}}{\text{number of strokes}} \quad (8)$$

#### 4. RESULTS AND DISCUSSIONS

.The depth of water level (i.e. suction heads) varied from 0.35 to 2.1 m depending on laboratory facilities and the stroke length of the pedal pump. Maximum discharge length, pump efficiency and mean pump speed of the double pedal pump obtained were 5.8 m, 57% and 60 strokes/min, respectively. The double pedal pump has a maximum discharge rate of 10.1 litres. Table 1 show that increase in suction head leads to a decrease in discharge rate. Islam *et al.* (2007) recorded pump efficiency of 46.53 % for a single cylinder and piston. Higher pump efficiency obtained in this study was attributed to the additional cylinder used. The constructed double pedal pump was found suitable for operation under a suction head up to 0.35 meters for several minutes (10 minutes). The operation of the double pedal pump was found more comfortable and suitable. It was quantified by the maximum operation time during which an average sized man can operate the pump without much physical troubles.

Table 1: Effect of Suction Head on Discharge Rate

Time(minute)	Number of stroke	Suction head(meters)	Pump speed(stroke/min)	Discharge (L/min)	Delivery head(m)	efficiency%
1	62	0.35	62	10.1	2.6	57
2	120	0.70	60	16.2	3.0	52
3	180	1	60	24.3	3.8	46
4	244	1	61	29.4	3.8	46
5	300	1	60	35.5	3.8	47
6	360	1	60	43.6	3.7	47
7	420	1	60	51.7	3.8	47
8	478	1	60	58.8	3.8	47
9	536	1	60	63.9	3.8	46
10	593	1	59	72.0	3.8	47

Table 2: Performance Test Data of the Double Pedal Pump

Time(minute)	Number of stroke	Suction head(meters)	Pump speed(stroke/min)	Discharge (L/min)	Delivery head(m)	efficiency%
1	62	0.35	62	10.1	2.6	57
2	120	0.70	60	16.2	3.0	52
3	180	1	60	24.3	3.8	46
4	244	1	61	29.4	3.8	46
5	300	1	60	35.5	3.8	47
6	360	1	60	43.6	3.7	47
7	420	1	60	51.7	3.8	47
8	478	1	60	58.8	3.8	47
9	536	1	60	63.9	3.8	46
10	593	1	59	72.0	3.8	47

## 5. CONCLUSION

The pedal operated piston pump was constructed to reduce various waterborne diseases and facilitate the production of crops through irrigation during the dry season. The pump was tested to find out the discharge rates and efficiencies at different time intervals. The result from the test shows that the pump has volumetric efficiency of 57 %. It could pump water at a maximum of 10.1 litres per minute. The pump is capable of drawing water from a depth of one meter effectively and therefore expected to be suitable to supply irrigation water for small farm lands.

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## **EFFECT OF DRYING ON NUTRITIONAL QUALITY OF DRIED MEAT (KILISHI)**

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### **ABSTRACT**

Kilishi is a dried meat product obtained from beef, goat meat, or lamb under hot and dry weather condition. 70g of fresh meat each from three different sources (cow meat, goat meat and sheep meat) was sun dried for complete twelve hours and their respective weight was obtained with electronic weighing balance at the interval of one hour. The amount of moisture in wet base was 69.29%, 74.02% and 66.71% while the amount of moisture in dry base was 2.26%, 2.86% and 2.00% for cow meat, goat meat, and sheep meat respectively. More also, the test analysis were carried out on both fresh meat and dried meat product (Kilishi) of the samples by using the standard procedure (AOAC). The results of the test analysis obtained on fresh and dried meat gotten from beef, goat, and sheep meats respectively are as follows: the percentage moisture was 69.00% and 11.00%, 74.00 and 11.83, 65.00% and 9.33%. The percentage ash was 1.00% and 9.50%, 0.50% and 5.17%, 0.67% and 16.00%.The percentage lipid (fat) was 10.50% and 19.67, 10.33% and 17.00%, 16.00% and 22.00%. The percentage crude protein was 19.00% and 38.99%, 15.05% and 37.22%, 18.06% and 38.68%.The percentage crude fibre was 4.17% and 4.83%, 2.33% and 2.83%, 2.67% and 2.83%.The percentage carbohydrate was -0.50% and 20.85%, 0.36% and 28.78%, -0.27% and 23.82%. From the results obtained it was observed that, drying prolongs the self-life of the meat by reducing its moisture content. However, the nutritional quality of the dried meat product (Kilishi) was increased due to various ingredients added to it.

**KEYWORDS:** Kilishi, Drying Rate, Nutritional Quality, Fresh Meat and Effect of Drying

## **1. INTRODUCTION**

Meat is highly perishable which has to undergo some form of preservation to avoid deterioration. The main method of meat preservation transferred by the medieval Arabic sources to West Africa was that of sun drying (Alonge et al, 1981). There are many methods used to prepare dried meat. These include the exposure of strips of lean meat to the sun, as in the manufacture of pemmican by North American Indians, or a combination of salting followed by air drying, as in the preparation of chargui in South American and Bilton in South African (Lawrie, 1979). There are other methods of meat preservation which are: drying, freezing, curing and smoking, cold storage and chilling etc.

Meat is an excellent source of high quality B-complex vitamins and certain minerals especially iron. It digests easily when cooked and supplies nutrients which contribute significantly to the dietary balance of meal. Meat is the flesh of animals consumed for food. In the tropics the bulk of meat consumed is mostly derived from sheep, goat, pig, bush meat, poultry, bird, domesticated animals or wild animal, reptile animal and other sea foods (Hendrickson, 1978).

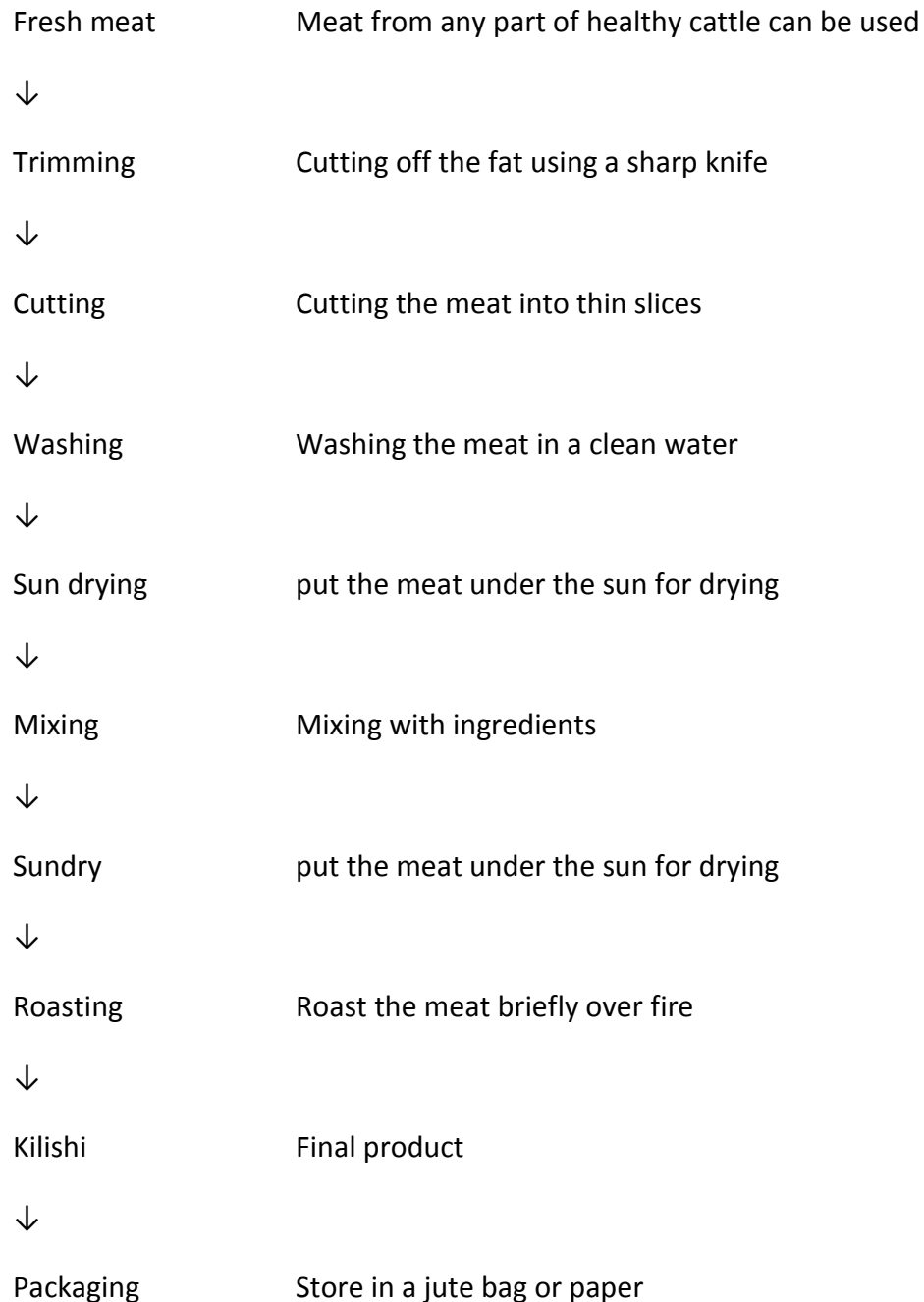
As a general rule, only lean meat is suitable for drying. Visible fatty tissues adhering to muscle tissue have a detrimental effect on the quality of the final product. The meat best for drying is the meat of medium aged animal in a good condition ([www.fao.org](http://www.fao.org)). However, the techniques of meat preservation can either be done by drying alone or in combination with other methods such as salting, curing or smoking. Meat drying techniques have been used for centuries and are considered as the oldest method of meat preservations (FAO, 1990; FAO, 1993).

Most processed and preserved meat by drying are usually more readily available in the market than any other preserved form such as freezing and irradiation. (Gerrard, 1971)

Meat drying is simply the exposure of strips or flat pieces of fresh meat to the sun or open air, this treatment reduces the meat water content rapidly that no bacterial spoilage can take place, even though the temperature remain high. However in order to avoid meat product contamination by insect, dust and other environmental impact during drying, cabinet solar dryers have been developed where warm air is conducted through hermetically closed

chamber. So far no source of energy other than sun has been used in solar drying method (FAO, 1993; FAO, 1994d)

The factors affecting the rate of drying includes; the physical and chemical properties of the product (such as shape, size, composition and moisture content), the geometrical arrangement of the product in relation to the heat transfer surface or medium, the characteristics of the drying equipment and the physical properties of the drying environment (such as air, temperature, humidity and velocity).The fig. 1 below shows the step by step approach to kilishi (dried meat) processing.



**Fig. 1:** the stages involved in the production of kilishi from raw meat sample. Source: (CTA, 1997)

To ensure good quality of kilishi (dried meat) product for human consumption, packaging, storage or transportation should meet the standardization criteria which include;

- The appearance of the dried meat should be as uniform as possible. The absence of large wrinkles and notches indicate the desired steady and uniform dehydration of meat
- The colour of the surface as well as the cross cut should be uniform and dark red.
- Taste and flavor are very important for the acceptance of dried meat by the consumers.

Packaging is a means of protecting the product from contamination to which the meat might be exposed on its way from producer to consumers. Numerous materials are used to package dry meat, such as paper, plastic foils, aluminum foils, cello phone and textiles. It is good to cover the piles of the packaged dried meat with plastic sheet, as additional protection against moisture and dust. The composition of lean muscle contained 74.0% moisture, 2.0% ash, 2.0% fat, 20.0% protein and 2.0% carbohydrate (Norman, 2004).

Kilishi is considered as a source of protein in human nutrition, therefore it is very essential to know the effect of drying and drying rate on nutritional drying of kilishi (dry meat). All these amongst other factors justify this research work.

The main objective of this study is to determine the effect of drying on the nutritional quality of kilishi meat with the view of establishing the moisture loss of kilishi during drying and its proximate composition.

## **2.0 MATERIALS AND METHODS**

### **2.1 Raw Materials and Their Sources**

Two hundred grams (200g) each of raw meat from three different sources, cow meat (beef), goat meat, and sheep meat were bought at Bosso Market Minna, Niger state. Each of raw meat was kept inside the polyethylene bags labeled I, II and III respectively under ambient temperature. These samples were taken to the Federal University of Technology Bosso Campus Minna. 60g each of the raw meat samples which was cut and put inside the polyethylene bags labeled A, B and C were taken to Biochemistry laboratory FUT, Minna for nutritional test and analysis. The remaining 140g each of the samples was processed into kilishi (see figure 1) and

their respective drying rate was determined by checking their weight using an electronic weighing balance at an interval of one hour during drying. The final products 'kilishi' were allowed to cool before packaging into another three set of polyethylene bags labeled D, E and F respectively, and were taken to Biochemistry laboratory FUT, Minna for nutritional test analysis.

## 2.2 Reagents and Instruments Used

### 2.2.1 Reagents

Tetraoxosulphate (vi) acid ( $H_2SO_4$ ), sodium hydroxide(NaOH), calcium chloride ( $CaCl_2$ ), calcium hydroxide( $Ca(OH)_2$ ), methyl orange indicator, ammonium chloride solution ( $NH_4CL$ ), petroleum ether, copper sulphate ( $CuSO_4$ ).

The proximate compositions of these samples were determined using the method as given by Association of Analytical Chemist Standard procedure (A.O.A.C, 1980) and micro kjeldahl method.

## 2.3 Determination of Moisture Content (%)

A metallic dish was dried in an oven at  $80^{\circ}C$  for 20 minutes, it was cooled in a desiccator and weighed ( $W_1$ ) g. 2g of sample A was put into the dish and weighed ( $W_2$ ) g, the dish with the sample A was dried in an oven for  $80^{\circ}C$  for 24 hours until a constant weight was reached, it was then quickly transferred into a desiccator to cool. It was weighed quickly with minimum exposure to atmosphere ( $W_3$ ) g. The loss in weight of the sample A during drying is moisture content. This procedure was repeated for sample B, C, D, E and F, respectively. The percentage moisture content was calculated using equation 1.

$$(\%) \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (1)$$

Where:

$W_1$  =Weight of empty metallic dish (g)

$W_2$  = Weight of metallic dish + fresh sample (g)

$W_3$  = Weight of metallic dish + dry sample (g)

$W_2 - W_1$  = Weight of the fresh sample (g)

$W_3 - W_1$  = Weight of dry sample (g)

#### 2.4 Determination of Ash Content (%).

The ash of a biology material is analytical term for inorganic residue that remains after organic matter has been burnt away.

A clean flat bottomed silica dish of about 7cm diameter was hold in a hot bunsen-burner flame for one minute, it was then transferred into a desiccator to cool and weighted ( $W_1$ ). A 2g of sample A was put into the dish and weighed ( $W_2$ ). The silica dish containing the sample A was heated gently on a bunsen-burner in a fume cupboard until smoking ceased, it was then transfer to a muffle furnace heated to about 500c. The heating continued until all carbon burnt away for about 24 hours. The furnace was switched off; however, the silica dish was taking out and covered immediately. It was placed inside a desiccators to cool and weighed ( $W_3$ ), this procedure was repeated for sample B, .C, D, E, and F respectively. The percentage ash content were calculated using equation 2.

$$\% \text{ Ash Content} = \left( \frac{W_3 - W_1}{W_2 - W_1} \right) \times 100 \quad (2)$$

Where:

$W_1$  = Weight of flat bottomed silica dish (g)

$W_2$  = Weight of flat bottomed silica + sample 'A' before burning (g)

$W_3$  = Weight of flat bottomed silica + sample 'A' after burning (g)

The portion of the sample which burnt off was the organic matter. It was calculated using equation 3.

$$(\%) \text{ Organic matter} = \left( \frac{W_2 - W_3}{W_2 - W_1} \right) \times 100 \quad (3)$$

## 2.5 Determination of Lipid Content (%)

The lipid content of a biological material can be estimated by direct extraction of the dry material exhaustively using a suitable lipid solvent e.g. petroleum, (40c-60c) diethyl ether etc. in a convenient continuous extractor, such as soxhlet, Bolton or Bailey Walker type, Direct extraction gives the proportion of free fat.

A 2g of the sample 'A' in powdered form was taken into a thimble of a known weight ( $W_1$ ). Both the sample A and thimble was weighted ( $W_2$ ), the thimble with sample A was placed inside a soxhlet extractor. A 30cm of acetone-ethanol mixture of (1:1) was put into a 500ml round bottom joint flask which was sited in electrically connected heating mantle and was switched on. The heat increased carefully and slowly until the solvent boiled. Condensed solvent with dissolved lipid was continuously rush back into the flask and the heating and the extraction process was continue for about 24 hours, then cooled in a desiccators and weighed ( $W_3$ ). This procedure was repeated for sample B,C,D,E, and F respectively.

The solvent was distilled off to about 20ml, the lipid in solvent solution was quantitatively transferred on to an evaporating dish, cooled, dried in desiccators the lipid thus recovered may be weighed and (%) lipid calculated using equation 4 below:

$$(\%) \text{ lipid content} = \left( \frac{W_2 - W_3}{W_2 - W_1} \right) \times 100 \quad (4)$$

## 2.6 Crude Protein Determination

Protein is the major compound containing Nitrogen in any food sample, so Nitrogen is used as an index of protein term "crude protein". The Kjeldahl method as described by Onwuka (2005) was used to determine the crude protein on samples. A factor of 6.25 was used in converting

nitrogen to protein. This was done by accurately weighing 2g of sample into a standard 250ml Kjeldahl flask containing 1.5g CuSO<sub>4</sub> and 1.5g Na<sub>2</sub>SO<sub>4</sub> as catalyst and 5ml concentrated H<sub>2</sub>SO<sub>4</sub>. The Kjeldahl flask (digestion) was placed on a heating mantle and was heated gentle to prevent frothing for some hours until a clear bluish solution was obtained. The digested solution was allowed to cool and this was quantitatively transferred to 100ml standard flask and make up to the mark with distilled water. 20ml portion of the digest was pipette into a semi-micro Kjeldahl distillation apparatus and treated with equal volume of 40% NaOH solution. The ammonia evolved was steam distilled into a 100ml conical flask containing 10ml solution of saturated boric acid to which 2 drops indicator (double indicator) had been added.

The tip of the condenser was immersed into the boric acid double indicator solution and then the distillation continued until about 2/3 of the original volume obtained. It was then titrated with 0.2NHCl until a purple-pink end point was observed. A blank determination was also carried out in the similar manner as described above except for the omission of the sample. The crude protein was obtained by multiplying the percentage of Nitrogen content by a factor (6.25).

Crude Protein = % Nitrogen x factor

The basis for Kjeldahl is as shown in equation 5 below:

$$\text{Crude protein} = \%N \times 6.25 = \frac{(\text{sample titre} - \text{Blank titre}) \times 0.1 \times 0.04}{\text{weight of sample}} \times \frac{100}{1} \times \frac{100}{20} \times \frac{\text{weight of sample}}{1} \quad (5)$$

## 2.7 Determination of Crude Fibre (%)

The crude fibre was determined in accordance with the method described by (A.O.A.C, 1980). A 2g of sample A was taken and defatted with petroleum ether for 8hrs. It was boiled under reflux for exactly 30 minutes with 200cm<sup>3</sup> of 1.25% H<sub>2</sub>SO<sub>4</sub>. It was filtered and washed with boiled water until the washing were no longer acidic. The residue was boiled in a round bottom flask with 200cm<sup>3</sup> of 1.25% NaOH for another 30 minutes and the crucible with sample (residue) was dried in the oven at 100°C. It was left in a desiccators to cool and weighed (C<sub>2</sub>). It was then incinerated in a muffle furnace at about 600°C for 3hrs. This was then put in a desiccator to cool and weighed (C<sub>3</sub>). This procedure was repeated for sample B, C, D, E, and F respectively. The percentage fiber content was calculated using equation 6 below

Weight of fibre =  $C_2 - C_3$

$$(\%) \text{ fibre} = \frac{C_2 - C_3}{\text{weight of original sample}} \times 100 \quad (6)$$

Where:

$C_2$  = weight of sample residue on oven dry

$C_3$  = weight of sample residue incinerated in a muffle furnace

### 2.8 Determination of Carbohydrate (%)

The values of carbohydrate (%) were obtained by subtracting the total percentage water, mineral, protein, and fat from hundred. This is known as carbohydrate by difference and is used because no satisfactory method exists for determining carbohydrate by direct analysis (Helen, 1979).

This method was used to determine the percentage carbohydrate of sample A, B, C, D, E, and F respectively. The percentage carbohydrate was calculated using equation 7 below.

$$(\%) \text{ carbohydrate} = 100 - (P+L+M+MC) \% \quad (7)$$

P = (%) protein

L = (%) Lipid (fat)

M = (%) Mineral

MC = (%) Moisture Content

### 2.9 Statistical Analysis

All data obtained were subjected to Analysis of Variance (ANOVA) at 95% confidence level using Statistical Package SPSS (20.0) software.

## 3.0 RESULTS AND DISCUSSION

**Drying rate:**At the initial dryingstage, the rate of water evaporation from the meat was very high but later decreased continuously until the constant weight was obtained (table 1a). There was loss in weight of about 69.29%, 74.02%, and 66.71% for cow, goat and sheep meat respectively;this is equivalent to the amount of water evaporated. The moisture content(wet base) was found to be the same as the percentage weight loss above, while the moisture content(dry base) was found to be 2.29%, 2.86% and 2.00% for the product of cow, goat and sheep meat respectively. However, it was generally observed that many food products such as meat undergo an initial rapid constant rate of drying period follow by a slower, decreasing drying rate period (Ihekoronye and Ngoddy, 1985). As the drying period increases, the weight of the sample decreases (table 1a).

**Moisture Content:**

it was observed that there was reduction in moisture content of fresh meat to dried meat product (kilishi) from 69.00% to 11.00%, 74.00% to 11.83%, 65.00% to 9.35% for cow, goat and sheep meat respectively (table 2a). However, the obtained values of moisture content for beef and goat meat were lower compared to value reported by Norman et al., 2004. Therefore, the reduction in moisture content of both fresh meat and the dried meat product (kilishi) is not only prolonging the shelf-life but also increases the concentration of nutritional values of dried meat product (kilishi) due to the ingredients that were added to it.

**Ash Content:**The ash contents of the meat increased from 1.00%, 9.5%, 0.50% to 5.17%, 0.67% and 6.17% for cow goat and sheep meat respectively. The obtained value of ash content for cow is in line with the reported value in the cited reference while that of goat and sheep meat were reduced by 0.03% when compared to the valued obtained by (Sawyer, 1975). The reduction in the ash content of the meat samples may be due to the feed taken by the animal,the age of and environmental control where it grown. The ash content of kilishi increased due to the ingredients added to it.

**Lipid Content:**It was also observed that there was an increase in lipid (fat) content from fresh meat to dried meat product (kilishi) from 11.00% to 19.67%, 10.33% to 17.00%, 16.00% to 22.00% for cow, goat and sheep meat respectively. The amount of lipid (fat) content of cow

(beef) and sheep meat or lamb and goat meat were higher than the values in the cited reference. However, percentage increase in lipid (fat) content of the dried meat product makes it to have high energy values in human nutrition and also increase its flavour.

**Crude Protein:**It could also be observed that there was an increase in percentage crude protein of dried meat product compared to fresh meat from 19.00% to 38.99%, 15.05% to 37.22, 18.06% to 38.68% for cow meat, goat meat and sheep meat respectively. The obtained values of crude protein for beef sheep meat and goat in this study were closer to the value obtained by (Norman, 2004). Likewise, the protein requirement of an individual is defined as the lowest level of protein intake that will balance the loss of nitrogen from the body of a person maintaining energy balance at modest level of physical activities (FAD/WHO, 1985).

**Crude Fibre:**More also, table 2a shows that, there was slight increase in percentage crude fibre of dried meat product compared to fresh meat from 4.1% to 4.83%, 2.33% to 2.83%, 2.67% to 2.83% for cow meat (beef), goat meat and sheep meat respectively. The slight increase in percentage of crude fiber of dried meat product indicated the quantity of indigestible matter in the dried meat product (kilishi) is not much due to the high digestibility of protein by reducing the moisture content of the meat and subjecting it to a moderate roasting on a glowing fire after drying.

**Carbohydrate:**From the result obtained in table 2a and b, it was observed that, the amount of carbohydrate of dried meat product (kilishi) compared to fresh meat increased from 0.5% to 20.85%, 0.36% to 28.78%, 0.28 to 23.82% for cow meat (beef), goat meat and sheep meat respectively. However, increase in amount of carbohydrate of dried meat product was due to various ingredients such as pepper, ginger, groundnut, onion, garlic, magi salt etc. added to it which also makes it to have high energy value in human nutrition and also increase the palatability of the dried meat product (kilishi).

Table 1(a): Average Values of the Drying Rate for the Three Different Meat Samples.

<b>Time (h)</b>	<b>Weight of Sample A (g)</b>	<b>Drying Rate of Sample A (Kg/h)</b>	<b>Weight of Sample B (g)</b>	<b>Drying Rate of Sample B (Kg/h)</b>	<b>Weight of Sample C (g)</b>	<b>Rate Drying of Sample C (Kg/h)</b>
<b>0</b>	70.00	-	70.00	-	70.00	-
<b>1</b>	61.88	0.062	49.63	0.050	63.77	0.064
<b>2</b>	53.89	0.027	43.09	0.022	56.63	0.028
<b>3</b>	49.85	0.017	39.39	0.013	51.97	0.017
<b>4</b>	43.81	0.011	36.24	0.009	47.08	0.012
<b>5</b>	40.09	0.008	34.27	0.007	43.49	0.009
<b>6</b>	37.09	0.006	33.38	0.006	40.49	0.007
<b>7</b>	36.67	0.005	33.10	0.005	40.12	0.006
<b>8</b>	35.48	0.004	32.72	0.004	39.73	0.005

<b>9</b>	34.07	0.004	31.24	0.003	37.41	0.004
<b>10</b>	30.26	0.003	30.84	0.003	33.90	0.003
<b>11</b>	28.04	0.003	29.56	0.003	29.95	0.003
<b>12</b>	21.45	0.002	18.15	0.002	23.30	0.002

Where

Sample A is Cow meat

Sample B is Goat meat and

Sample C is Sheepmeat

Table 1(b): ANOVA for Drying rate of the Three Different Meat Samples (cow, goat, and sheep meat)

			Sum of Squares	df	Mean Square	F	Sig.
<b>meat source * Drying Time</b>	Between samples	(Combined)	0.000	12	0.000	0.000	<b>1.000</b>
	Within samples		26.000	26	1.000		
	Total		26.000	38			
<b>average weight of sample * Drying Time</b>	Between samples	(Combined)	6073.859	12	506.155	24.661	<b>0.000</b>
	Within samples		533.638	26	20.525		
	Total		6607.497	38			
<b>rate of drying * Drying Time</b>	Between samples	(Combined)	0.009	12	0.001	125.510	<b>0.000</b>
	Within samples		0.000	26	0.000		
	Total		0.009	38			

Table 2(a): The Average Values of Nutritional Content of Fresh Meat (Cow Meat, Goat Meat and Sheep Meat) and Their Respective Dried Meat Products (Kilishi).

Meat source	Moisture		AshContent		Lipid		Content Crude		Protein		Crude Fibre (%)		Carbohydrate	
	Content (%)		(%)		(%)		(%)		(%)		(%)		(%)	
	FM	K	FM	K	FM	K	FM	K	FM	K	FM	K	FM	K
Cow meat	69.00	11.00	1.00	9.50	10.50	19.67	19.00	38.99	4.17	4.83	0.50	20.85		
Goat meat	74.00	11.83	0.50	5.17	10.33	17.00	15.05	37.22	2.33	2.83	0.36	28.78		
Sheep meat	65.00	9.33	0.67	16.00	16.00	22.00	18.06	38.68	2.67	2.83	0.27	23.82		

Where

FM = Fresh meat

K = Kilishi

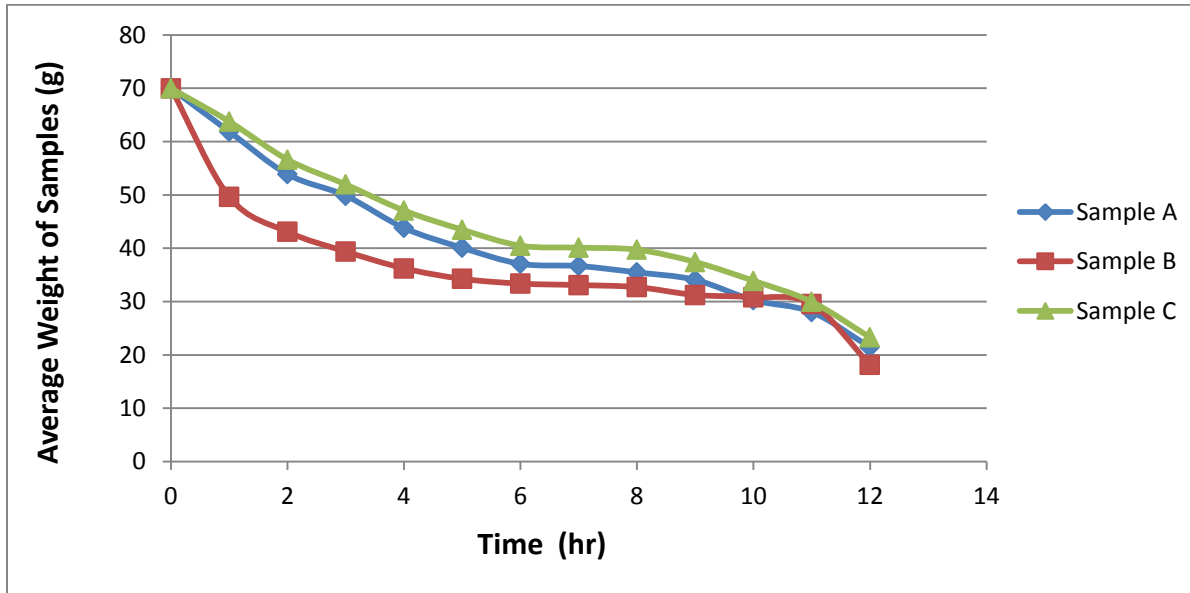
Table 2 (b):ANOVA Table for proximate analysis of Fresh Meat (Cow Meat, Goat Meat and Sheep Meat) and Their Respective Dried Meat Products (Kilishi)

		Sum of Squares	df	Mean Square	F	Sig.
<b>moisture content (%) * meat treatment</b>	Between samples (combined)	5153.284	1	5153.284	469.448	<b>0.000</b>
	Within samples	43.909	4	10.977		
	Total	5197.194	5			
<b>ash content (%) * meat treatment</b>	Between samples (combined)	135.375	1	135.375	9.092	<b>0.039</b>
	Within samples	59.559	4	14.890		
	Total	194.934	5			
<b>lipid content (%) * meat treatment</b>	Between samples (combined)	79.498	1	79.498	9.541	<b>0.037</b>
	Within samples	33.329	4	8.332		
	Total	112.826	5			
<b>crude protein (%) * meat treatment</b>	Between samples (combined)	656.888	1	656.888	255.046	<b>0.000</b>
	Within samples	10.302	4	2.576		
	Total	667.190	5			

<b>crude fibre (%) * meat treatment</b>	Between samples (combined)	290	1	0.290	0.253	<b>0.641</b>
	Within Groups	4.584	4	1.146		
	Total	4.874	5			
<b>carbohydrate content (%) * meat treatment</b>	Between samples (combined)	871.697	1	871.697	108.524	<b>0.000</b>
	Within samples	32.129	4	8.032		
	Total	903.826	5			

---

3.2



*Figure 2: A Graph of Average Weight of Samples Against the Drying Period (Time)*

## **4.0 CONCLUSIONS AND RECOMMENDATIONS**

### **4.1 Conclusions**

From the results obtained in this study, It could be seen that as the drying period increases the weight of the samples decreases. This decrease in weight leads to some physical changes such as shape, colour, size and the texture of the meat. However, continuous drying process makes the meat to become smaller, thinner and to some extent hard. Therefore, the rate of drying is dependents on the drying period, the temperature, and the air circulation.

It is obvious from the study that the drying method used to process the fresh meat to dried meat product (kilishi) helps in prolonging self- life of the meat and also stop the microbiological activities that can takes place at high moisture content by reducing the moisture content of the meat. All the spices and ingredients added to it such as ginger, groundnut, pepper, magi, onion, salt, etc. increase the palatability, mineral content, protein content, fat content, amount of carbohydrate and also stabilized the colour of the dried meat product (kilishi).

However, it can be seen from the results that fresh meat is not a good source of carbohydrate. There are some variations in the nutritional contents of each of the meat sample (cow meat, goat meat, and sheep meat), these variations may be due to feeds intake by the animals, the breed, age, sex, and environmental location where these animals are grown up.

### **4.2 Recommendations**

Drying the meat under the sun may either be over or under dried due to inability to control the intensity of the sun. Therefore, modern method of drying such as oven drying method which

will save more time and also provide the access to regulate the temperature through temperature regulator of oven machine should be adopted.

It is not only in the dry season period that, the maximum production of dried meat product could be obtained. However, continuous production of dried meat product (kilishi) can also be obtained throughout the year by adopting the advance method of drying such as tray drying.

Roasting of the dried meat product (kilishi) should be done under low and moderate heat because over heating may affect the amino acid which in turn affect the content of the dried meat product (kilishi).

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## **PREDICTION ACCURACY OF THREE INFILTRATION EQUATIONS FOR A SANDY LOAM SOIL IN MINNA, NIGERIA.**

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### **ABSTRACT**

Prediction of soil infiltration is a complex process with many factors contributing to the rate. Three infiltration models were chosen to ascertain their predictive ability of a sandy loam soil in Minna, Nigeria. The models were Kostiakov, Philip and Horton infiltration equations. Field measurements of infiltration were conducted using the double ring infiltrometer. Parameters were developed from measured infiltration data for each of the equations and laboratory analyses of soil samples were carried out. These models were compared to determine which one most accurately predicted the measured infiltration rates from the field data. The  $R^2$  values of the Kostiakov, Philip and Horton models were 0.979, 0.611, and 0.757, respectively. The results indicate that Kostiakov provided the best fit with the field measured data among the models tested. The root mean square error (RMSE) of the infiltration equations showed that Kostiakov had the least value of 0.723 compared to that of Philip and Horton with RMSE values of 1.669 and 2.470, respectively. All three models studied provided good overall agreement with field-measured data. However, Kostiakov provided the best fit with experimental data for the soil and is therefore recommended for the characterization of the infiltration process of the study area.

### **1.0 INTRODUCTION**

Infiltration is the entry of water into the soil from the soil surface. Soil infiltration is an important soil quality indicator because it has important agricultural and environmental effect and is strongly affected by land management practices. The process of infiltration can go on only if there is room present for additional water at the soil surface. The available volume for additional water in the soil is affected by the porosity of the soil and the rate at which earlier infiltrated water can move away from the surface through the soil. The maximum rate at which water can enter a soil in a given condition is the infiltration capacity. If the amount of water at the soil surface is less than the infiltration capacity, all of the water available will infiltrate. If rainfall intensity at the soil surface occurs at a rate that surpasses the infiltration capacity, ponding begins and is followed by runoff over the ground surface, once depression storage is filled. Infiltration capacity which is an important soil hydrological property is influenced by soil structure, aggregate stability, particle size distribution, land use type, vegetation and topographic and climatic influences (Fu et al., 2000). Infiltration capacity is an important component in planning land disposal of waste water, selecting and setting up irrigation

systems, deciding suitable water conservation techniques on agricultural lands and in the hydrological modeling of runoff processes (Criddle et al., 1956).

There are different equations for determining infiltration rates. These equations describe infiltration processes and produce different predictions for infiltration rates. They use different parameters and were developed for different purposes. In order to characterize infiltration for field applications, expression of the infiltration rate or cumulative infiltration algebraically in terms of time and certain soil parameters is important. The equations can be classified into physically based and empirical equations. Philip equation is a physically based equation. It has more advantages over the others because it does not require measured infiltration data but are based on assumptions of uniform movement of water from the surface downward and a disadvantage that the above assumption can never be fully valid.

Kostiakov and Horton equations are empirical equations. Unlike the physically based equations, they give infiltration rates based on measured infiltration data or from more approximate estimation procedures; therefore, they provide more realistic estimates when measurements can be provided for the same or very similar conditions to the site for which the prediction is to be made. Their initial parameters are determined based on actual field-measured data (Skaggs and Khaleel, 1982; Rawls et al., 1993).

However, one characteristic of infiltration that all the equations predict is an initially rapid decrease in infiltration rate with time for ponded surfaces (Skaggs and Khaleel, 1982).

Due to various works done by different researchers on infiltration rate, different infiltration equations were developed. Not all these equations will be appropriate for a particular soil type. Therefore, it becomes imperative to determine which of the equations best fits a soil type with the aid of infiltration data collected. In Nigeria, few similar studies have been carried out in this regard (Ahmed, 1982; Eze, 2000; and Idike, 2002). The aim of this study was to determine the infiltration rates of a sandy loam soil in Minna, Nigeria; predict relative infiltration rates of the soil using some time dependent infiltration equations, and to establish which of the equations studied (Philip, Horton and Kostiakov) best fits the sandy loam soil.

## **2.0 INFILTRATION THEORY.**

### **2.1 PHILIP'S EQUATION.**

The mathematical and physical analysis of the infiltration process developed by Phillip (1957b) separates the process into two components - that caused by a sorptivity factor and that influenced by gravity. Sorptivity is the rate at which water will be drawn into a soil in the absence of gravity; it comprises the combined effects of adsorption (the taking up by the surface of a solid or liquid of the atoms, ions, or molecules of a gas or other liquid) at surfaces of soil particles and capillarity (a phenomenon in which a liquid's surface rises, falls, or becomes distorted in shape where it is in contact with a solid) in soil pores. The gravity factor is due to the impact of pores on the flow of water through soil under the influence of gravity.

Philip (1957a) derived an equation:

$$F = \frac{1}{2} S t^{-\frac{1}{2}} + A \quad (1)$$

where:

F= infiltration (rate cm/hr)

S= sorptivity (rate at which water will be drawn into the soil in the absence of gravity)

t= time (mins.)

A= gravity factor

The constants A and S can be determined by plotting the graph of F (infiltration rate) against  $t^{-\frac{1}{2}}$ . An advantage of the Philip equation is that it has only two parameters, which eases calculation. The two coefficients S and A can be evaluated directly from observed infiltration tests. The two parameters, however, becomes a problem when t becomes very large because it is unable to give a constant rate of infiltration. The sorptivity (S) is influenced by the initial and final moisture contents. As the moisture content approaches saturation, sorptivity tends to zero and the infiltration rate becomes equal to the field saturated hydraulic conductivity. This implies that the steady infiltration rate reached after a long time should be largely independent of the antecedent moisture content (Phillip, 1957b).

## 2.2 KOSTIAKOV'S EQUATION.

Kostiakov (1932) proposed the empirical equation:

$$F = Ct^a + b \quad (2)$$

where:

F= infiltration rate (cm/hr)

t= time after onset of infiltration (mins)

c, a and b are constants.

The values of the constants are determined with the measured data. The first thing to be done is to plot a graph of infiltration rate, F, against time, t. Two (2) points ( $t_1$  and  $F_1$ ) and ( $t_2$ ,  $F_2$ ) are chosen on the graph drawn from the data. After that is done, a point  $t_3 = \sqrt{t_1 t_2}$  is chosen and the corresponding F value picked as  $F_3$ . The value of b is then determined using equation (3).

$$b = \frac{F_1 F_2 - F_3^2}{F_1 + F_2 - 2F_3} \quad (3)$$

Equation (2) can be re-written as:  $F - b = Ct^a$  (4)

Taking the logarithm of both sides of equation (4), we have

$$\text{Log}(F - b) = \text{log } C + a \text{ log } t \quad (5)$$

The logarithm helps to express the equation in the form:  $y = Mx + c$  where M is the slope, x is the variable and c is the intercept along the y-axis. C and a are determined with equation (5) by substituting values.

To determine the value of F using the Kostiakov equation, the values of b, C and a are substituted into the equation (2) for each value obtained at t.

The equation for the rate of infiltration is obtained by differentiating equation (2) to obtain:

$$F = act^{a-1} \quad (6)$$

The greater the value of C, the higher the initial infiltration value (Naeth et al., 1991). The Kostiakov equation is widely and commonly used because of its simplicity, ease of finding the

two constants from measured infiltration data and reasonable fit to infiltration data for many soils over short time periods (Clemmens, 1983, Mishra et al., 2003; Haghiabi et al., 2011).

The major flaws of this equation are that it predicts that the infiltration capacity is infinite (immeasurable) at  $t$  equals zero and approaches zero for long times, while actual infiltration rates approach a steady value (Philip, 1957a; Naeth et al., 1991).

Various modifications have been made on the Kostiakov equation by different researchers like Israelson and Hanson (1967) and Mbagwu (1993),

### 2.3 HORTON'S EQUATION.

The Horton model of infiltration (Horton, 1939, 1940) is one of the best-known models in hydrology. Its best feature is its simplicity and good fit to experimental data. Horton recognized that infiltration rate ( $F$ ) decreased with time until it approached a minimum constant rate ( $f_c$ ).

The Horton equation is given as:

$$F = f_c + (f_o - f_c) e^{-kt} \quad (7)$$

where

$F$  = infiltration rate; cm/hr

$f_c$  = the final constant infiltration rate; cm/hr

$f_o$  = the infiltration capacity at  $t = 5$ ; cm/hr

$k$  = positive constant for a given soil initial condition

$t$  = time (mins)

The parameters  $f_c$ ,  $k$  and  $f_o$  must be evaluated from measured infiltration data. Subtracting  $f_c$  from both sides of equation (7) and then taking the log of each side gives the following equation for a straight line.

$$\text{Log } (F - f_c) = \text{Log } (f_o - f_c) - k \log e t \quad (8)$$

When experimental value  $f_c$  is subtracted from the experimental values of  $F$  and the logs of resulting values are plotted against time  $t$ , then  $k$  can be determined from the slope of the line ( $M$ ).

$$\begin{aligned} M &= k \text{ Log } e \\ X &= t \text{ (variable)} \\ \text{If } M &= k \log e, \text{ then } k = \frac{M}{\log e} \end{aligned} \quad (9)$$

Horton's equation has advantages over the Kostiakov equation. First, at  $t$  equals 0, the infiltration capacity is not infinite but takes on the finite value  $f_o$ . Also, as  $t$  approaches infinity,

the infiltration capacity approaches a nonzero constant minimum value of  $f_c$  (Horton, 1940; Hillel, 1998). Horton's equation has been widely used because it generally provides a good fit to data. Although the Horton equation is empirical in that  $k$ ,  $f_c$  and  $f_o$  must be calculated from experimental data, rather than measured in the laboratory, it does reflect the laws and basic equations of soil physics (Chow et al., 1988). However, the Horton equation is cumbersome in practice since it contains three constants that must be evaluated experimentally (Hillel, 1998). A further limitation is that it is applicable only when rainfall intensity exceeds  $f_c$  (Rawls et al., 1993). Another criticism of the Horton model is that it assumes that hydraulic conductivity is independent of the soil water content (Novotny and Olem, 1994). The Horton equation is adapted to ponded condition since it cannot be used to predict rainfall infiltration prior to surface ponding.

### 3.0 MATERIALS AND METHODS.

#### 3.1 Study site

The study was carried out at the Federal University of Technology, Minna research farm, Gidan Kwano located along Minna-Bida road, Southeast of Minna, Niger State. The experimental site lies approximately on longitude of  $06^{\circ} 28' E$  and latitude of  $09^{\circ} 35' N$ . A detailed description of the study site is presented by Ahaneku (2014). Fig 1 shows the map of Niger State indicating the study area.

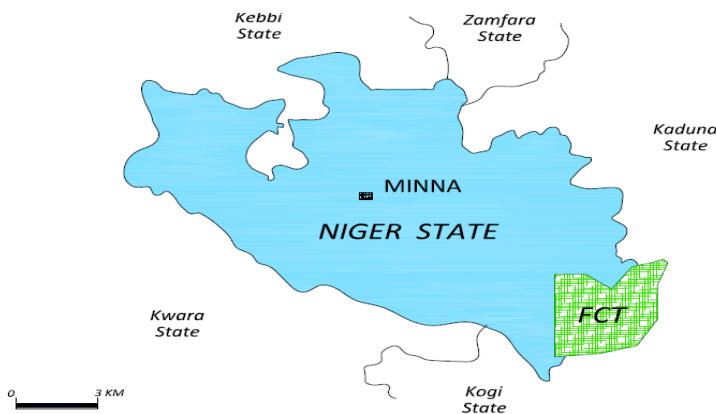


Fig 1: Map of Niger state indicating study area (Minna).

#### 3.2 Infiltration rate measurement.

Prior to the tests, soil samples were collected from the site and taken to the laboratory for the determination of soil physical and hydraulic properties like bulk density, moisture content, porosity, hydraulic conductivity, and texture. Different points were chosen randomly (but not too far from each other), at the selected area for the infiltration runs. The infiltration measurement was carried out using double ring infiltrometers made of gauge 12 rolled iron sheet with inner and outer ring diameters of 30cm and 60cm, respectively and 25cm high. The rings were installed into the ground to a depth of 12.5cm. The infiltration tests were done at varied time interval within 2 hours twenty minutes. Infiltration runs were replicated four times.

## 4.0 RESULTS AND DISCUSSION

### 4.1 Analysis of results

The results of the physical properties of soil tested are presented in Table 1. These include: the particle size analysis, moisture content, bulk density, porosity and hydraulic conductivity. The moisture content of each replicate was the antecedent moisture content when the infiltration run was conducted.

Table 1: Some physical properties of the soil of the experimental site

Replicate	Soil textural class	%Sand	%Clay	%Silt	Moisture content (%)	Bulk density (g/cm <sup>3</sup> )	Porosity (%)	Hydraulic conductivity (cm/hr)
I	Sandy loam	87.112	9.00	3.888	14.18	1.60	36	2.90
II	Sandy loam	87.184	8.64	4.176	15.26	1.55	38	3.00

Table 2 shows the mean and standard deviation of the data from the infiltration runs for the observed and the infiltration equations. From the table, it can be seen that replicates III and IV have lower values of mean and standard deviation than I and II. This was as a result of the low infiltration rates during the infiltration runs of replicates III and IV which was due to higher moisture content in the soil compared to that of replicates I and II which had higher values as a result of high infiltration rates. Replicates III and IV had different moisture content because the tests were carried out several days after I and II on the same site.

Comparing the graphs of I, II, III, IV replicates in Fig 2, indicate that I and II showed a sharp decline while III and IV showed a gradual decline. This was as a result of higher moisture content and low rate of infiltration of III and IV compared to higher infiltration rates of I and II. Using the Philip's equation, it was observed that the graph of the calculated infiltration when compared to the observed in fig 3 showed a clear deviation from the graph of the observed. In contrast, the graph of cumulative infiltration (cm) against time (mins) using Kostiaikov's equation when compared when compared with the observed (Fig 4) showed that the calculated data had a negligible difference due to the closeness in values of the data. Using Horton's equation, fig 5 shows a graph of infiltration rate  $\log (F_c - F_o)$  against time (mins). The graph shows a high degree of deviation between the observed data and the calculated. Comparing the graphs of Philip, Horton and Kostiaikov, a higher degree of accuracy was observed with the Kostiaikov's equation in terms of parameters that best describes the tested soil.

Table 2: Mean and standard deviation values for the data of all equations for the infiltration runs compared with the observed data.

Replicate	I	II	III	IV
<b>OBSERVED:</b>				
Mean	16.105	18.978	8.811	10.516
Standard deviation	7.983	7.746	1.801	3.202
<b>PHILIP:</b>				
Mean	9.080	11.552	6.620	7.238
Standard deviation	3.915	4.013	1.061	1.706
<b>HORTON:</b>				
Mean	13.222	16.908	10.035	11.557
Standard deviation	6.769	6.660	1.110	3.002
<b>KOSTIAKOV:</b>				
Mean	12.006	15.260	7.901	8.805
Standard deviation	4.873	7.321	4.267	4.311

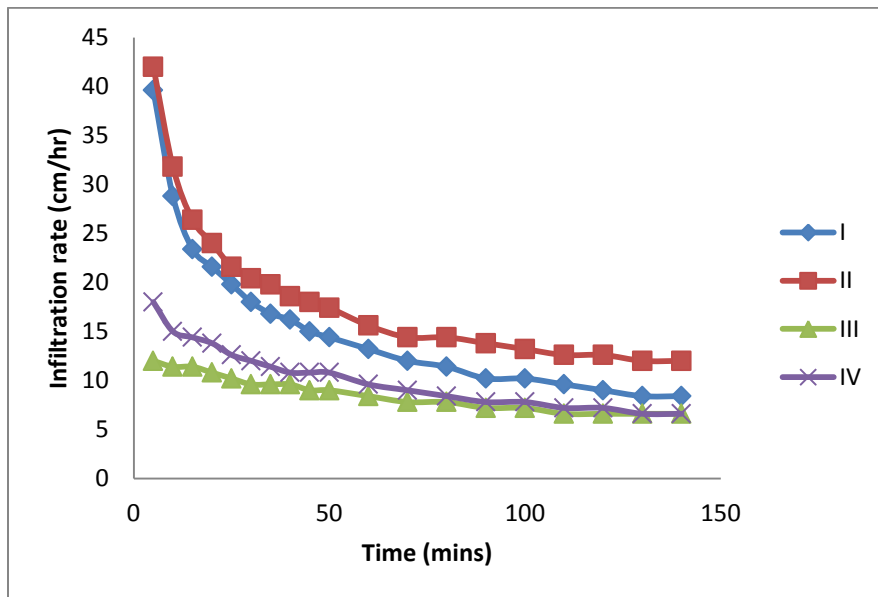


Fig 2: Graph showing the infiltration rates of all replicate runs.

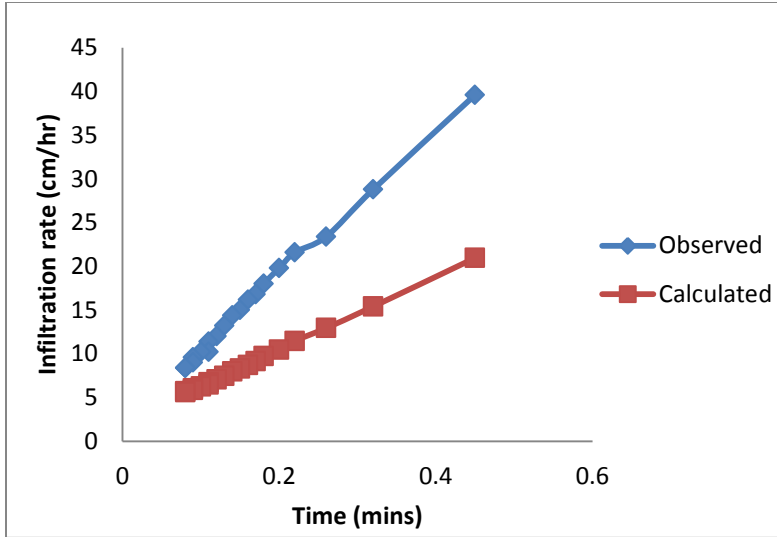


Fig 3: Graph of infiltration rate (cm/hr) against time  $t^{-1/2}$  (mins) of observed and calculated using Philip's equation.

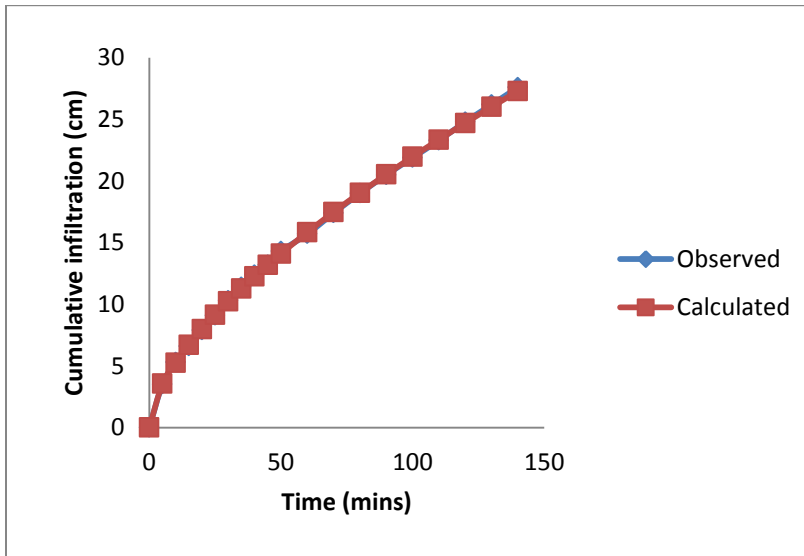


Fig 4: Graph of cumulative infiltration (cm) against time (mins) of observed and calculated using Kostiakov's equation.

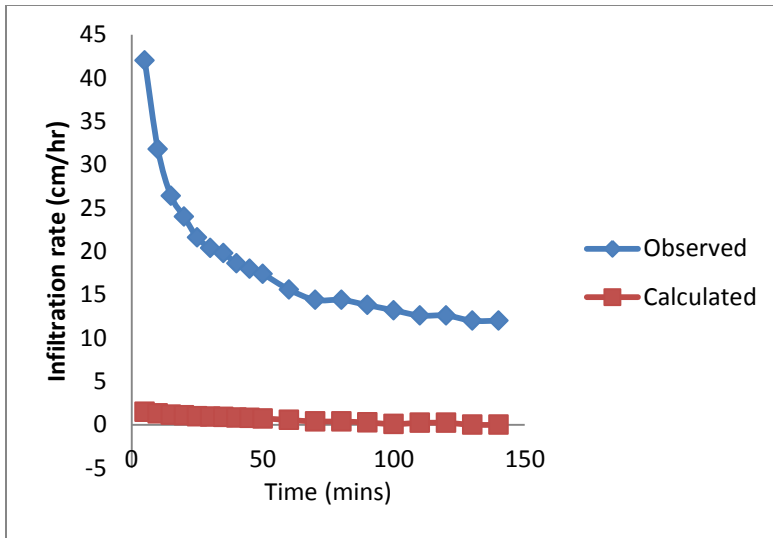


Fig 5: Graph of infiltration rate  $\text{Log} (F_o - F_c)$  (cm/hr) against time (mins) of observed and calculated using Horton's equation.

#### 4.2 Infiltration rate prediction.

The estimated values of the models parameters are presented in Table 3. From Table 3, the average values of the time exponent of Kostiakov equation 'a' was observed to range between 0.542 and 0.662 which is in accordance with the theory of infiltration that puts the value to be positive and always less than unity. The negative values of b for the replicates III and IV were attributed to the rains before the infiltration test was carried out. The values of these parameters do not possess any specific physical meaning; however, they reflect the effect of soil physical properties of influence on infiltration as well as antecedent soil moisture content and surface conditions (Zerihun and Sanchez, 2003). The parameters of the Philip's equation were estimated by plotting a graph of infiltration rate  $F$  (cm/hr) against time  $t^{-1/2}$  (mins) for all the replicates. A linear equation in the form of  $y = mx + c$  was gotten, the  $m = S$  and  $c = A$  for all the replicates. It can also be seen that the replicate with the highest infiltration rate (which was II) had the highest value of  $S$ , while the replicate with the lowest infiltration rate (which was III) (Fig.2) had the lowest value of  $S$ .

Table 3: Estimated values of the models parameters for each of the replicates

Replicates	Philip		Horton			Kostiakov		
	S	A	$f_c$	$f_o$	$k$	b	a	C
I	84.759	2.008	8.403	9.60	0.057	0.488	0.542	1.318
II	86.869	4.305	12.00	42.00	0.054	0.610	0.662	1.013
III	22.975	4.700	6.60	12.00	0.008	-0.779	0.649	0.634
IV	36.904	4.159	6.60	18.00	0.017	-0.932	0.572	0.983

### 4.3 Statistical analysis

Three statistical tools, namely Coefficient of determination ( $R^2$ ), Root mean square error (RMSE) and Coefficient of variation (CV) were used to assess the predictive accuracy of the three infiltration equations based on field data. Typically, values of  $R^2$  below 0.2 are considered weak, between 0.2 and 0.4, moderate, and above 0.4, strong. The three infiltration equations had strong values with  $R^2 > 0.4$ ; however, Kostiakov's had the highest value (Table 4). The average  $R^2$  value shows that Kostiakov's equation had a value of 0.979. Horton's equation comes in second with 0.757 and lastly, Philip's equation with 0.611. If one considers higher values of  $R^2$  as indicator of goodness of fit of a model as suggested by Davidroff and Selims (1986), the results show that the Kostiakov equation provided the best fit with the experimental data for the tested soil. This result is consistent with the findings of other researchers (Ahmed 1982; Eze 2000; Idike 2002 and Ajayi et al., 2016) who tested similar models for similar soil.

Table 4: Mean statistical parameters for the infiltration equation for all replicates.

Equations	$R^2$	RMSE	CV
Observed	0.770	-	-
Philip	0.611	1.669	11.694
Horton	0.757	2.470	18.162
Kostiakov	0.979	0.723	3.558

Root mean square error (RMSE) with a lower value more closely predicts the measured infiltration rate, higher values provide less accurate estimates of the measured infiltration (Hartley, 1992). From the mean values of the infiltration equations for all the replicates (Table 4), Kostiakov's equation is a better fit for the tested sandy loam soil with a RMSE value of 0.723 compared with that of Philip and Horton's equation with RMSE values of 1.669 and 2.470, respectively.

The CV values for each of models tested (Table 4) shows that Kostiakov equation had the lowest value of 3.558, followed by Philip's (11.694) and lastly Horton's (18.162).

Based on the results of all the tests and analyses carried out, Kostiakov's equation was more accurate in predicting the infiltration rate of the tested soil than the other models.

## **5.0 Conclusions.**

The infiltration rates of a sandy loam soil in Minna, Nigeria were determined in the field. Time – dependent infiltration models were used to compare the observed data. Results indicated that Kostiakov equation best predicted the infiltration rates of the soil compared with the other models. Kostiakov equation had an average  $R^2$  value of 97.9% compared with those of Horton and Philip which had average  $R^2$  values of 75.7% and 61.1%, respectively.

The results further showed that antecedent soil moisture content affected infiltration rates.

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## COMPRESSIVE STRENGTH PROPERTIES OF CASSAVA ROOTS AS AFFECTED BY MOISTURE CONTENT

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### ABSTRACT

In Nigeria, recent transformation of cassava into an industrial raw material has made the need for mechanization of its postharvest processing operations imperative for sustainable rural development as a means of achieving Millennium Development Goals (MDGs). Processing technologies presently available for processing cassava roots have low efficiencies due to dearth of relevant data on the engineering properties of the root. This paper presents the studies on strength properties of cassava roots that are considered useful for the mechanization of cassava postharvest processing operations. Improved cassava variety (TMS 30572) roots harvested twelve months after planting was used in the study. The properties studied include stress at peak, energy to break and the Young's modulus of the roots. The tests were conducted at moisture contents of 50, 55, 60, 65 and 70% (wet basis) using the Universal Testing Machine (UTM). Results obtained were analyzed to evaluate the strength, toughness and stiffness of cassava as well as the influence of moisture contents on these three parameters. The stress at peak, energy to break and the stiffness modulus ranged from 0.61 to 0.88 N/mm<sup>2</sup>; 4.80 to 6.67 Nm and 4.81 to 9.28N/mm<sup>2</sup> respectively within the range of moisture content studied. A non-linear relationship-3<sup>rd</sup> order polynomial was observed between moisture content and the strength properties studied.

**Keywords:** Strength, toughness, stiffness, moisture content, mechanization.

### 1. INTRODUCTION

Cassava is now a popular household and industrial crop worldwide due to its multi-purpose nature especially in the area of global food security and bio fuel production as it constitute a major source of human and animal diet in the lowland tropics and much of the sub-humid tropics of West and Central Africa. It is grown in tropical parts of Africa, Brazil, China, Phillipine, and Indonesia (FAO, 2004). Nigeria is the largest producer of the crop, contributing about 34 metric tons annually (Ajibola, 2000) and this output has continued to increase yearly till date with a total annual output of 49 metric tons (Uthman, 2011). Consumption of cassava-based products relative to other root and tuber crops among Nigerian households comparatively rank high (Kolawole *et al.*, 2007a). The global market for cassava chips and pellet is also growing with China being the largest buyer of chips. It imported 4 million tons of cassava chips in 2011 out of 'the 6 million tons domestic demand for the product with Nigeria being one of the suppliers. This and others point to the imperative of mechanized production and processing of the crop

for sustainable rural development as a means of achieving Millennium Development Goal (MDG).

Generally, freshly harvested cassava roots start deteriorating almost immediately after harvest depending on the variety of cassava (Oriola and Raji, 2013). Roots of some cassava cultivars deteriorate within 24 hours after harvest while a few can still remain wholesome for about a week (Ilori and Adetan, 2013). Therefore, it is imperative to process them into shelf-stable forms immediately after harvest. Cassava processing operations, however, are still being carried out predominantly using the traditional methods which have been roundly described as arduous, time-consuming, unwholesome, unhygienic, thus, unsuitable for large scale processing operations (Adetan *et al.*, 2003; Quaye *et al.*, 2009). Efforts at mechanizing these operations were reviewed by Oriola and Raji (2013). Most of the technological outcomes of these efforts have been widely acknowledged as being inefficient (Adetan *et al.*, 2006; Davies *et al.*, 2008; Kolawole *et al.*, 2010). A major constraint is the poor quality of the products from these machines resulting from low efficiencies of these technologies. A review work by Oriola and Raji (2013) highlighted some of the problems with the machines which include peeling off of unacceptable percentage of useful flesh during mechanical peeling, reduction of peeling efficiency with time resulting to increased time of operation, production of grated mash or cassava chips with uneven particles size resulting in varying and low product qualities between processors and between batches. The dewatering machines (hydraulic or screw type) only increases the processing (dewatering) capacity per batch but still takes the usual longer time to dewater to acceptable moisture content thereby promoting fermentation of the cassava mash. Locally fabricated flash dryers are yet to be efficient (IITA, 2006).

Mechanization involves the design and development of equipment and its success is largely dependent on availability of relevant data on the engineering properties of the crop. The design of equipment for handling and processing of cassava requires a thorough understanding of the engineering properties of cassava roots. Physical properties of cassava roots influence the level of damage sustainable by it during handling operations (Kolawole *et al.*, 2007b). In realization of this, there have been a lot of research attempts at determining the engineering properties of cassava roots towards the development of appropriate mechanical systems for its postharvest operations (Owhovoriola *et al.*, 1988; Adetan *et al.*, 2003; Kolawole *et al.*, 2007a; Nwagugu and Okonkwo, 2009; Kolawole, 2012; Ademosun *et al.*, 2012; Ilori and Adetan, 2013). Few of these studies focused on the compressive strength properties of the crop which is as important as the other engineering properties of cassava such as physical properties and frictional properties that were mostly focused by researchers. Owhovoriola *et al.* (1988) experimented with a novel peeling concept involving compression of unpeeled tubers of cassava against a sharp-edged rig and rolling off the peels without disturbing the flesh (peel-flesh separation through compression). The data on the compressive strength properties of cassava as determined by Owhovoriola *et al.* (1988) were used in the design of a cassava peeler by the same author and 92% efficiency was obtained with the peeler. This same principle was built upon by Adetan (2002) using the knowledge of compressive strength properties of the roots to develop an experimental mechanical peeling machine. This peeling concept was found to be invaluable, reliable and promising (Adetan *et al.*, 2006) as no useful flesh loss was recorded. However, some of the roots got crushed during the process of compression. This may be due to the

misleading results emanating from the improvised method used in determining the compressive properties of the roots as evidently reported by Ilori and Adetan (2013). Kolawole *et al.* (2007b) earlier determined the strength and elastic properties of the roots similarly with improvised tools and reported a positive relationship between the stress (tensile and compressive) and strain of cassava while Nwagugu and Okonkwo (2009) reported a negative relationship between strength and moisture content. This work was therefore conducted to study the compressive strength properties of cassava roots with a more sensitive equipment in order to enhance a better understanding of the behavior of the roots in compression and particularly to provide data for the development of economical and more efficient cassava processing machines.

## 2. MATERIALS AND METHODS

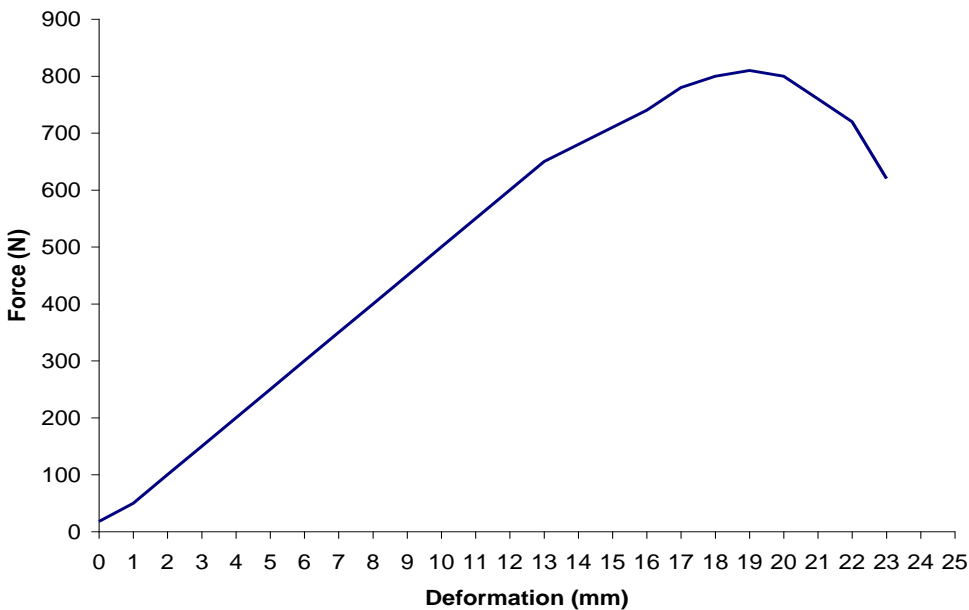
Experimental samples used in this study were prepared from fresh tubers of TMS 30572 harvested from the Teaching and Research Farm of the Department of Agricultural Engineering, Ladoké Akintola University of Technology, Ogbomoso, Oyo State, Nigeria, 12 Months After Planting. Twenty five cylindrical samples of length 60mm and diameter 30mm were used (Kolawole *et al.*, 2007b). The initial moisture content of the samples was first determined with the use of Halogen moisture analyzer. Thereafter, the samples were placed in an oven which had already attained a temperature of 70°C. They were brought out in batches (5 samples per batch) after attaining the desired moisture contents of 50, 55, 60, 65, and 70% (wb) and placed in a desiccators for an hour to allow for moisture equilibration before being used for experimentation. The compressive strength tests were conducted with the Universal Testing Machine (UTM). Cassava samples were set between the upper and lower jaws of the UTM, one at a time and compressed to failure at plunger speeds of 50mm per minute. The force-deformation plots of the tests were automatically generated on the computer attached to the universal testing machine. Data were analyzed using the Origin Lab 8.5.

## 3. RESULTS AND DISCUSSION

Results of the compressive strength tests are presented in Table 1. A typical (sample) compression curve as recorded in force-deformation coordinate system for the studied cassava variety is shown in Figure 1.

**Table 1: Mean Compressive Strength Properties of Cassava**

Moisture Content (% w.b)	Peak Force (N)	Energy to Break (Nm)	Peak Stress (N/mm <sup>2</sup> )	Young's Modulus (N/mm <sup>2</sup> )
50	428.34	4.80	0.61	4.81
55	551.68	6.37	0.78	5.74
60	518.30	4.91	0.73	6.24
65	571.34	5.65	0.81	9.28
70	624.68	6.67	0.88	8.13



**Figure 1: Typical Compression Curve of Cassava Tuber**

The curves generally have two major parts, the linear part which corresponds with the limit of elasticity, and the curved part, the crest of which depicts the peak force, from where its corresponding deformation at peak could be determined. The lower part of the curve (to the right) extends, occasionally, irregularly, indicating a yield, and eventually ended with failure. This is evident in the results of the Force and Stress at break which were lower than those of the peak values. This pattern of deformation has been reported for different crops: apple (Rebouillat and Peleg, 1988); cocoa pods (Maduako and Faborode, 1994); sweet cassava (Nwangugu and Okonkwo, 2009) and palm kernel seed (Ozumba and Obiakor, 2011). The stress-strain curve of the compressive strength tests reported by Kolawole *et al.*, (2007b) for some tubers of an improved cassava variety (TMS 4(2) 1425 also gave this shape, a linear portion with a downward facing curve that ended with failure.

The mean peak compressive force of the roots, as shown in Table 1, ranged between 428.34 and 624.68 N which correspond to a peak stress of 0.61 and 0.88 N/mm<sup>2</sup> respectively. These values of force at peak are close to the 499 N reported by Nwagugu and Okonkwo (2009) for compressive force along the fibre direction of the sweet cassava root but the stress values are far above the 0.080 – 0.047 N/mm<sup>2</sup> and 0.032 – 0.093 N/mm<sup>2</sup> reported by Kolawole *et al.* (2007b) for tubers of an improved cassava variety. The large variation may be due to the improvised tools used by the latter. Results reported by Ilori and Adetan (2013) for two cassava varieties may not be directly comparable as they worked only with unpeeled cassava roots, although the lower limits of the range of values of compressive force they reported: 504.65 – 1770.19 N for TMS 30572 and 428.32 – 1721.95 N for TMS 4(2) 1425 were within the range obtained from this study. Table 1 also shows that, within the moisture content range used in this study, the least peak force and stress were obtained at 50% moisture content (wet basis) while the highest occurred at moisture content of 70%. The peak force and stress also increased

rapid from 428.34 N and 0.61 N/mm<sup>2</sup> at 50% moisture content to 551.68 N and 0.78 N/mm<sup>2</sup> respectively when the moisture content of the samples was increased to 55%. It was, however, observed that the strength of the roots reduced slightly 518.30 N (0.73 N/mm<sup>2</sup>) when the moisture content was further increased to 60%. Beyond this moisture level, the strength of the samples continued to increase up to 70% moisture content. This means that the molecules of the roots gave in a bit to re-arrange themselves to offer more resistance to increased stress (Baryeh, 1990) at elevated moisture contents. Figure 2 shows that the strength of the roots increased non-linearly with increased moisture content. This perhaps provides a scientific reason for the practice of harvesting the root mostly during the rainy season when the strength increases with each rainfall. The non-linear relationship between root strength (y) and moisture content (x) as depicted in Figure 2 is  $y = 0.0175x^3 - 0.1625x^2 + 0.5x + 0.262$

(Equation 1)

(R<sup>2</sup> = 0.9157).

This is, however, in contrast to the negative and linear relationships reported by Nwagugu and Okonkwo (2009) and Kolawole *et al.* (2007b) respectively for cassava even though the values were within the range reported by the former. Results of the analysis of variance showed that moisture content significantly influenced the strength of the roots (P<0.05).

The toughness of the roots, represented by the energy to break, ranged from 4.80 to 6.67 Nm. This followed the same trend as the peak stress, increasing between the moisture content of 50 and 55% but, just like peak stress it decreased slightly at 60% beyond which it increased steadily up to 70%. The non-linear relationship between root toughness and moisture content as depicted in Figure 3 is

$$y = 0.2758x^3 - 2.4039x^2 + 6.3402x + 0.69 \quad (\text{Equation } 2)$$

(R<sup>2</sup> = 0.7414).

This means that the root is brittle in nature at low moisture content. This perhaps is the reason for the high rate of breakage of the roots when harvested during the dry season when the moisture content of the soil as well as the roots would have reduced considerably. The trend however improves with the advent of rain. The relationship of toughness, as well as other strength parameters (peak compressive stress and stiffness), with moisture content is also shown in Figures 2 – 4 and it is non-linear. The regression equations produced by the graphs suggest a 3<sup>rd</sup> order polynomial. The influence of moisture content was, however, not significant (P>0.005)

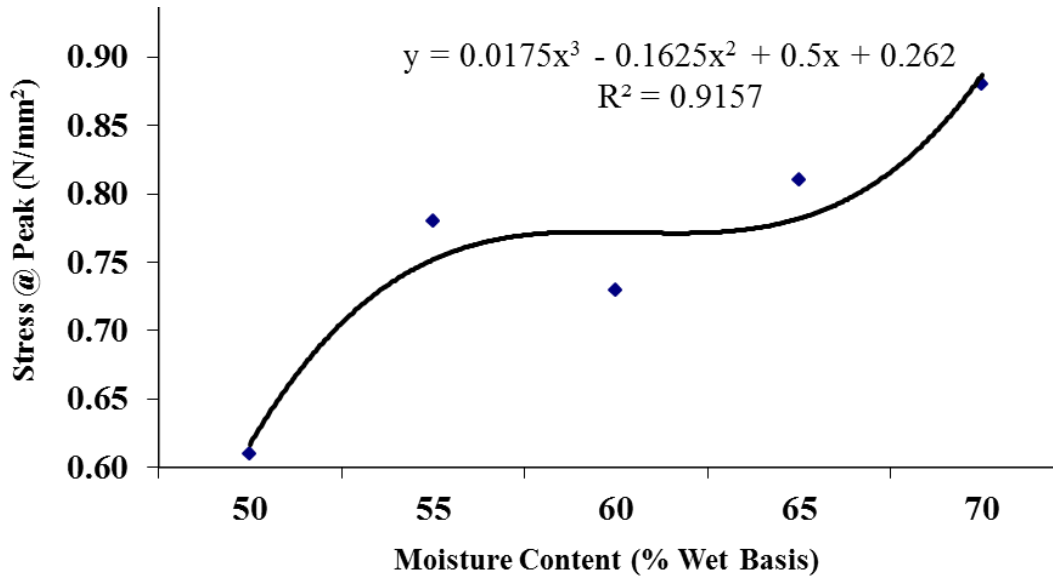


Figure 2: Peak Stress of Cassava Root at different Moisture Content

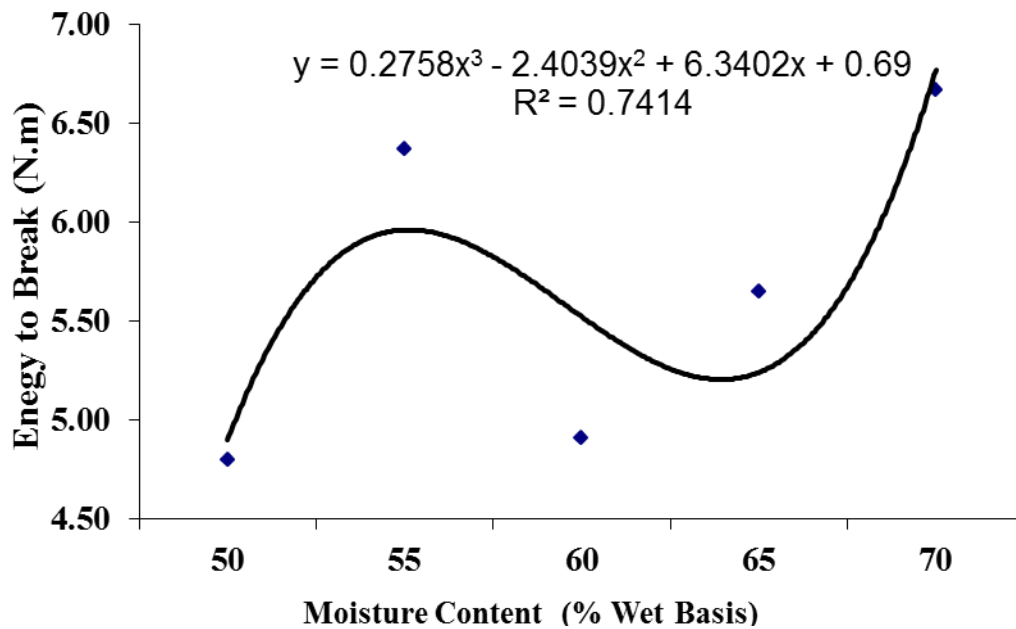


Figure 3: Toughness of Cassava Root with Moisture Content

The stiffness modulus, represented by the Young's modulus of the samples also ranged from 4.81 to 9.28 N/mm<sup>2</sup>. It was observed to increase steadily from 4.81 to 6.24 N/mm<sup>2</sup> between moisture contents of 50 and 60% after which it increased rapidly to 9.28 N/mm<sup>2</sup> within the moisture region of 60 and 65% (Figure. 4).

$$y = -0.3133x^3 + 2.7043x^2 - 5.6824x + 8.24 \quad (\text{Equation 3})$$

$$R^2 = 0.899$$

Thereafter, it decreased to 8.13 N/mm<sup>2</sup> at 70% moisture content (Table 1). The range of 0.5 – 2.497 N/mm<sup>2</sup> reported by Kolawole *et al.* (2007b) for the stiffness modulus of cassava roots within the same moisture range grossly underestimated the stiffness of the roots. Again, the improvised tools used for conducting their experiments might be responsible for this very wide variation. The influence moisture content on the stiffness modulus of the roots was found to significant.

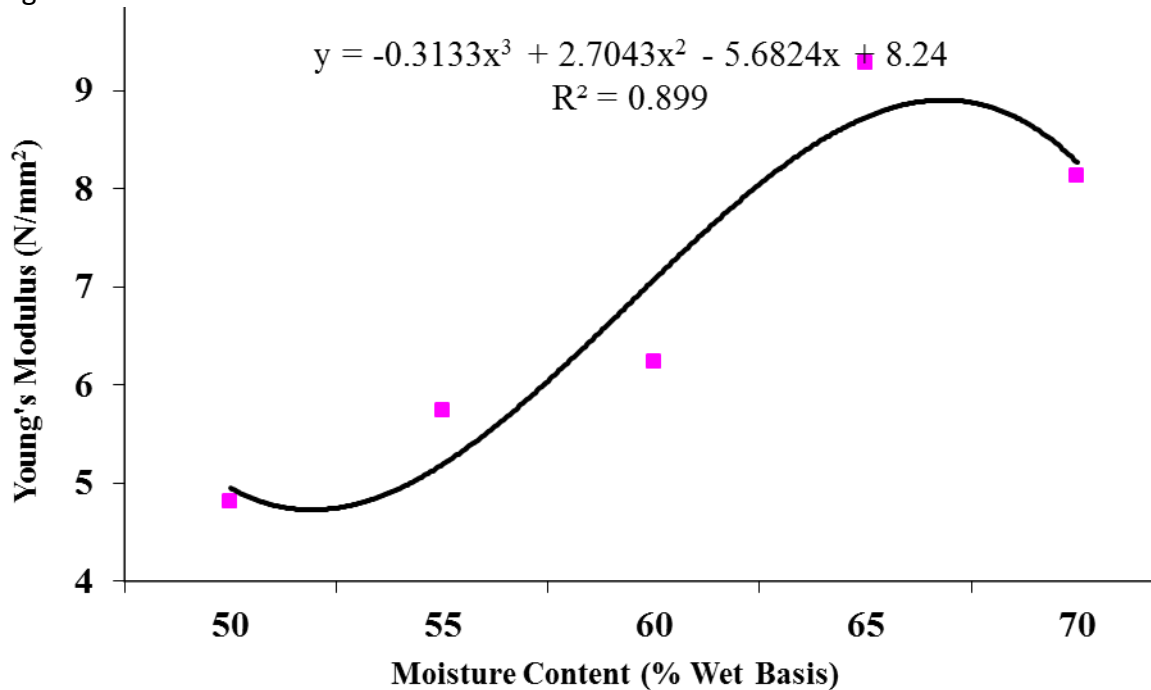


Figure 4: Stiffness of Cassava Root with Moisture Content

#### 4. CONCLUSIONS

This study has shown that the stress at peak, energy to break and the stiffness modulus ranged from 0.61 to 0.88N/mm<sup>2</sup>; 4.80 to 6.67Nm and 4.81 to 9.28N/mm<sup>2</sup> respectively, within the range of moisture content studied, which shows that the strength properties of the cassava roots are generally low and they increased with increase in moisture content. The roots also attained a yield point before fracture and the relationship of the strength properties with moisture content is non-linear in nature in contrast with earlier reports. This information would be useful in the design and development of cassava root harvesting and processing machinery.

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**FARM MACHINERY SELECTION FOR AGRICULTURAL PRODUCTION BASED ON GROSS-MARGIN COSTING ANALYSIS IN LAFIA L.G .A OF NASARAWA STATE, NIGERIA**

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**ABSTRACT**

A Survey was conducted in Lafia ,Lafia North and East Local and development areas of Nasarawa State, Nigeria to compare the costs of using hired tractors with the costs of operating privately – owned tractors. The results of survey showed that the State land areas cultivated by the survey farm enterprises was 245ha.The State number of tractors was 15 and all the tractors have the same power rating of 53.7kW (72hp).The total annual fixed cost for operating the tractors was ₦888,425.36 while the total variable cost was ₦218,535.36. The cost of hiring by government was less than that of privately-owned enterprise. It was discovered that a tractor ploughing at the rate of 1.2ha/hr and working for an average of 8hrs/day will plough 9.6ha of land per day. The result of the study also highlighted the factors that affect farm machinery selection and how best these factors could be influenced by well-planned selection practices. A gross-margin cost analysis was used in the profit evaluation of specific machinery work combination. It was found that the allocation of capital to purchase machinery can be made as effective as possible with machinery being chosen on the basis of which one will give the beneficial productivity. The paper also identified poor selection and in efficient operation as factors partly responsible for the increase in machinery operation. The study recommended among other things that the selection of farm machinery for agricultural production should be area specific due to ecological conditions and also based on the type of farm enterprise.

**Keywords:** Farm machinery, selection, Agricultural production, Gross-margin cost, Lafia, Nigeria

**1. INTRODUCTION**

The Agricultural industry, like manufacturing, utilizes labour, power and the resources of production in a planned programme of activity. In agriculture, the resources of production include land, fertilizer and a planned programme that involves the agronomic or cultural

method and a general system of farming, which are practiced. Farm machinery is recognized as the medium by which farm labour applies to the various production processes (McColly and Martin, 1955, Yohanna, 2006 & 2007). With the shift from hand –operated implements to power – operated machines, the farmer has become a larger producer with a decrease in the effort and time necessary to obtain a unit of production. The management of an organized farming enterprise now involves the selection of agricultural machines to perform the necessary operations. The proper choice and management of the power and machinery plant are ever – present problems (Smith, 1965 and Yohanna, 2007).

The satisfactory performance, efficiency and economy of a tractor and its complement of machines depend on their adaptability to the crops produced, the hectare involved and the conditions under which the machines must operate. In the production of crops certain field operations must be carried out. The machines selected must not only be adapted to use with the tractor, they must also satisfactorily perform the desired operations. Since a tractor is usually used for more than one crop, there are some machines that will be employed with all the crops such as a plough. Other machines may be special and used in connection with only one crop e.g. a potato planter. Some machines are selected for special conditions and may not serve every season; yet the lack of such machines at a critical time could mean the loss of a crop. A rotary hoe or a crust breaker is an example of such a machine (McColly and Martin 1955, Kumar et al., 2012, Ojha and Michael, 2003 & 2011 and Sahay, 2004).

Smith (1955) and Onwualu et al (2006) stated that the factors to be considered in selection of an agricultural machine over another include the trade mark, trade name, models, repairs, designs, ease of operation, ease of adjustment, adaptability to factors such as power requirement, cost of operation, initial cost (of machine), year of service expected and purchase of equipment is economical in relation to the size of farm and the work to be performed by the equipment. Anazodo (1985) observed that the application of human, animal and mechanical equipment in agriculture with reference to technical, socio – economic and cultural constraint of farm can be acknowledged in the continuing official promotion of primitive hand tool technology characterized by low production efficiency. Olaoye (2007) stated that timeliness of tillage and planting, weeding and/or harvesting are critical factors

where affordable labor is insufficient to permit timely operation. Other factors that influence successful mechanization include supporting infrastructures, land and agro-ecological conditions, technical skills and services.

Farming is generally rain fed and of the subsistence variety (IFPRI, 2010). The solution to the hunger problem lies in serious farm mechanization, high yielding varieties of seeds and the availability of fertilizer, pesticide and other farm inputs. Farm mechanization has been seen as the pivot to agricultural revolution in many parts of the world, and has contributed greatly to increased output of food crops and other agricultural products to meet the demands of the ever increasing world population. Through farm mechanization, many industrial raw materials are produced for the rapidly expanding world industries (Ituen, 2009). Tools, implements and power machinery are essential and major inputs to agriculture. The mechanization is generally used as an overall description of the application of these inputs (Clarke, 2000); while the term agricultural machinery is generally referred to as the collection of machines for agricultural production (Yohanna, 2007).

Mechanization pattern is a function of size of the farm holding, which is the limiting factor on the choice of different categories of agricultural tool, implements and machinery applied to each farm size. Therefore, to fully utilize the potential power available from agricultural machinery, care must be exercised in the manner to selecting economic, adequate and efficient machinery selection for optimum agricultural production (Ogunlowo, 1997). A rational machinery selection consists of four segments namely power requirement, tractor – implement combination, field machine matching and cost analysis. There are two types of ownership of tractors in Nigeria namely private and government. The government ownership, which has been the dominant source of power for farm operations, is administered in the tractor hiring units (THU) of the Ministry of agriculture and natural resources, Farm mechanization agencies, Agricultural development projects/programmes in the States of the federation. The major factors militating against full mechanization in Nigerian agriculture is the fact that the costs of owning and operating a tractor are the greatest factors in farm production costs (Ogunlowo, 1997). Other factors as stated by Onwualu et al (2006) include prevalence of fragmented farm holdings, prevailing agronomic practices, lack of classified data

and information, inadequate repairs and maintenance facilities, lack of trained machinery operators, poor credit facilities, inadequate research programmes, inadequate agricultural extension services, absence of incentives for indigenous design and manufacture of machines, inadequate infrastructural facilities and problem of unemployment. Thus, by selecting the optimum size tractor and undertaking properly formulated tractor job matching procedures; a substantial profit can be sustained. Whitson et al (1981) pointed out that a farm operator who operates primarily with owned machinery is faced with the task of selecting the proper size and number of equipment items to perform field operation within a given time frame.

Cervink and Chancellor (1975), Ogunlowo (1997) and Olaoye and Rotimi (2010) opined that capital costs, operating costs and energy requirement of farm machinery were important budgeting factors on most commercial farms. Murray and De-Beer (1978) viewed it as costly practice not to fully utilize the potential power available from agricultural machinery. They concluded that an effective mechanization plan needed to take into account the tractor and implements, which must be chosen so that the tractor is fully utilized with respect to the power available and so that the tractor – implement combination is matched to the size of the job at hand.

Mechanization involves many tools and machines, usually available from which farmer could choose, but when deciding on a particular machine, Booyesen and De-Beer (1977) and Fernandes et al (2008) stated that it was necessary to consider the rest of the system such as availability and type of labor and implements already on the farm. Also Witney (1988), Williams (1992), Aked (1991 &1992), Onwualu et al (2006) and Olaoye and Rotimi (2010) stated that there is need to minimize service and maintenance as factors to be included in the process of choosing new tractor and equipment. Field machinery capacity requirement depends upon the amount of work to be done and time available to complete the job (Singh and Holtman, 1979, 2004 and Murase, 2007). In Hughes and Holtman (1979) and Ojha and Michael (2003), it was found that selecting the best size machine and implements for a given farm operation helps to avoid yield loss from untimely field work and excessive fixed costs of oversized machines.

Yohanna (2006) and Onwualu et al (2006) stated that there is proliferation of brands of tractors in Nigerian markets with little or no attention paid to those factors that guarantee efficiency and long service life. The irony of this situation is that the majority of these imported tractors and implements often break down within 1000 hours of operations and in most cases, the tractors become totally grounded and eventually abandoned due to non-availability of spare parts for replacement. Through personal experiences and information gathered from field officers, it was discovered that in most cases lack of genuine spare parts come directly from wrong choice of machine type and inefficient attention to the manufacturer recommendations.

The objective of this paper is to determine the factors affecting farm machinery selection and use for effective and efficient machine-implement matching that will increase agricultural productivity and maximize profit.

## **2.0 MATERIALS AND METHODS**

### **2.1 AREA OF STUDY**

The study reported here is carried out in Lafia Local Government and Development Areas of Nasarawa State, Nigeria. The State lies within the tropics (lat. 8.5<sup>0</sup>N and long. 8.5<sup>0</sup>E). It is bounded in the North by Kaduna State, in the East by Plateau and Taraba States, in the West by Abuja, the Federal capital territory (FCT) and in the South by Benue and Kogi States. It covers a land area of 27,117sq. Km and has an estimated population of two million. The State has a tropical climate with two distinct seasons, the raining season (March – October), followed by the dry season (November – February). The annual mean temperature is between 21<sup>0</sup>C and 37<sup>0</sup> C and the annual rainfall is between 1100 to 1600mm. The topography is undulating, flat and hilly in most parts (Wikipedia 2014).

### **2.2 SAMPLING TECHNIQUES**

The primary and secondary data were used in the study. The primary data was obtained through the use of structured questionnaires. The questionnaire was administered to both literate and

illiterate farmers/workers to extract information from them. For the illiterates, an assistant was used to interpret and fill the questionnaires for them. The primary data included farm size, cropping pattern, kinds of farm machines, type of tools, time required for each stage of farm operations, hiring rates, power ratings of machines, models of tractor etc. The secondary data was obtained from Nasarawa State Development Programme (NADP) newsletter and monthly seminar reports, Journals, State ministry of agriculture and water resources and Farm mechanization Agency (FAMA). For consistency of records, only farm enterprises in the State and not individual farmers were used in the primary data collection stage. This was because only few individuals could buy tractors and because individual farmers have very small farm areas. Another reason for the restriction was that most of these individual farmers are illiterates and hardly kept records. The farm enterprises used had a minimum farm area of 10 ha and most of them had records or documentations where records of the previous years were kept.

Within the three Local Government/Development areas under study, 7 farm enterprises were randomly selected from each area. Ten questionnaires were distributed in each of the farm enterprises. At the end of the survey, responses were retrieved from 6, 5 and 4 farm enterprises in Lafia municipal, Lafia East Development area and Lafia North Development area respectively. In all 75 of the farmers from 21 farm enterprises approached responded to the survey representing 71.4%, retrieved for analysis.

Gross Margin analysis (GMA) of each farm enterprise was calculated and the resulting net farm income per hectare was determined for each farm. This was used to determine which enterprise was making more profit than others with regards to the use of farm machinery at their disposal. The following relationship was used to calculate the Gross Margin (GM)

$$GM = R - TVC \text{_____} (1)$$

Where, R = Revenue generated and

TVC = Total variable or operating cost.

Total operating or variable costs include the cost of ploughing, harrowing, ridging, spraying, planting, harvesting, procurement of inputs, cost of tractor services, maintenance, repairs and

spare parts. Fixed cost includes depreciation of machines, shelter, insurance and interest on investment. There are no taxes on agricultural machinery in Nigeria.

### **3.0 RESULTS AND DISCUSSIONS**

In the study area surveyed, farm less than 5ha and 9ha were designated as small and medium farms respectively while with a size of 10ha and above were classed as large farms based on the level of mechanization practiced in Nigeria (Ogunlowo, 1997). From this classification, most of the areas covered were in the medium – to – large farm categories. Table 1 is a compilation of the survey results from the respondents. The diverse use of tractors on some large farms resulted in less numbers of labour used per unit land area as one multipurpose machine could do the job of many farm workers. The tractor models used on most farms visited were the Massey Ferguson 375, Steyr 768 and Steyr 8075. These makes have the same average power of 53.7kW (72Hp) and the average cost of operating these tractors was ₦20, 000=00 per day. Table 2 shows the relationship between farm size and total average cost per hour for government (THU) and privately owned tractors based on the number of hours used per annum. It also shows that the larger the farm size and the number of tractors used, the higher the total variable cost (TVC). A farmer hiring a tractor has the right over the tractor for the period of time he/she pays for it. The tractor will therefore only be available to him/her despite his/her hiring power when the owner of the tractor releases it, since farm operations are time specific and as such the farmer hiring the tractor has to beat the time and the farmer leasing the tractor has to finish his/her own farm work before leasing out his/her tractor. This is responsible for the increase or higher number of labour normally found on farms that depend on hiring tractors for their farm operations. These reasons contribute to high costs of labour for hiring tractors when compared to privately – owned tractor operations. In the tractor hiring situation, the farmer pays for all farm operations the machines will perform while the owner of the machine takes care of the cost of fuelling, repairs and maintenance and wages of the operators.

Table 3 gives the relation of annual use and cost of the hired and privately –owned tractor. The annual use of privately-owned tractors is higher than the hired tractors. This was responsible for the difference in the operating costs (Table 4). The other reasons for the difference in price were

that the hired tractors' operators did not give careful attention to the tractors and these operators were also randomly selected to operate any of the tractor models. These caused frequent tractor breakdown and in such cases, the costs of spare parts for hired tractors were excessive.

The results of tractor annual use on these costs of operating tractors in the study areas are shown in Table 4. These tractors have the same power ratings of 53.7KW, age and operating under similar conditions. The total annual fixed cost with the 53.7kW MF or Steyr tractor was N888,425.36 while the total cost per hour were N721.12 and N464.40 for 1232 hours and 2184 hours annual use respectively. The table shows the cost advantage of owning farm machinery (tractors). When the tractors and implements belong to the farmer, he/she does not need to pay for the use of his/her operations, rather he/she accounts for the operating costs, cost of labour and all the inputs he/she needed on the farm. These form his/her total variable costs (TVC). From the table, the larger the farm size, the higher the TVC, and the more the tractors and implements, the higher the TVC. It should be noted that the cost of labour or labour size is a function of the number of tractors and different types of jobs the tractor could do. The investigation also revealed that the repair and maintenance costs are proportional to the tractor age i.e. as the tractor gets older, the cost of repairs and maintenance increases (Table 5 and Fig.1). The regression equation for tractor repair and maintenance cost in terms of age is given as:-

$$R_C = 1170T_A - 1735 \quad (R^2 = 0.979) \text{-----}(2)$$

$$R=0.994$$

Where,  $R_C$  = Repair cost (N), and

$T_A$  = Age of tractor (year).

### 3.1 DETERMINATION OF PROFIT BY GROSS-MARGIN ANALYSIS

Gross margin is the difference between total revenue and cost before accounting for certain other costs in calculating margins and in the ways they analyze and communicate these important

figures. Gross-Margin Analysis (GMA) is an economic process used to determine whether an enterprise is operating at profit or loss level (Wikipedia, 2014). From the survey, it was discovered that a tractor ploughing at the rate of 1.2ha/hr and working for an average of 8 hours will plough 9.6 ha of land per day. It then means that for an area of 20ha, it will take one tractor 2 days for the working period. This is so because the tractor will spend some time out of the 8 hours of each day for loading, fuelling and turning in the field. Hence the effective operating time will be enough to finish the ploughing. This survey revealed that when the tractors were under-utilized, the farmers incurred high TVC, lower profit per ha per tractor (Table 6). As the number of tractors on the farms are reduced, the profit per ha per tractor will be significantly changed thus reducing the TVC. What this shows is that it is profitable to use the exact optimum number of tractors for a particular farm operation. It was also observed that the higher the number of tractors with regards to the farm size, the lower the profit. Table7 shows the profit accruing to the farmers practicing mixed cropping operation. The total operating cost in the Table includes costs of farm inputs, labour, repair and maintenance, fuel, oil and lubrication used for the crop production in the local and development areas under study. The land limitation, available hours of field time, farm machinery size and cropping alternatives found in the survey area were also taken into consideration in the course of results compilation.

#### **4.0 CONCLUSION**

From the survey carried out, it is necessary to take into consideration the economic factors that affect the choice of tractor and implement for effective machinery use. Tractors perform farm jobs effectively only when they are properly matched with their implements. Farm machines operate over uneven terrain, through dust, sand, mud, and stones, it is therefore essential that the machinery to be employed must be ready to face the stress and strain under which it must operate without efficiency loss. The tractor and implement must be chosen so that the tractor is fully utilized with respect to the power available. Since the size of a tractor is expressed in terms of its weight, horse power and implements capacity, adequate matching of implement with tractor is ensured when the tractor power is known with respect to the number of furrow it can normally

pull on any particular soil and the width of other standard implements it may be expected to handle.

From this survey, it pays to select appropriate number of tractors for farm operations as this ensures high profit, minimizes the possibility of under-utilizing farm resources and thus saves costs. Also the use of Gross margin approach to farm machinery selection will enhance profitable decision on tractor-implement combination to accomplish a specific farm job. The expected benefits of GM approach include reduction in loss in values in terms of quality and quantity of crops and better utilization of man and machine.

The study showed that the selection of farm machinery should be area-specific and also based on the type of farm enterprise; since timeliness of operation affects crop yield and hence profitability of using machinery/equipment chosen must be reliable. This includes timely completion of all operations. The study also shows that for the use of a privately-owned tractor to be profitable, the annual use should be at least 2184 hours because this is the least number of hours that gives minimum costs of using the tractor. Also for cost of operating THU to be minimized, the tractor operators should be trained to acquire the necessary basic skills in tractor use and maintenance. It was also found that substantial profit can be obtained by selecting the optimum number of tractors and undertaking properly formulated tractor job matching processes.

The qualitative assessment of the performance of equipment is highly essential and is achieved by evaluating its suitability to the ecological condition, ease of operation and how good the quality of job the equipment does under the prevailing condition. The suitability and adaptability of imported equipment to Nigeria climate and ecological conditions constitute the problem that should be solved in assessing the effective performance of agricultural equipment.

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**TABLE 1. Farm Group, farm Area and Tractor use of Respondents**

Farm Group	Total Area	% farm	No of tractor	Hectare per tractor
	Cultivated	Area		
Small	22	8.89	2	11
Medium	75	30.61	4	18.8
Large	148	60.41	9	16.4

Source: Field survey. 2013.

**Table 2: Relationship Between farms Area and total average cost per hour for government and privately-owned tractor.**

Farm Enterprises	Each enterprise Area (ha)	farm No of tractors	Govt hiring unit Cost per hour (N)	Privately –owned unit Cost per hour (N)
1	10	1	2,500	3,125
2	12	1	2,500	3,125
3	15	1	2,500	3,125
4	18	1	2,500	3,125
5	20	1	2,500	3,125
6	22	1	2,500	3,000
7	25	2	2,500	3,000
8	30	2	2,500	3,000
9	45	2	2,500	3,000
10	48	2	2,500	3,000

Source: Field survey, 2013.

**Table 3: Average Annual use and costs of government (THU) and privately owned Tractor**

<b>Ownership</b>	<b>Average use (hr)</b>	<b>Cost per hour (N/hr)</b>
Government	1232	2,500
Private	2184	3000- 3,125

**Source: Field survey, 2013.**

**Table 4: Effects use on costs**

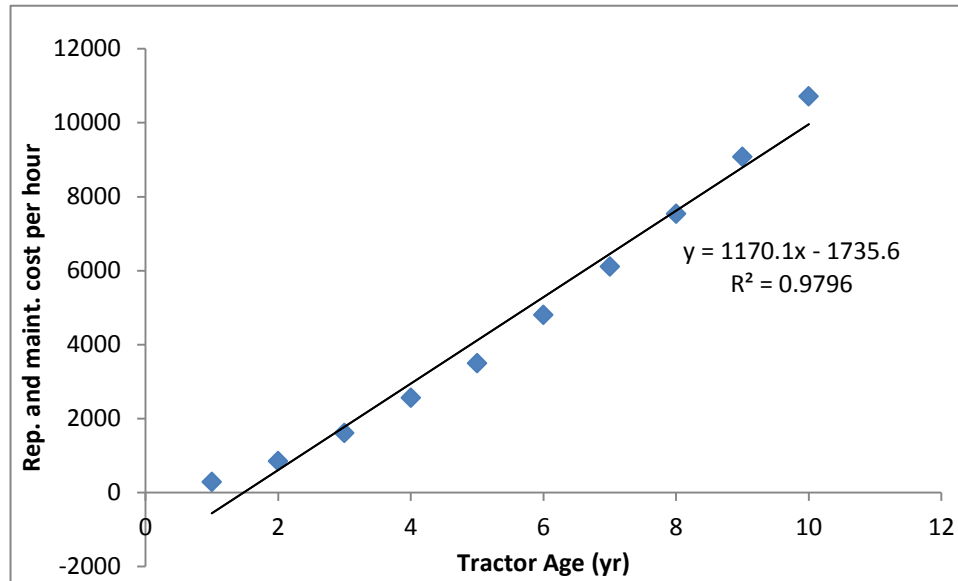
	Seasonal use of Tractor (N)	
	1232 hours	2184 hours
Tractor initial cost: N4, 200,000.00		
Power: 53.7Kw (72 Hp)		
<b>Fixed costs</b>		
Depreciation of 10% of initial cost	378,000	378,000
Interest on investment (9%)	207,900	207,900
Insurance and shelter at (2%)	84,000	84,000
<b>(a) TOTAL FIXED COST</b>	<b>669,900</b>	<b>669,900</b>
<b>Variable costs</b>		
Fuel cost	99,800	180,500
Lubrication at 2% fuel cost	6,336	12,100
Repairs and maintenance	100,000	188,500
Interest on operating cost @ 6% & 4% respectively.	12,369.36	13,244
<b>(b) TOTAL VARIABLE COST</b>	<b>218,525.36</b>	<b>344,344</b>
<b>Total costs = a + b</b>	<b>888,425.36</b>	<b>1,043,444</b>
<b>Total costs per Hour</b>	<b>721.12</b>	<b>464.40</b>

**Source: Field survey, 2013**

Table 5: Relationship between Tractor Age and Repair and Maintenance Cost

<b>Tractor Age</b>	<b>Average Repair and Maintenance cost per hour (N/hr)</b>
1	283.68
2	844.60
3	1604.82
4	2552.52
5	3490.64
6	4796.68
7	6106.80
8	7534.32
9	9072.12
10	10,711.80

**Source: Field survey 2013**



**Fig. A plot of tractor age against repair and maintenance cost per hour**

**TABLE 6: EFFECT OF TRACTOR USE ON PROFIT**

Land Area	No of	Fixed cost	Total variable	Revenue	Gross Margin	Profit	Profit per	
Profit per hr	Tractor	(FC) (N)	cost (TVC)	( R )	(GM)	(GM-FC)		
per(ha)								
Hectare	Tractor (N)	( N )	(N)	(N)	(N)	(N)	(N) -----	
22	2	11 8800	156860.5	774378.86	617518.29	498718.29	22669.01	11334.51
75	4	237600	179245.72	1603620	1424374.28	1186774.22	15823.266	3955.91
<u>148</u>	<u>9</u>	<u>445500</u>	<u>351079.58</u>	<u>3976664.5</u>	<u>3625585.59</u>	<u>3180085.59</u>	<u>21487.06</u>	<u>2387.45</u>
22	1	59400	117637.50	77581.50	559944	500544	22752	22752
75	2	99000	231593.14	1603620	1372026.86	1273026.86	16973.69	8486.85
<u>148</u>	<u>5</u>	<u>247500</u>	<u>282193.50</u>	<u>3497992</u>	<u>3215798.50</u>	<u>2,968,298.5</u>	<u>20056.07</u>	<u>4011.21</u>

**Source: field survey, 2013**

**Table 7. The effect of some selected crop alternatives on operating costs, crop yields and sales prices for lafia local and development areas of Nigeria.**

Land area (ha)	Mixed cropping yield (kg/ha)				Revenue generated from sales (N/ha)				Cost benefit of cropping alternatives	
	Ma	ca	cp	me	Ma	ca	cp	me	TOC(N/ha)	RAOC(N/ha)
22	1144	1198	94877	34993	44988	20996	95982	10828	127054	45740
	(14)	(5)	(2)	(1)						
75	11827	68767	4877	28654	58190	100711	95982	21204	201535	74552
	(43)	(20)	(8)	(4)						
148	9876	125738	6828	73400	48590	148590	134375	54317	285775	102879
	(95)	(31)	(15)	(7)						

Source: Field survey, 2013 &2014

**NOTE:** Ma-maize, ca-cassava, cp-cowpea, me-melon

TOC-Total operating cost (N/ha)

RAOC-Return above operating cost (N/ha);

Figures in brackets are land allocated to each crop alternatives.

## PHYSICO - MECHANICAL PROPERTIES OF CASTOR (*recinus communis*) PLANT FIBRE AND ITS UTILIZATION AS AN ENGINEERING MATERIAL

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### ABSTRACT

In many communities, natural fibres and other waste materials from agricultural production are extracted without proper utilization due to inadequate knowledge of its engineering properties. This study is aimed at the extraction of fibre from SA -2 variety of castor plant at different stages of the plant growth with the view of evaluating some properties of the fibre relevant to its possible utilizations. The properties evaluated were physical and mechanical. ASTM (1997), TAPPI(1980) standard methods for the physical and material tensile testing machine (Cusson P5030) for mechanical properties were employed. The physical properties determined were moisture absorption (5.024%, 5.066% and 4.136%) and density ( $0.458\text{gcm}^{-3}$ ,  $0.684\text{gcm}^{-3}$  and  $1.234\text{gcm}^{-3}$ ) at initial (4WAS), flowering(8-9WAS) and matured(16WAS) stage, respectively. The mechanical properties analysed were found to be (2.220kgf and 4.180kgf) breaking load, elongation at break (4.513mm and 6.65mm), stress ( $0.005\text{kgf/mm}^2$  and  $0.006\text{kgf/mm}^2$ ), strain (0.056 and 0.066), modulus of elasticity ( $0.125\text{kgf/mm}^2$  and  $0.102\text{kgf/mm}^2$ ) and the specific work at rupture( $3.000\text{kgf}$  and  $5.700\text{kgf}$ ) at flowering(8-9WAS) and matured (16WAS) stages, respectively. The fibres were better when matured than any other stage but the fibres at all stages were recommended for various possible utilization in composite and engineering applications.

Keyword: castor fibre, moisture absorption, density, modulus of elasticity and specific work at rupture

### 1.1 INTRODUCTION

Castor plant is a glabrous annual or perennial shrub or a small tree growing to a height of 3-8m. Castor breeding has already reduced the plant from a tree(up to 10m tall) to a herb (of about 1.5m), with concomitant reduction in branching(Simmonds,1976). There are many varieties of both wild and cultivated castor, varying in plant height, colour of stem and seeds, bean size (William et al., 1989).Chhidda et al.,(2006) reported that,SA – 2 castor variety, is a drought resistant and medium tall plant (180 – 200cm). Its seeds are dull white with brown mottling and small in size. This variety takes about 95 – 100 days to mature. Castor plant contains valuable resources that include oil, protein, carbohydrate, minerals and fibre among others. Hence, investigating on some physical and mechanical properties of SA – 2 variety of castor plant fibre will go a long way in identifying possibilities in its utilization at home and industry (as composites materials).

Physical properties such as size, shape surface area, volume, density porosity, colour and appearance are important in designing particular processing equipment or to determine the behaviour of properties for its handling (Sahay and Singh, 2001). Ability of fibre to absorb or de-absorb moisture should be considered when evaluating the stability of the fibre for various applications especially for textile, paper and composite (Narendra and Yang, 2005). Properties such as density and electrical conductivity among others are related to the composition and internal structure of a fibre (Narendra and Yang, 2005). Plant fibre have low density, so when used in the construction of car parts such as door panel and roof will lead to reduction in the amount of fuel consumed since it would require a little energy to propel a lighter object than a heavier object (Aguet al., 2012).

The mechanical properties of biomaterial explain the behaviour of the material under applied forces. Ogbonnaya and Bosede (2011) asserted that, knowledge of mechanical properties (properties that have to do with the behaviour of agricultural products under applied forces) such as stress, strain, hardness and compressive strength is vital to engineer's handling of agricultural products. Khurmi (2007) agreed that, every material is elastic in nature and that is why whenever some external system of forces acts on a body it undergoes some deformation. As the body undergoes deformation, it's molecules set up some resistance to deformation. This resistance per unit area to deformation is the stress. The degrees to which a structure deform or strain depend on the magnitude of an imposed stress (William, 1997). Most agricultural products are visco – elastic, they behave differently under static tensile or compressive force and under dynamic or repeated dynamic loads. It is important to note whether the product may be deformed by tensile or compressive force (Drambi, 2011). The behaviour of plant fibre proved to be soft and flexible, which make it difficult to ascertain its properties comprehensively.

## **2. MATERIALS AND METHODS**

### **2.1 CROP VARIETY AND LOCATION**

SA -2 variety of castor plant was cultivated in Yola and harvested during its initial (4WAS), flowering (8-9WAS) and matured (16-WAS) stages of growth. Natural fibres were extracted from the stem of the plant using water retting extraction process, giving the fibres of different lengths and diameters. The fibres were visually selected in order to verify the absence of defects before tests were conducted.

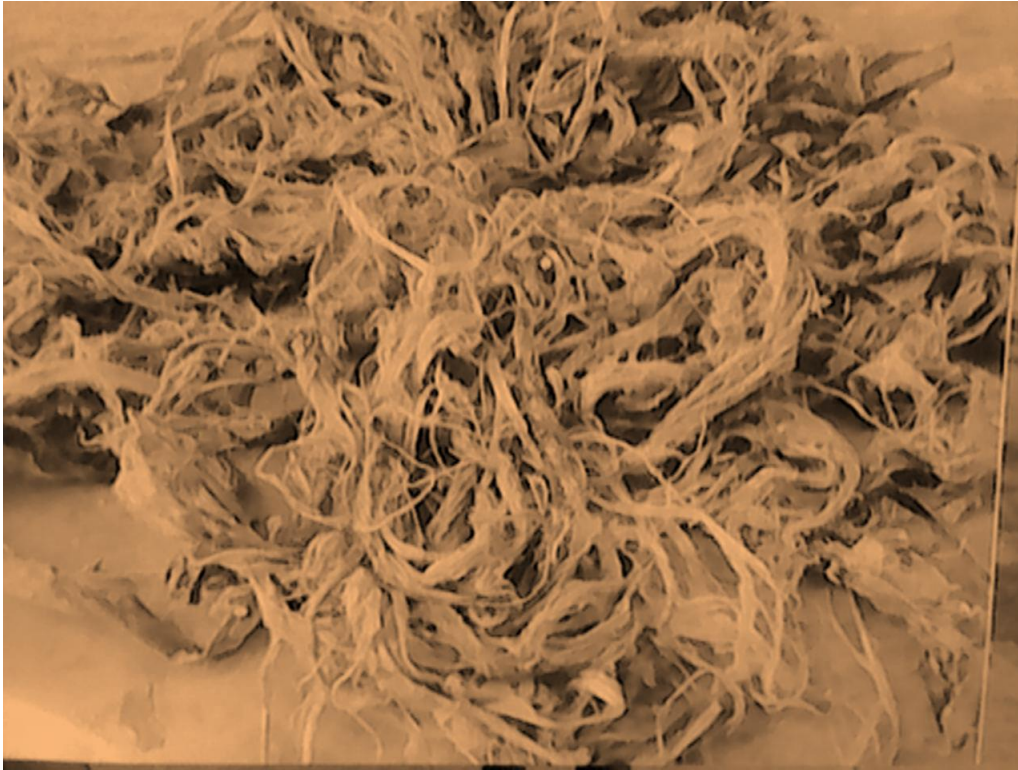


Fig 1. The extracted castor fibre

## 2.2 EXPERIMENTAL PROCEDURE

### 2.2.1 *Determination of Moisture Regain*

American society for testing and material (ASTM,1997) standard testing method for moisture regain was adopted to determine moisture absorption of castor fibre at initial, flowering and matured stages. Castor fibre sample was conditioned for 24hrs at  $27 \pm 2^{\circ}\text{C}$  and the weight taken as ( $W_1$ ). The conditioned fibre sample was oven dried at a temperature of  $105^{\circ}\text{C}$  for 4hrs and the weight taken as ( $W_2$ ). Moisture absorption percentage of the given sample was calculated according to the formula in equation 1 as reported by Brindha et al.,(2013).

$$\text{MoistureAbsorption\%} = \frac{W_1 - W_2}{W_1} \times 100 \quad 1$$

### 2.2.2 *Determination of the Fibre Density*

The density of castor plant fibre each at initial (4WAS), flowering (8-9WAS) and matured (16WAS) stages was determined by conditioning the fibre sample for 24hours at 65% relative humidity and at a temperature of  $25^{\circ}\text{C}$  before carrying the test. Two grams(2g) of each sample was accurately weighed. Each weight was immersed in toluene in a calibrated glass tube (10ml measuring cylinder) and volume of toluene displaced was determined which equals the volume of castor fibre immersed. The density of the fibre sample was calculated from the formula below`.

$$\text{Density} = \frac{\text{Mass}}{\text{volme}} \text{ in g/cm}^3 \quad 2$$

The method adopted was as described by Technical Association of pulp and paper industries (TAPPI, 1980).

### 2.3 ANALYSIS OF THE FIBRE ENGINEERING PROPERTIES

Engineering properties such as breaking load, elongation at break and specific work at rupture are those to be analysed using Material tensile testing machine. While parameters like tensile stress, tensile strain and modulus of elasticity are to be evaluated from the measured properties.

Castor fibre samples obtained at flowering and matured stages each of equal length of 100mm were prepared for tensile testing. Material tensile testing machine (Cusson P5030) model was used. The length of each fibre specimen was tightly secured on the spacer to prevent the specimen from slipping off during the tensile test. The tensile tester was actuated and the cross head was pulled upward so that the sample was stretched until breakage was observed. At this point, the cross – head stopped and the load and its corresponding elongation at breaking point were read directly from the monitor attached to the machine. Twenty five (25) replicates for each sample were carried out for these studies.

### 2.4 STATISTICAL ANALYSIS

Data collected was subjected to descriptive statistics and analysis of variance (ANOVA,  $P < 0.01$  and  $P < 0.05$ ) for each species separately using appropriate statistical software (SPSS) version 20.0 from which source of variation were drawn.

## 3. RESULTS AND DISCUSSIONS

The results of the study are presented in tables 1 and 2 and figures 2 and 3 below.

**Table1. Measured fibre physical properties**

Stages of the plant growth			
Parameter	Initial (4WAS) $T_1$	Flowering (8-9WAS) $T_2$	Matured (16WAS) $T_3$
Moisture absorption, %	$5.024 \pm 0.206$	$5.066 \pm 0.482$	$4.136 \pm 0.336$
	$0.458 \pm 0.044$	$0.684 \pm 0.096$	$1.234 \pm 0.039$
Density/cm <sup>3</sup>			

WAS=Weeks after sowing,  $T_1$ =Treatment 1,  $T_2$ = Treatment 2 and  $T_3$ =Treatment 3

Moisture absorption of the fibre determined at different stages of the plant growth as shown in table 1, were found to be (5.024%, 5.066% and 4.136%) at initial (4WAS), flowering (8-9WAS) and matured (16WAS) stages, respectively. The values decreased by 18.360% from flowering (8-9WAS) to matured (16WAS) stages. ANOVA conducted revealed that, the values were highly significant difference at  $P < 0.01$  level. The result also showed that this castor fibre absorbed low moisture and it will be good in composite application. Also, when compared with other plant fibre, it has been realised that they were lower than flax (Brindha et al., 2013), jute (Debiprasad et al., 2012), sisal and cotton (Naveen et al., 2014). While density of the fibre evaluated were (  $0.458 \text{ gcm}^{-3}$ ,  $0.684 \text{ gcm}^{-3}$  and  $1.234 \text{ gcm}^{-3}$  ) at initial, flowering and matured stages, respectively. The values of the density increased by

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 80.42% from flowering (8-9WAS) to matured (16WAS) stage. Statistically, the values were significant at  $P < 0.05$  level

**Table 2. Measured fibre engineering properties**

Parameters	Initial (4WAS)	Stages of the Plant growth	
		Flowering (8 – 9 WAS)	Matured (16 WAS)
$T_1$		$T_2$	$T_3$
Breaking Load (Kgf)	___	2.220 ± 0.665	4.180 ± 2.355
Elongation at break (mm)	___	4.513 ± 2.517	6.653 ± 2.926
Tensile Stress (kgf/mm <sup>2</sup> )	___	0.005 ± 0.001	0.006 ± 0.003
Tensile Strain	___	0.056 ± 0.021	0.066 ± 0.029
Modulus of elasticity (kgf/ mm <sup>2</sup> )	___	0.125	0.102
Specific work at ruptur (kgf)	___	3.000	5.700

Table 2. Summary result of mechanical analysis of castor plant fibres.

The load - elongation behaviour of the fibre at different stages of the parent's plant growth is shown in figures 2 and 3. The breaking load and breaking elongation curve for the fibre at flowering stage (8–9 WAS) as in figure 2, revealed that breaking elongation of the fibre sample increase sharply from 0.4 to 1.4mm and corresponds to increase in load from 1kgf to 1.6kgf. The point corresponding to 0.65mm is called the yield point. It may be noted that if load (kgf) on the specimen is removed then the increases in the length of the fibres specimen at that particular stage from 0.4 to 0.65mm will not disappear, but it will remain as a permanent set. The point of rupture of the fibre at that flowering (8-9WAS) stage occurred at 3kgf breaking load to a corresponding breaking elongation of 1mm. Even when the load increases beyond this point, the failure remain as it is since rupture has already occurred.

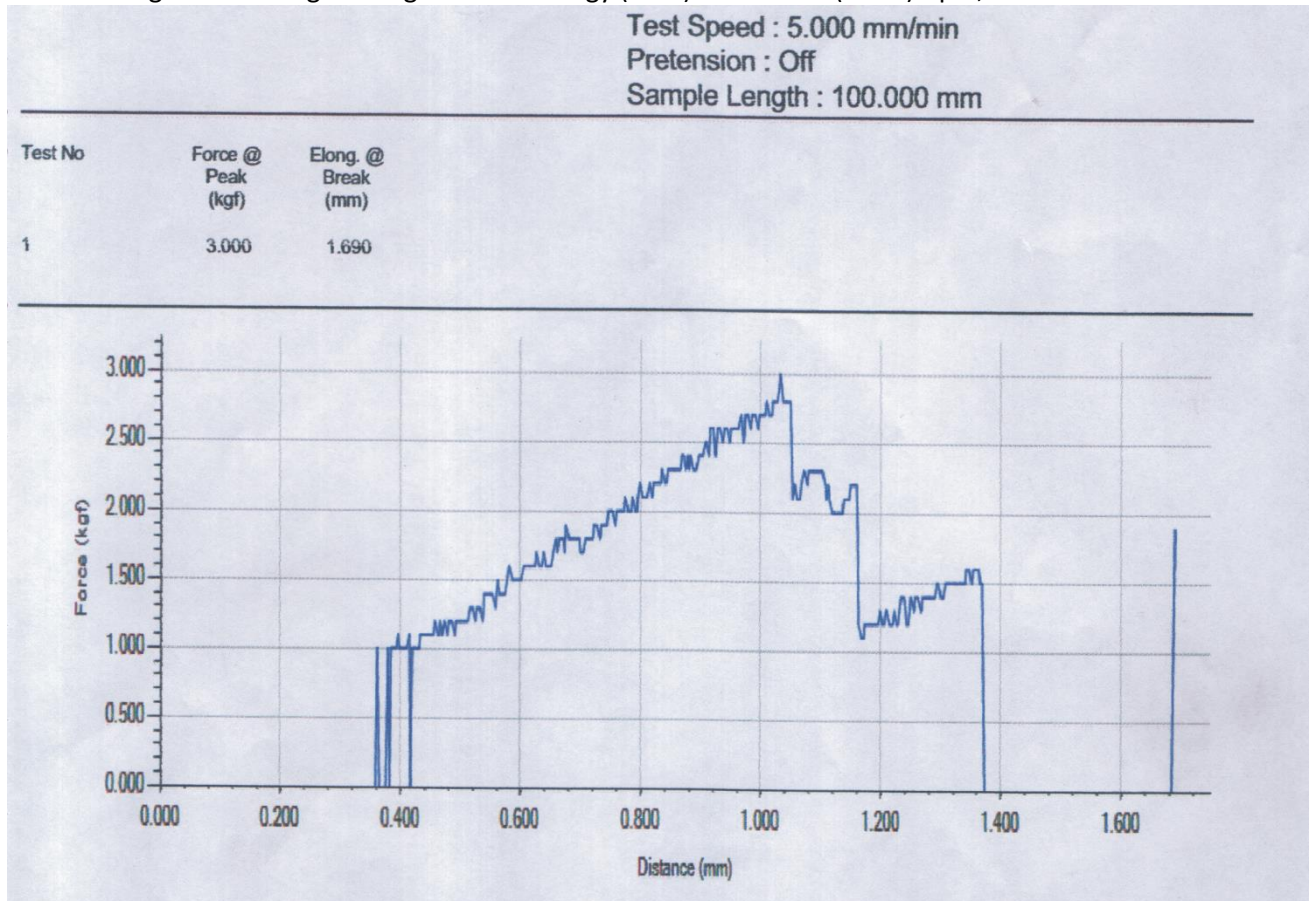


Fig 2. Load – elongation curve at flowering (8-9WAS) stage

Load – elongation behaviour of the fibre obtained at matured (16WAS) stage is presented in figure 3, this figure showed proportional increase in breaking load with increase breaking elongation up to elastic point.

. The point at 3.5kgf where the curve deviates from the straight line is known as elastic point. This agrees with the result reported by (Shulka and Sharma, 1987). Beyond this point it formed another yield point precisely at 4.8kgf with increase in elongation to 6.2mm. Further increase in load from this point resulted to rupture of the fibre at 5.7 kgf corresponds to breaking elongation at 7.3mm.

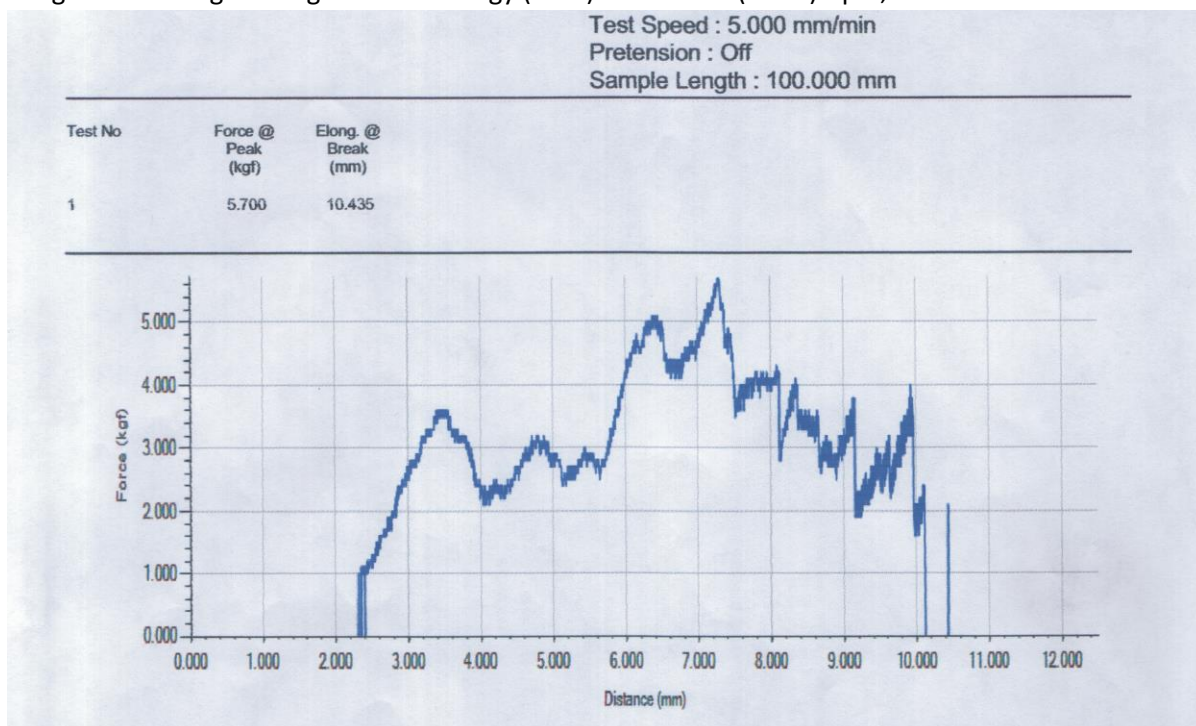


Fig 3. Load – elongation curve at matured (16WAS) stage

The mean values of stress – strain properties evaluated at flowering (8-9WAS) and matured (16WAS) stages were shown in table 2. Stress were found to be (0.005kgf/mm<sup>2</sup> and 0.006 kgf/mm<sup>2</sup>), Strain (0.056 and 0.066) and modulus of elasticity computed found to be (0.125 kgf/mm<sup>2</sup> and 0.102kgf/mm<sup>2</sup>) at flowering (8-9WAS) and matured (16WAS) stages, respectively.

The result in Table 2, also revealed that tensile stress and tensile strain increases from flowering(8-9WAS) to matured (16WAS) stages, while the computed modulus of elasticity decrease from flowering to matured stage.

The modulus of elasticity of these fibre at all stages mentioned were greater than different varieties of Banana fibre of Poovan, Kadhali, Mondhan and Rasthali as reported by (Brindah, et al., 2012). Higher modulus of elasticity makes the fibre stiff and suitable for use in application such as composite and carpet materials as suggested by (Narendra and Yang, 2009).

#### 4. CONCLUSION

SA-2 variety of castor plant fibre evaluated shows that at all stages of the plant growth, the fibres absorbed less moisture when compared with other plant fibres. The engineering properties analysed revealed that the values were higher at matured than flowering stage except modulus of elasticity that was higher at flowering than at matured stage. Hence, these fibres were better at matured than at flowering stage. On comparing these fibres properties with other plant fibres, the fibres can be effectively utilized in home and industrial applications especially in composites and carpet manufacture.

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## **ANTHROPOMETRIC PARAMETERS OF TRACTOR OPERATORS IN KANO STATE, NIGERIA**

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### **ABSTRACT**

An anthropometric survey was conducted in Kano State of Nigeria to provide major anthropometric parameters of tractor operators for easy adaptation to tractors available. Six easily determined body dimensions related to tractor control components (hand and leg levers) design were measured for a sample of 43 tractor operators. Data were analyzed statistically and the mean, Coefficient of Variation and Standard Deviation calculated. The variation was found at 5% level of significance. Dimensional models are suggested for 5th and 95th percentile drivers, which may be used as design tools. Knowledge of user dimensions can aid proper machinery adaptation since no manufacturer can design for all potential users. This would reduce occupational injury and enhancing safety and productivity since the operator is the major participant when total productive maintenance (TPM) is being considered.

**KEYWORDS:** Operator, Tractor, anthropometry, hand-and foot-controls, adaptation, Kano State

### **1.0 INTRODUCTION**

The increase in population in most countries has necessitated the use of tractors and other farm implements in food production and processing to feed the growing population.

Kano State has been leading other regions in Nigeria in terms of population for over three decades. This region is also blessed with abundant fertile land with favourable rainfall and large bodies of water for irrigation. This large population needs to be fed, clothed, sheltered and provided with other basic infrastructure for progressive modern development. The need for sufficient food for healthy growth in any society cannot be overemphasized. Traditional methods of farming using hand- and animal- drawn equipment over the years is giving way for tractor-powered machines to increase production, release more labour for the urban industries and make farming more attractive to the youth.

The farm tractor is one of the machines that form the pivot of agricultural mechanization and the basis for the utilization of other machines/equipment for various agricultural operations as ploughing, harrowing, ridging, planting, weeding, fertilizer application, harvesting and transportation within and outside the farmstead (Nkakini et al., 2008). The operator apart from operating the tractor can perform many maintenance activities such as housekeeping, equipment cleaning/sheltering, lubrication, inspection and routine adjustments (Stephens, 2004). However, these could only be possible if the operator is not over stressed due to non-compatibility or adaptation with the tractor design.

In order to meet the challenges of increased mechanical power for agriculture, various tractor importations and establishment of tractor assembly plants were embarked upon in Nigeria since late 1970's, as farm mechanization has been proposed as the only way out for all the issues plaguing agricultural operations (Powar and Aware, 2007). This resulted in myriad of tractor makes and models in most organizations in charge of mechanization programmes. Unfortunately, this effort at mechanization did not yield the expected results due to the fact that many of the tractors were imported without spare parts or not suitable for the Nigerian farming population (Yisa, 2002).

Yisa (2002) assessed the ergonomic suitability of two makes of assembled tractors (Fiat and Steyr) designed and manufactured in Europe using 20 randomly selected subjects. Eleven anthropometric parameters were measured (Table 1).

Table 1: Anthropometric data of subjects

	<b>mean</b>	<b>Standard deviation</b>	<b>5<sup>th</sup> percentile</b>	<b>95<sup>th</sup> percentile</b>
Standing height, cm	169.3	10.7	151.7	186.9
Full-hand length, cm	79.5	5.1	71.1	87.9
Popliteal length, cm	51.3	4.0	44.8	57.8
Body weight, kg	56.0	4.6	48.4	63.6
Seat-pan width, cm	31.0	1.8	28.0	34.0
Seat-pan depth, cm	54.2	5.3	45.5	62.9
Seat-back support height, cm	31.2	1.7	28.3	34.0
Elbow height, ccm	49.5	5.0	41.3	57.5
Hand-pan width, cm	10.2	1.3	8.1	12.3
Hand grip, cm	9.7	1.2	7.8	11.6
Full-leg length, cm	90.6	10.7	79.95	108.1

Source: Yisa, (2002)

Results show that with the provision of footsteps in the Fiat 80-66, the task of getting onto the tractor is made easier than in the case of Steyr 8075 where this facility is not available. Although the seat design was adjudged to be satisfactory in both tractors, lack of adjustable back support does not give good protection to the operators' spinal column. The steering wheel is very easily operated in the Fiat 80-66 which is not the case with Steyr 8075. Hand and foot controls are located at convenient locations.

Mokdad, (2002) did a study on anthropometry of Algerian farmers where 514 male farmers were selected and data on 36 body dimensions taken. These body dimensions were thought to be useful for the design and redesign of agricultural equipment and tools. Out of these only 18 are found relevant for tractor operators.

Different statistical methods can be used in anthropometric studies. The choice of method depends to a great extent upon the nature of data and the purpose for which they are collected

and presented. Mokdad, (2002) uses descriptive and inferential statistics to make data suitable for design purposes and to study the differences which might exist between the subject groups.

Victor et al., (2002) conducted an anthropometric survey of Indian farm workers to approach ergonomics in agricultural machinery design (Table 2). Anthropometric data varies from one region to another worldwide. Majumdar (1972) reported that body dimensions of Indians vary from region to region. Anthropometric surveys of western, northern, central and southern India have been reported (Fernandez and Uppugonduri, 1992).

Table 2: Comparison of anthropometric data of Indian (Chhattisgarh region) male farm workers with Western data

S/No.	Body dimension	Indian	American NASA (1978)	Swedes NASA (1978)	Germans (Jurgens et al., 1972)	Japanese, (Yokohori, 1972)
No. of subjects		300	3091	87	NA	NA
1	Weight (kg)	56.69	74.9	71.6	NA	NA
2	Stature	163.78	173.2	174.1	174.5	165.8
3	Chest circumference (cm)	82.79	99.2	NA	NA	NA
4	Bideltoid breadth	36.40	NA	NA	NA	NA
5	Arm length	82.4	NA	NA	NA	NA
6	Sitting height	77.47	90.5	NA	91.9	NA
7	Popliteal height (sitting)	49.84	44.0	NA	45.4	NA
8	Buttock popliteal length	57.64	49.4	NA	NA	NA
9	Hip breadth (standing)	30.60	35.4	NA	NA	NA

Source: Victor et al., (2002). Note: Unit, cm unless otherwise stated; NA , not available.

Nine measurements selected from a farm machinery design point of view were taken. These include body weight, stature, chest circumference, bideltoid breadth, arm length, sitting height, popliteal height (sitting), buttock popliteal length and hip breadth (standing). They found a maximum coefficient of variation (12.42%) in body weight and minimum in stature (3.39%). Static body dimensions differ from dynamic ones which are used for design and redesign of equipment, tools and work places. Dynamic measurements are more representative of human

activities. To translate static body measurements into dynamic ones, Kroemer's suggestions (Kroemer, 1983) can be followed.

Patel et al., (2000) developed an ergonomic facility for improvement of tractor designs. They generated anthropometric data for Indian population and used it for the development of work space envelopes.

Tractors are companions for many agriculture workers. Well-designed human-tractor interfaces, such as well-accommodated tractor operator enclosures (i.e. cabs, hand-and foot controls and protection frames) can enhance worker productivity, comfort and safety (Matthews 1977, Kaminaka 1985, Liljedahlet al. 1996).

More recent design parameters – impediment of steering wheel, hand controls and protection frames for tractor drivers – were not specifically examined at that time. Over the following five decades, two concepts—the need to establish operator space envelopes and tractor control locations that fit operators' body size – have been increasingly recognized as important design elements (Dupuis 1959, Adams et. al. 1975, Purcell 1980, Bottoms 1983, SAE International 1989, 1992, 1994, Yadav and Tewari 1998). At the current time, these design parameters are considered standards. Adjustable seats, steering wheels and other controls have become the norm.

One of the important principles of ergonomics is that workplace dimensions should match the body dimensions of the expected users (Mokdad, 2002). A good match can be obtained if anthropometric data are applied. Incorrect workplace design where anthropometric data are ignored can cause psychological discomfort, physical fatigue and could be harmful and damaging in the long term. Thus, anthropometric data are essential for the design of safe, comfortable and effective machines, tools and workplaces. In the developed countries, structured and highly developed researchers have been collecting anthropometric data from different segments of the populations for a long time. The first systematic large-scale anthropometric studies were started in the 1940s (Mokdad, 2002). In developing countries, many researchers have collected anthropometric data for the purpose of designing tools, equipment, workplaces and assessment of compatibility of existing facilities with intended users.

Hsiao et al. (2005) determined the critical anthropometric measures and 3- D feature envelopes of body landmarks for the design of tractor operator enclosures. One hundred agriculture workers participated in the study. Their body size and shape information was registered, using a 3-D full-body laser scanner. Knee height (sitting) and another eight parameters were found to affect the cab-enclosure accommodation rating and multiple anthropometric dimensions interactively affected the steering wheel and gear-handle impediment. A principal component analysis has identified 15 representative human body models for digitally assessing tractor-cab accommodation. A set of centroid coordinates of 34 body landmarks and the 95% confidence semiaxis- length for each landmark location were developed to guide tractor designers in their placement of tractor control components in order to best accommodate the user population.

Finally, the vertical clearance (90 cm) for agriculture tractor enclosure in the current SAE International J2194 standard appeared to be too short as compared to the 99th percentile sitting height of male farm workers in this study (100.6 cm) and in the 1994 National Health and Nutrition Examination Survey III database (99.9 cm) and of the male civilian population in the 2002 Civilian American and European Surface Anthropometric Resource database (100.4 cm).

The tractor industry and the agricultural community have a pressing need for a scientifically rigorous assessment of the fit, adaptation and function of these products. The operator could work longer hours with a tractor suiting his hand/leg reaches (Sanders and McCormick, 1993) and comfortable seat and back rest. This paper describes the development of an anthropometric model of tractor operators from Kano State of Nigeria for adaptation to tractor makes available by managers of tractor fleets.

## 2.0 MATERIALS AND METHODS

### 2.1 Study Area and Selection of Tractor Operators

Kano State (Fig. 1) has forty four Local Government Areas (LGAs) and ten LGAs (Ajingi, Albasu, Bebeji, Bichi, Bunkure, Dawakin Kudu, Gwarzo, Kabo, Makoda and Tudun Wada) were selected for this study. These are spread across the length and breadth of the state. In each LGA visited, the anthropometric measurements of available tractor operators working in the organization were documented using a structured questionnaire.

### 2.2 Main Study Concept

This study was conducted as part of a larger work on assessment of tractor downtime in an organization as composed in a flowchart (Figure 2). This article concerns the first part on operator anthropometry adaptation to tractor ergonomics design. The second (on repair and maintenance (R&M) costs prediction models) and the third (on engine condition assessment using atomic spectrometry oil analysis) parts have been treated (Ahmad, et al. 2012, 2014a and 2014b).

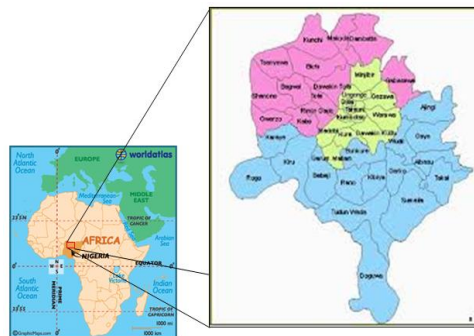


Figure 1: Map of Kano State of Nigeria

### **2.3 Determination of Operator Anthropometric Data**

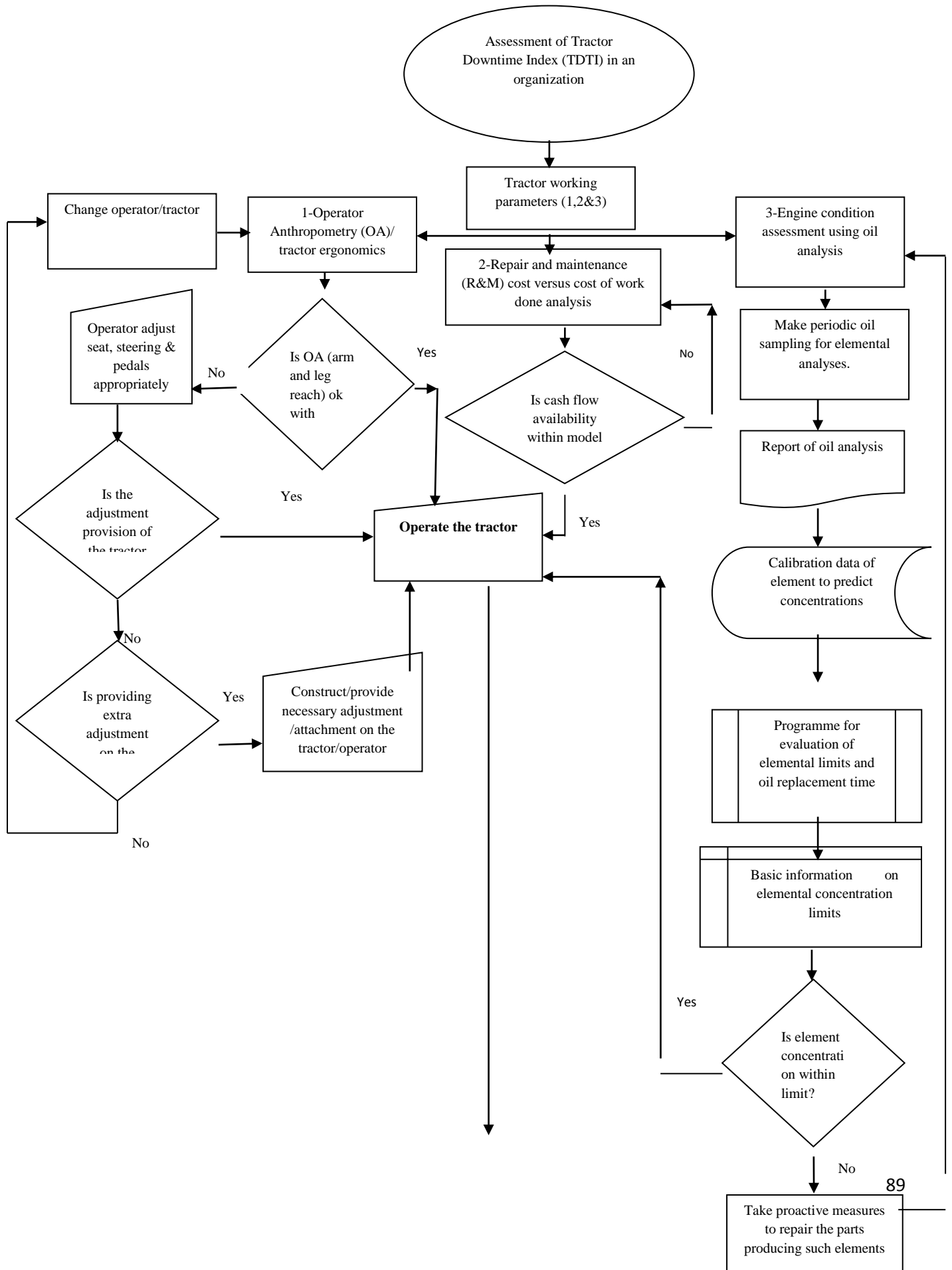
The data were taken carefully to measure six fundamental body measurements (body weight, standing height/stature, full hand length, elbow-fingertip length, full leg length and knee length) for the tractor operators in correct posture and precise manner. Standing height (stature) and body weight were measured in standing posture. Subjects were asked to stand on a flat surface and very close to an erect wall exceeding their height. Correct standing posture was ensured with their feet closed and their body vertically erected, while their heels, buttocks and shoulders touching the same vertical wall. A straight edge ruler was placed horizontally on top of the subject's head and touching the wall. The position of the ruler against the wall is marked with white chalk and the reading from the floor to the mark taken using graduated tape.

A standard bath room weighing balance was used in taking the body weight by placing it on a flat surface and asking the subjects to climb it after removing any apparel (cap, shoes, wrist watch, GSM handset, etc).

The other four measurements were taken in a sitting position by asking the subjects to sit on an adjustable chair without back rest. After sitting on the chair at a level corresponding to the knee height (by making 90° angle between shin and thigh) and pushing the chair until the buttock, shoulder and head were touching the vertical wall.

### **2.4 Anthropometric Data Analysis**

The tractor operator's anthropometric data collected were analysed to produce anthropometric model parameters of the study area. The parameters were evaluated as was done by Yadav et al. (1999) in deriving the anthropometric model of Indian tractor operators. These include: mean, standard deviation, coefficient of variation, range and percentiles (5<sup>th</sup>, 95<sup>th</sup> and difference between the two).



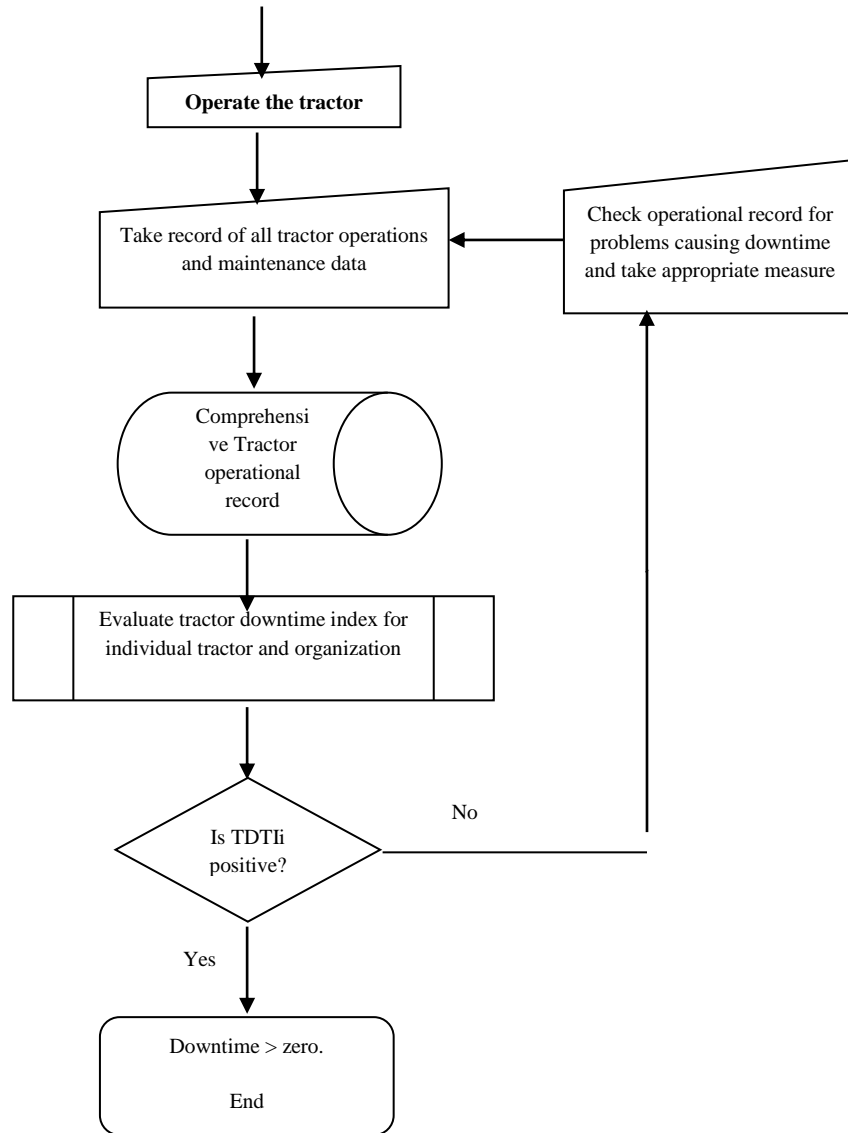


Fig. 2: A flowchart showing an application of anthropometric parameters

### 3.0 RESULT AND DISCUSSIONS

A total of forty three tractor operators were captured in the ten LGAs surveyed. The analysed data obtained are presented in Table 3. The anthropometric data of tractor operators (Table 3) could be used to adapt individual operator to the particular tractor model to work with. Since operators of tractors can be changed from time to time, manufacturers cannot provide design/adjustments for all likely subjects in a particular market segment. Therefore, tractor fleet managers could easily use these six measurements and make appropriate modifications (as shown in the study flowchart –section 1 of Fig. 2) to match operators with tractors available especially concerning hand controls which has the highest coefficient of variation (19%) in the

study area (Table 3). Studies by Jain et al. (2008) showed that present tractor seats in India need minor modifications/improvements in seating dimensions as per BIS recommendations. This may cause excessive pressure on the underside of the thigh, which can reduce blood circulation to the lower legs.

Dimensional models are suggested for 5th and 95th percentile drivers, which may be used as design tools. Knowledge of user dimensions can aid proper machinery design for reducing occupational injury and enhancing safety and productivity as suggested by Yadav et al. (1999) in their study of anthropometric model of tractor operators in India.

Table 3: Anthropometric data of tractor operators from the study area (n= 43).

Body dimension	Mean	CV	SD	Range	Percentile		
					5 <sup>th</sup>	95 <sup>th</sup>	Diff btw 95 <sup>th</sup> and 5 <sup>th</sup>
Body weight (kg)	65.1	0.05	7.7	47-96	54	180	
Stature (cm)	167.5	0.07	5.4	152-183	156	180	24
Full-hand length (cm)	74.13	0.19	12.7	64-87	68	83	15
Elbow to fingertip length (cm)	47.23	0.06	2.8	42-53	43	51	8
Full-leg length (cm)	104.37	0.07	7.0	94-122	98	116	18
Knee length (cm)	52.24	0.06	3.4	47-61	49	58	9

Short operators will require lower steps for access on the tractor. Statistical analysis has revealed that 42 % of tractor accidents in a study were encountered during climbing in and out of the cab (Suutarinen, 1992). Light weight operators could be ballasted with additional weight to damp vibrations from engine and surface terrain in order to obtain maximum allowable driving time per day (Maleki, et al., 2008). Leg and arm controls should be adaptable to subjects reach (Table 3), if designed adjustment limits are not adequate. These figures are not for generalization but for use to adapt existing ergonomic designs of tractors to suit available subjects which could reduce tractor accident by more than 20% (Suutarinen, 1992). Meister (1971) in his famous four principles of human factors design philosophy stated that it is easier to modify/adapt equipment characteristics than to modify human capabilities. That is, it is easier to design controls to be actuated within 'human' force capabilities and to locate them within 'human' limits of reach than to endure the operator with greater strength or to change his physical dimensions to a more desirable configuration. Tractors require more pedal force

than road vehicles (Mehta, et al., 2007). They also stated that clutch and brake pedals on Indian tractors be optimally positioned based on stature dimension at 40% in front and 19% below the seat reference point (SRP)

Staff turnover is inevitable in any organization. This may be caused by retirement, promotion, resignation, termination or even death. Replaced staff may be trained to any level but the anthropometric dimensions for compatibility with the machine operated by the former staff cannot be met always. Therefore, qualified agricultural engineers are required as managers of tractor fleets. This would enable them make necessary adjustments to existing tractor ergonomic designs to suit available manpower recruited as tractor operators.

One of the main reasons for piston scuffing or scoring is overloading an engine due to driving habits and harsh operating conditions (Singh, 2005). If the operator is not well suited with the tractor, his behavior will be erratic and non-consistent.

#### **4.0 CONCLUSION**

This study conducted a survey on tractor operators in Kano state of Nigeria and determined their anthropometric models for adaptation with the available tractor ergonomic designs. The highest coefficient of variation (19%) among the six parameters measured was in the full-hand length. This calls for better strategies of adapting tractor hand controls to the user population by the tractor fleet managers.

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## **ENERGY EFFICIENCY AND GLOBAL WARMING POTENTIAL OF RICE (*Oryza sativa*) PRODUCTION IN LOKOJA, NIGERIA.**

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### **Abstract**

Energy use in agriculture has developed in response to population increase, limited supply of arable land and desire for an increasing standard of living. Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural production, since it enhances financial savings, fossil resources preservation and air pollution reduction. This study determined energy efficiency and global warming effect of rice production in Lokoja, Kogi state.

Structured questionnaires were administered to selected rice farmers in the study location to collect data on the input and output resources per hectare of rice cultivation. Secondary data which were not site-specific were sourced from relevant literature and database. Basic information on energy inputs and rice yields were entered into Excel spreadsheet SPSS 16.0 for analysis and descriptive statistics as well as graphs were used in the interpretation of the data.

The study indicated that manual energy accounted for 25.49% of total energy used, while thermal and chemical energy were 7.64% and 66.87% respectively. Other energetic parameters obtained include: energy ratio 3.59; energy productivity 0.24 kg/MJ; specific energy 4.09MJ/kg; and Net energy gain 19093.72 MJ/ha. The total global warming potential in rice cultivation was obtained as 375.53 kg CO<sub>2</sub> equivalent. The results of this study have shown that rice cultivation in study location (Lokoja, Kogi state) is energy efficient based on values of energetic parameters obtained. However, the cultivation of crop has contributed negatively to global warming potential.

**Keywords:** Energy efficiency, Energy ratio, Energy productivity, Rice production, Global warming potential.

### **1. INTRODUCTION**

Rice is the second most important cereal in the world after wheat in terms of production, and it cuts across regional, religious, cultural, national and international boundaries with very high demand (WARDA, 2005). It is a nutritious food, providing about ninety per cent of calories from carbohydrates and as much as thirteen per cent of calories from protein (WARDA, 2005). Rice production is geographically concentrated in Western and Eastern Asia. Asia is the biggest rice producer, accounting for ninety percent of the world's production and consumption of rice (WARDA, 2005). Today, rice is grown and harvested on

every continent except Antarctica where conditions make its growth impossible. Nigeria ranks the highest, both as producer and consumer of rice in the West Africa sub-region (WARDA, 2005). African rice production is concentrated in the sub-Saharan and western regions of the continent, because of population density, easy market access, availability of water etc. (Sakurai, 2006).

Agriculture is an energy user and energy supplier in the form of bio-energy (Alam, et al., 2005). Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labour-intensive practices, or both (Shahin, et al., 2008).

Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural productions; it provides financial savings, fossil resources preservation and air pollution reduction (Singh, 2000).

Energy is one of the most valuable inputs in production agriculture. It is invested in various forms such as mechanical (farm machines), human labour, animal draft, chemical fertilizer (pesticides, herbicides), electrical, etc. The amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production (Stout, 1990).

Energy analysis is necessary for the efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested in every step of the production process (hence identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions (Debendra and Bora, 2008).

Rice production and productivity has been negatively affected all over the world as a result of global warming and climate change. Global warming results from a build up of greenhouse gases in the atmosphere, which allow the sun's rays to enter the atmosphere but prevent the dissipative heat from leaving (Van-Kooten, 1993). Climate change is caused by the release of greenhouse gases into the atmosphere and is expected to affect agriculture and livestock production, hydrologic balances, input supplies and other components of agricultural systems. These gases accumulate in the atmosphere, which result in global warming (Aydinalp and Cresser, 2008). The production of greenhouse gases is enhanced by a variety of human activities including agriculture.

Koc and Ceylan (2013) reported that rice production levels fell because of global climate change and scarcity, thus putting foreign trade relations in dire straits. Due to the fact that rice is cultivated mostly along flood plains, the rise in sea level has caused recurrent floods

affecting the rice just after the time of flowering when farmers are expecting their harvest. This effect has also caused the burning off of the flowers and leaves of the plant in some places where drought and early rainfall cessation is being experienced.

Net emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O can be reduced by undertaking energy efficient management practices like variable rate fertilizing, no-till farming, and more selective use of pesticides. This study is therefore aimed at determining the energy efficiency and global warming potential of rice production in Lokoja, Nigeria. Other practices associated with reduction in energy-use include: the use of shelterbelts, crop diversification and inclusion of pulse crops, legume green manuring, improved fertilizer management practices, precision agriculture and the conversion of marginal cropland to grassland or forest. These practices result in carbon sequestration, one process by which atmospheric carbon is stored in the soil, and will further reduce the effects of global warming (Zentner, 1998).

## **2. MATERIALS AND METHODS**

### **2.1 Data Collection**

Primary data on land area sown with rice, sources of power utilized, number of hours needed in each operation for rice cultivation, and total crop production were collected through a structured questionnaire prepared to capture required information from farmers selected at random in the study area which is along the flood plain of River Niger at Lokoja, Kogi State. The area lies between latitude 7.50<sup>0</sup> N and longitude 6.44<sup>0</sup> E, and is predominantly occupied by Nupe, Kakanda and Bassa tribes. Secondary data were collected from published materials such as journals, proceedings, technical reports, textbooks, etc and the information was used in the calculations.

### **2.2 Description of Rice Cultivation Operation in the Study Area**

Rice planting is done manually. Crop maintenance operation carried out after planting is also done manually. For fertilizer application, 100 kg/ha of NPK is used. Pre-emergence herbicide (2 kg of Oryzo plus and gramoxone) is sprayed on the field immediately after planting or at most two days after planting before the crop begins to germinate at the rate of 2.5 L/ha. Post-emergence herbicide (2 kg of Solito) is also applied after 8 weeks of planting. This serves the purpose of supplemental weeding before the crop begins to flower so that its yield can be enhanced. Bird scaring is an activity that is carried out for three weeks from the 10<sup>th</sup> week to the 13<sup>th</sup> week when the stalks begin to mature. This was done by employing people who drive away the birds manually, in order to prevent them from sucking out the milk in the head which otherwise would have become the grain. Harvesting, threshing and packing operations are also carried out manually.

### **2.3 Computations**

The inputs used for rice production in the study area include; manual energy (human labour), seeds, thermal energy (fossil fuel), and chemical energy (fertilizers, herbicides). For the estimation of energy input for agriculture, an average of 8 hours of work per day was selected

according to Ozkan, et al.,(2004). All these inputs were converted to energy equivalent using Table 1.

**Table 1: Energy Equivalent of Inputs and Outputs in the Production of Rice**

Particulars	Energy Equivalent		Reference
	Unit	(MJ/unit)	
<b>A. Inputs</b>			
1. Human labour	h	1.96	Mandal et al., 2002
2. Machinery	kg	62.70	Mandal et al., 2002
3. Diesel and Lubricants	L	56.31	Mandal et al., 2002
4. Tractor	kg	93.61	Canackci et al., 2005
5. Chemical fertilizers	kg		
(a) Nitrogen	(N)	60.60	Mandal et al., 2002
(b) Phosphate	(P <sub>2</sub> O <sub>5</sub> )	12.00	Mandal et al., 2002
(c) Potassium	(K <sub>2</sub> O)	6.70	Mandal et al., 2002
6. Chemicals			
(a) Insecticides	kg	101.20	Yaldiz et al., 1993
(b) Fungicides	kg	216.00	Yadav et al., 2013
(c) Herbicides	kg	238.00	Yadav et al., 2013
7. Seed (Rice)	kg	17.00	Canackci et al., 2005
<b>B. Outputs</b>			
1. Rice Grain	kg	17.00	Mandal et al., 2002
2. Straw	kg	12.50	Mandal et al., 2002

## 2.4 Energetic Parameters

Energy analyses were performed based on the following field operations; land preparation, planting, crop maintenance (MTCE) (bird scarring, herbicides, and fertilizer application), and also harvesting operations.

### i. Energy Efficiency

This is also called energy ratio. The energy efficiency is the ratio of the total energy output (MJ/ha) to the total energy input (MJ/ha). It was calculated using the equation of Singh et al., 1997 as ;

$$\text{Energy Eff.} = \frac{\text{Total Energy Output (MJ/ha)}}{\text{Total Energy Input (MJ/ha)}} \quad (1)$$

### ii. Energy Productivity

This is the ratio of the total grain yield (kg/ha) to the total energy input (MJ/ha). It was calculated using equation of Singh et al., 1997 as;

$$\text{Energy Productivity} = \frac{\text{Grain Yield (kg / ha)}}{\text{Total Energy Input (MJ/ha)}} \quad (2)$$

### iii. Specific Energy

It is the ratio of the total energy input (MJ/ha) to the grain yield (kg/ha). The specific energy is also the inverse of the energy productivity. It was calculated using equation of Singh et al., 1997 as;

$$\text{Specific Energy} = \frac{\text{Total Energy Input (MJ/ha)}}{\text{Grain Yield (kg/ha)}} \quad (3)$$

### iv Net Energy

The net energy is the difference between the total energy output and the total energy input. It was calculated using equation of Mandal et al., 2002 as;

$$\text{Net Energy} = \text{Energy Output (MJ/ha)} - \text{Energy Input (MJ/ha)} \quad (4)$$

## 2.5 Green House Gas Emission

Computation for inventory data sets consist of emissions and energy of the activities associated with rice production in Lokoja per hectare. Emission inventory data were not available in Lokoja; thus, they were calculated as a function of production activities and the emission factors (Table 2 and 3) using the following equations:

$$\text{Emission} = \text{Activity} \times \text{Emission Factor} \quad (5)$$

$$\text{Impact} = \text{Emission} \times \text{Classification Factor} \quad (6)$$

**TABLE 2: Activity Data for Calculating GHG Emissions in Rice Production Systems**

Source	Activity	Emission Value	Unit (per ha)
Land preparation	Diesel use	9.40	kg fuel
Pesticide application	Pesticide use (propanil)	3.87	kg
Fertiliser application	N fertiliser use	37.05	kg
	P fertiliser use	37.05	kg
	K fertiliser use	37.05	kg
Herbicides application	Chemical use (glyphosate)	0.10	kg

Source: Eshun et al., (2013).

**Table 3: Classification Factors Used For Emissions of GHG in Rice Production Systems**

Compounds	Classification factors	Reference
CO <sub>2</sub>	1 kg = 1 CO <sub>2</sub> -eq	(IPCC, 1997)
CH <sub>4</sub>	1 kg = 21 CO <sub>2</sub> -eq	(IPCC, 1997)
N <sub>2</sub> O	1 kg = 310 CO <sub>2</sub> -eq	(IPCC, 1997)

Source: Eshun et al., (2013).

## 3. RESULTS AND DISCUSSION

### 3.1 Human Labour Use in Rice Production

The result for the cultivation of one hectare of rice in Lokoja indicated that the level of mechanisation is very low as human labour is mostly used to carry out all the four operations considered. Five (5) people (10.42%) were involved in land preparation and planting respectively; Ten (10) people (20.83%) were involved in crop maintenance and twenty-eight (28) people (58.33%) were involved in harvesting. The values are shown in Figure 1.

### 3.2 Time Use in Rice Production

The time distribution in the production of rice indicated that out of the total 220 hours of operation, land preparation took 10 hours (4.54%); planting 16 hours (7.27%); crop maintenance 150 hours (68.18%) and harvesting took 44 hours (20.00%) respectively. It was obvious that crop maintenance operation is the highest consumer of time and energy, since energy is a time dependent concept. To reduce the total time taken, there is a need to minimise the time required for bird scaring (126 hours, 57.27%) by available mechanical or biological bird-scaring devices instead of having to engage human beings. This will also help to reduce drudgery associated with the activity. The values are shown in Figure 2.

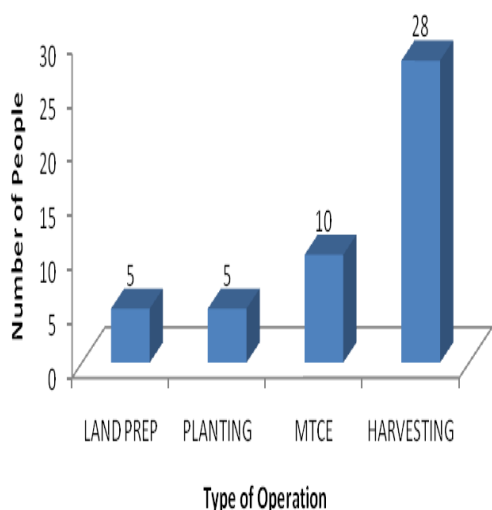


Fig. 1: Human Labour use

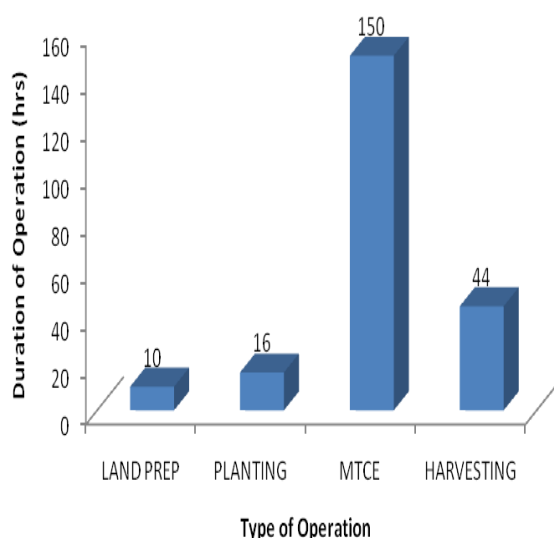


Fig. 2: Duration per operation in rice production

Note: MTCE represents crop maintenance/ protection operations.

### 3.3 Diesel and Lubricants Use in Rice Production

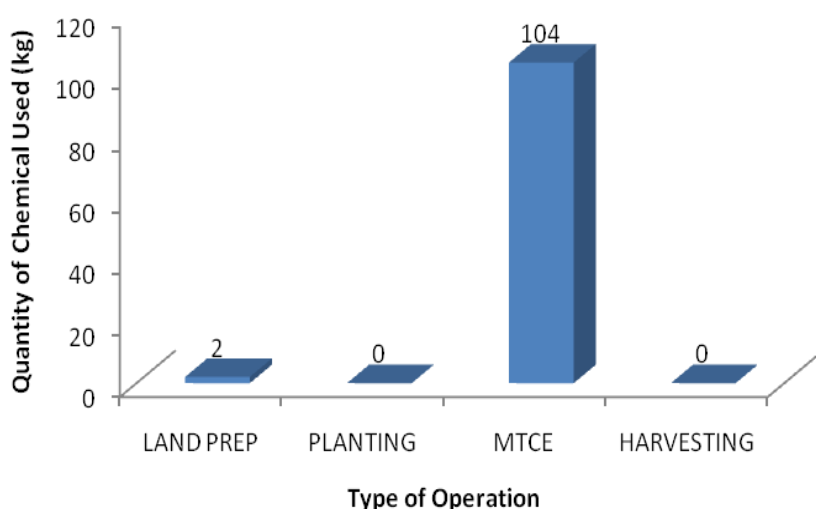
The only operation which required the use of diesel in rice production is ploughing. Ten (10) L/ha of diesel was used for ploughing.

### 3.4 Chemical Use in Rice Production

The use of chemicals in rice production occurs during land preparation (herbicide application) and crop maintenance (application of inorganic fertilizers, both pre-emergence and post-emergence herbicides). Of the total of 106.00 kg of chemicals used for both land preparation and crop maintenance, 2 kg (1.89%) was used for land preparation while 104 kg (98.11 %)

was used for crop maintenance. This is shown in Figure 3. Also, 6 kg (5.66%) herbicides were used while 100 kg (94.34%) inorganic fertilizers were used. This indicates that the bulk of the chemicals used on rice farm are inorganic fertilizers (nitrogen, phosphorus and potassium) which led to the green house gas emissions, and this contributed to climate change and global warming. The values obtained also compares with those obtained by Pervanchon et al.,(2002) and Zentner et al., (2004).

In order to ensure climatic and environmental sustainability, there is a great need to reduce the quantity of emission from these chemical substances, and organic fertilizers could be used to replace or highly supplement the prevailing use of inorganic fertilizers.



**Fig. 3: Chemical use in rice production**

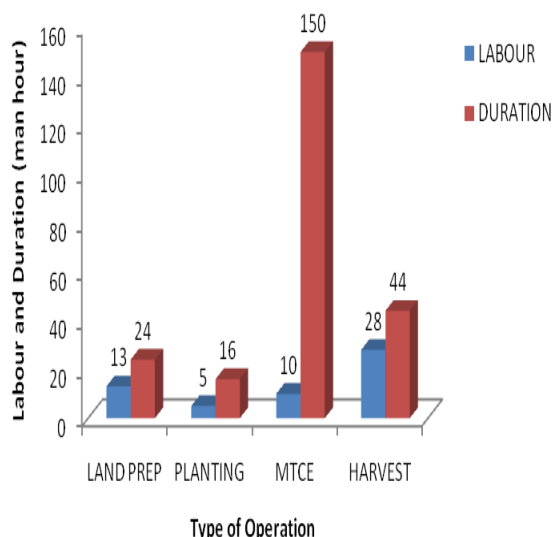
**Table 4: Inventory of Input Use in Rain fed Rice Production per Hectare in Lokoja**

Operation	Manual (M) (people)	Time (T) (hr)	M × T	Diesel (D) (ltrs)	Chemical (C) (kg)
<b>A. Land Preparation</b>					
i. Land Clearing	3	8	24	—	2.00
ii. Ploughing	2	2	4	—	—
iii. Harrowing	—	—	—	—	—
<b>Total</b>	<b>5</b>	<b>10</b>	<b>50</b>	<b>10</b>	<b>2.00</b>
<b>B. Planting</b>					
	<b>5</b>	<b>16</b>	<b>80</b>	—	—
<b>C. Crop Maintenance</b>					
i. Fertilizer	2	8	16	—	50.00
a. N	—	—	—	—	25.00
b. P <sub>2</sub> O <sub>5</sub>	—	—	—	—	25.00
c. K <sub>2</sub> O	—	—	—	—	—
ii. Pre-emergence	3	8	24	—	2.00
iii. Post-emergence	2	8	16	—	2.00
iv. Bird Scaring	3	126	378	—	—

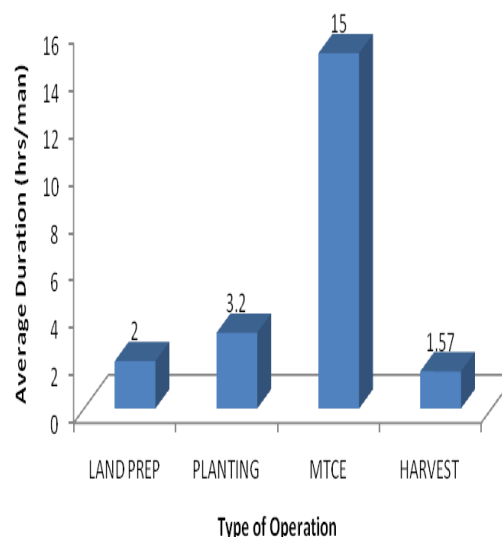
<b>Total</b>	<b>10</b>	<b>150</b>	<b>1500</b>	<b>—</b>	<b>104.00</b>
<b>D. Harvesting</b>					
i. Harvesting	10	16	160	—	—
ii. Threshing	8	12	96	—	—
iii. Packaging	10	16	160	—	—
<b>Total</b>	<b>28</b>	<b>44</b>	<b>1232</b>	<b>—</b>	<b>—</b>

### 3.5 Interactive Effect of Human Labour, Time Consumption, Fuel and Chemical Use on Rice Production in Lokoja

The interaction between time and labour use (man hour) revealed that, of the total 2862 man hours involved in the production of one hectare of rice, crop maintenance took 1500 man hours (52.41%), harvesting (1232, 43.04%), planting (80, 2.80%) and land preparation (50, 1.75%) respectively. On the average time used per man, crop maintenance operation required an average of 15 hours/man; Planting 3.2 hours/man, land preparation 2.00 hours/man, and harvesting 1.57 hours/man respectively. This shows that crop maintenance operation was the highest both in the combined man hour and average time consumption per person among all the factors considered. It had an average consumption time of five (5) greater than what was consumed during planting operation. This goes to indicate that so much time is used by human labour in crop maintenance operations especially bird scaring as shown in Figures 4 and 5 respectively.



**Fig. 4: Interactive of labour and duration (Average duration/man) expended**



**Fig.5: Average time consumption per man expended in rice production**

### 3.6 Energy Analysis in Rice Production

**(i) Energy consumption by types in rice production**

The data on the energy inputs for rice production were converted to their equivalent energy in MJ. The total energy used was grouped into Manual, Thermal and Chemical energy and is presented in Table 5. Manual energy was used for all the operations involved in rice production, chemical energy was used in land clearing and maintenance operations while thermal energy was used only for land preparation (ploughing).

From Table 5 chemical energy contributed 4925.50 MJ (66.87%) and is the single largest contributor of energy in rice production. This is due to the use of NPK fertilizer and herbicides (for land clearing, pre-emergence and post-emergence). The NPK fertilizer contains nitrogen, phosphorus and potassium and is in the form of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O respectively. The energy contributions of the individual chemicals were also calculated and the results indicated that nitrogen (N) contributed the highest overall individual energy (3030 MJ) which is 57.16% and 41.13% of the chemical energy use and total energy use respectively. This is followed by P<sub>2</sub>O<sub>5</sub> (300MJ, 4.07 %) and K<sub>2</sub>O (167.50, 2.27%). This high value of energy consumption through fertilizer usage is comparable with other works (Khan, *et.al*, 2010).

Manual energy contributed the second largest share of energy in rice production which is 1877.68 MJ (25.49%) per hectare. Of this value bird scaring contributed 740.88 MJ which is 87.10% of the manual energy used and 10.06% of the total energy consumed. This makes bird-scaring the second largest individual contributor to the overall energy in rice production. The value is followed by harvesting (313.60 MJ, 4.26%), packaging (313.60 MJ, 4.26%), threshing (188.16 MJ, 2.55%), planting (156.8 MJ, 2.13%), land clearing (47.04 MJ, 0.64%), pre-emergence herbicide (47.04 MJ, 0.64%), post-emergence (31.36 MJ, 0.44%), fertilizer application (31.36 MJ, 0.44%) and ploughing 7.84 MJ (0.10%) respectively.

Thermal energy only contributed 563.10 MJ (7.64%) of the total energy and this came from the diesel used during ploughing.

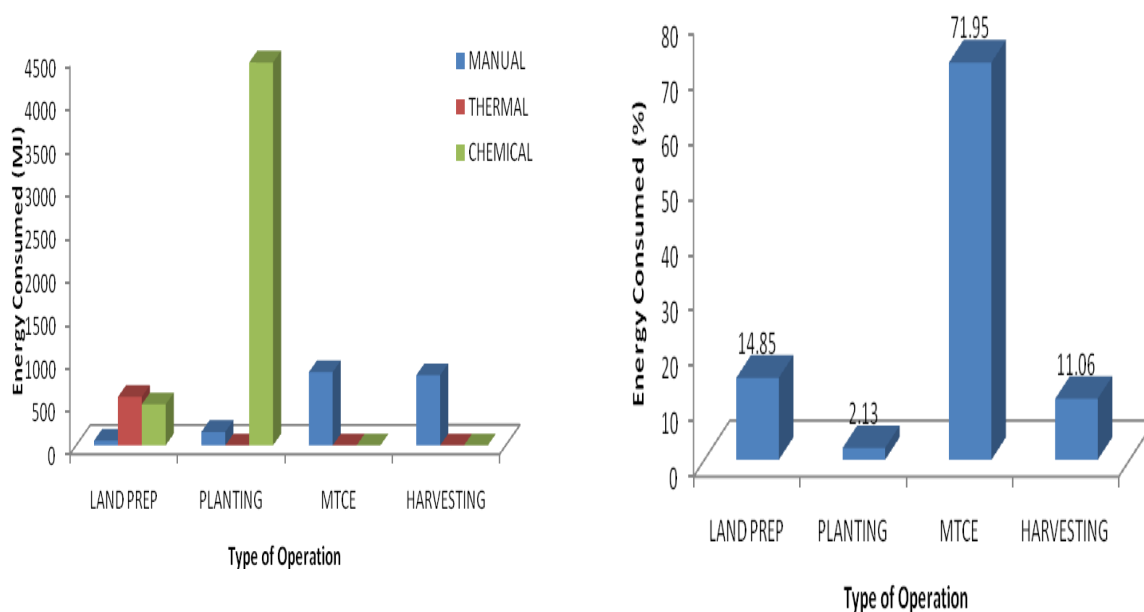
**Table 5: Equivalent Energy (MJ) Consumed in Rice Production**

Operation	Manual Energy (MJ)	Thermal Energy (MJ)	Chemical Energy (MJ)	Total Energy (MJ)	% of Total
<b>A. Land Preparation</b>					
i. Land Clearing	47.04	—	476.00	523.04	7.10
ii. Ploughing	7.84	563.10	—	570.94	7.75
<b>Total</b>	<b>54.88</b>	<b>563.10</b>	<b>476.00</b>	<b>1093.98</b>	<b>14.85</b>
<b>B. Planting</b>	<b>156.80</b>	—	—	<b>156.80</b>	<b>2.13</b>
<b>C. Crop Maintenance</b>					
i. Fertilizer	31.36	—	—	31.36	0.43
a. N	—	—	3030.00	3030.00	41.13
b. P <sub>2</sub> O <sub>5</sub>	—	—	300.00	300.00	4.07
c. K <sub>2</sub> O	—	—	167.50	167.50	2.27

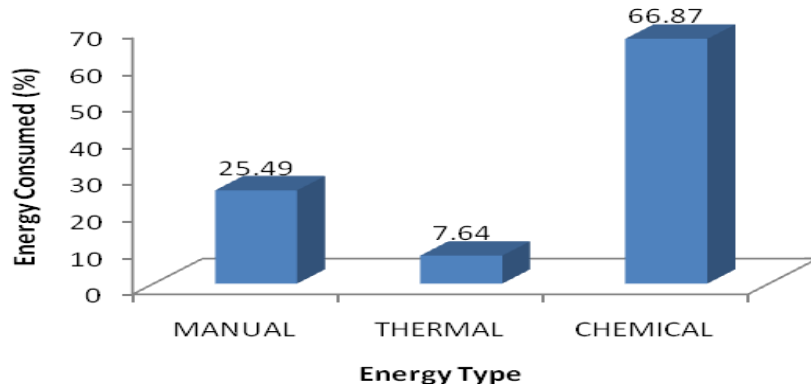
ii. Pre-emergence	47.04	—	476.00	523.04	7.10
iii. Post-emergence	31.36	—	476.00	507.36	6.88
iv. Bird Scaring	740.88	—	—	740.88	10.06
<b>Total</b>	<b>850.64</b>	<b>—</b>	<b>4449.50</b>	<b>5300.14</b>	<b>71.95</b>
<b>D. Harvesting</b>					
i. Harvesting	313.60	—	—	313.60	4.26
ii. Threshing	188.16	—	—	188.16	2.55
iii. Packaging	313.60	—	—	313.60	4.26
<b>Total</b>	<b>815.36</b>	<b>—</b>	<b>—</b>	<b>815.36</b>	<b>11.06</b>
<b>Grand Total</b>	<b>1877.68</b>	<b>563.10</b>	<b>4925.50</b>	<b>7366.28</b>	<b>100.00</b>
<b>% of Total</b>	<b>25.49</b>	<b>7.64</b>	<b>66.87</b>	<b>100.00</b>	<b>—</b>

### (ii) Energy consumption by operation

The percentage of energy used for each operation was also considered in order to identify the energy consumed by each operation and which operation consumed the highest energy. Figure 7 shows that crop maintenance operation has the highest energy consumption of 5300.14 MJ which represents 71.95% of the total energy used. This is followed by land preparation (1093.98 MJ, 14.85%), harvesting (815.36 MJ, 11.06%) and planting (156.80 MJ, 2.13%) respectively. Thus, effort should be made to reduce the energy consumption during crop maintenance operation. Other environmental-friendly methods of improving soil fertility such as use of animal dung and plant residues should be employed to replace or supplement the use of synthetic nitrogenous fertilizer.

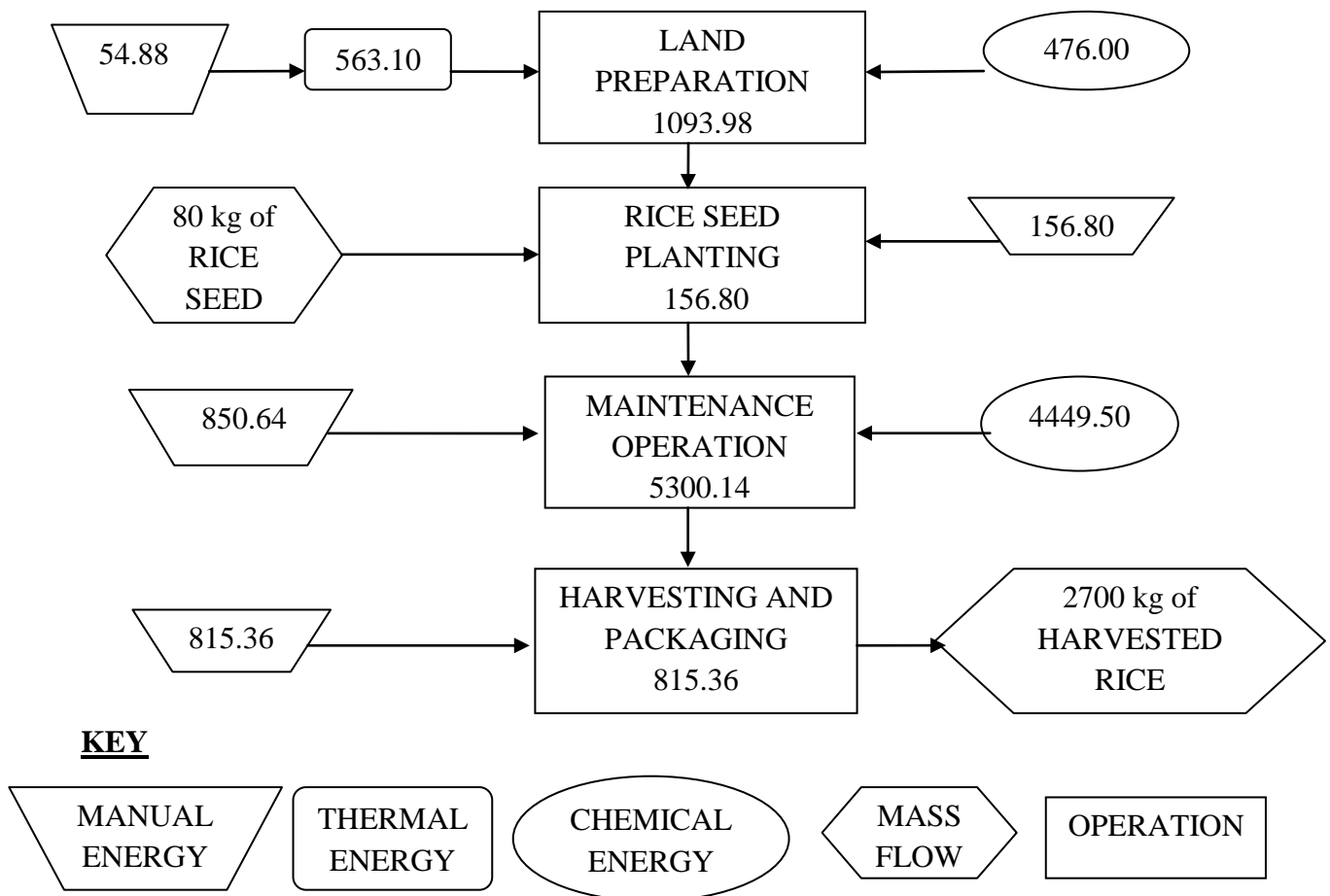


**Fig. 6: Interaction of energy and operation type in rice production**



**Fig. 7: % Total energy used by operation in rice production**

**Figure 8: Percentage total energy type used in rice production in Lokoja**



**Figure 9: Energy accounting and mass flow diagram for rice production in Lokoja****(iii) Other energetic parameters considered in the study**

Table 6 gives a summary of different energetic parameters considered in Rice production in Lokoja. Energy ratio value was 3.59. This compares well with 3.13 obtained by Shahin et al., (2008) who worked on wheat in Iran but is lower than that obtained by Khan *et al*, (2010) who had a value of 6.70 in Australia. Avval et al., (2012) got a value of 4.24 for sunflower production in Iran. The higher values obtained in Australia and Iran was due to the higher level of mechanization involved in their production system.

The value of energy productivity was 0.244 kg/MJ which compares well with Shahin et al., (2008) and Avval et al (2012) who had 0.16 kg/MJ and 0.17 kg/MJ respectively. However, Khan et al (2010) obtained 1.48 kg/MJ while Avval et al obtained 0.17 kg/MJ. Energy productivity measures the amount of a product obtained per unit of energy input. It evaluates how efficiently energy is utilized in different production systems that yield a particular product Ortiz-canavate and Hermanz, (1999).

Specific energy was 4.092MJ/kg which compares favourably with Shahin et al., (2008) and Avval et al (2012) who obtained 6.25MJ/kg and 5.90 MJ/kg respectively. The higher the value the more profitable is the production process in terms of time, cost and energy relationship.

The net energy gain (NEG) was 19093.72 MJ/ha. It is the difference between the total energy output and total energy input and it compares with Avval et al., (2012) who obtained 31062.7 MJ/ha. This value revealed that the crop is energetically sound as it produced large energy gain.

**TABLE 6: Summary of values of energetic parameters considered for rice production in Lokoja.**

ITEM	UNIT	QUANTITY
Energy Ratio/Efficiency	-	3.59
Energy Productivity	kg/MJ	0.244
Specific Energy	MJ/kg	4.092
Net Energy Gain (NEG)	MJ	19093.72

### 3.7 Green house gases emission and global warming potential

Carbon (IV) oxide emitted was 126.3 kg CO<sub>2</sub> equiv (26.5%); methane 5.72 kg CO<sub>2</sub> equiv (1.2%) and nitrogen (II) oxide 345.183 kg CO<sub>2</sub> equiv (72.3%) respectively from one hectare of rice produced in Lokoja as shown in Table 7 and Figure 10.

Furthermore, Land preparation accounted for 30.89 kg (7%)-CO<sub>2</sub> equivalent; Planting 21.48kg (5%); Fertiliser 345 kg (72%) and Transport 50.82 kg (10%) of the total green house gases emitted respectively.

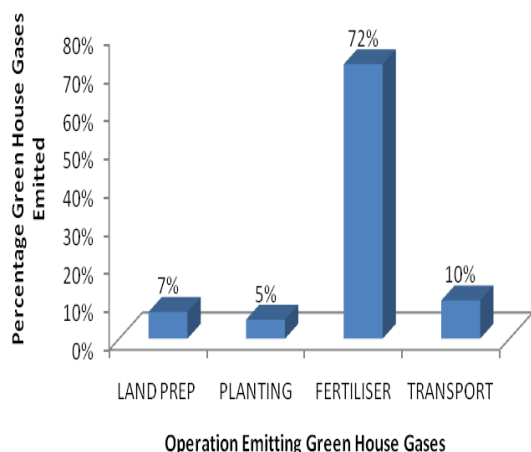
The total impact of green house gases from one hectare of rice cultivated is 1,042.42 kg of which N<sub>2</sub>O accounted for 1011.46 kg (97.03 %); CO<sub>2</sub> 29.61 KG (2.84%) and CH<sub>4</sub> 1.36 kg (0.13 %) respectively as presented in Table 8. These gaseous emissions indicated that rice production has greatly contributed to global warming potential in the study area (Lokoja).

**TABLE 7: Greenhouse gases emission from rice production activities (kgCO<sub>2</sub>eq/ha)**

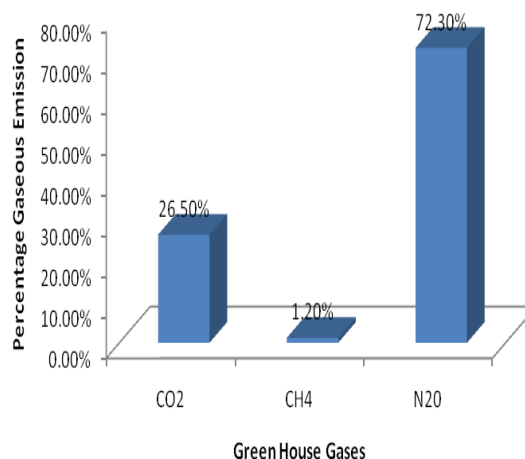
Activity/Source	CO <sub>2</sub> Emission		CH <sub>4</sub> Emission		N <sub>2</sub> O Emission		Total	
	kg	kg CO <sub>2</sub> equiv	kg	kg CO <sub>2</sub> equiv	kg	kg CO <sub>2</sub> equiv	kg CO <sub>2</sub> equiv	%
LAND PREP	29.6	29.6	0.06	1.26	0.0001	0.031	30.89	7
PLANTING	20.5	20.5	0.045	0.95	0.0001	0.031	21.48	5
FERTILISER					1.1	345	345	72
TRANSPORT	48.5	48.5	0.106	2.23	0.0003	0.09	50.82	10
<b>TOTAL</b>	<b>126.3</b>	<b>126.3</b>	<b>0.272</b>	<b>5.72</b>	<b>1.1006</b>	<b>345.183</b>	<b>477.2</b>	<b>100</b>
<b>% Total</b>		<b>26.5</b>		<b>1.20</b>		<b>72.30</b>		

**TABLE 8: Emission and impact of greenhouse gases in rice production in Lokoja**

Compounds	E.F (×10 <sup>-3</sup> )	E	QUANTITY	C.F	Impact (kg)	% Total
CO <sub>2</sub>	3150.00	9.40	1 kg = 1CO <sub>2</sub> -eq		29.61	2.84
CH <sub>4</sub>	6.91	9.40	1 kg = 21CO <sub>2</sub> -eq		1.36	0.13
N <sub>2</sub> O	30.00	37.05	1 kg = 310CO <sub>2</sub> -eq		1011.46	97.03
<b>Total</b>					<b>1042.43</b>	



**Fig. 10: Activity emitting green house gases**



**Fig. 11: Percentage gaseous emission from major green house gases**

#### 4. CONCLUSIONS

The result of this work revealed that human labour was involved in the execution of all operations carried out in rice production in Lokoja, particular for such operations such as; weeding, harvesting, land preparation which led to drudgery and loss of many man-hours. Fertilizer application is the major consumer of energy and also the highest contributor of green house gases emission in rice production. It consumed a total of 4449.50 MJ of chemical energy and emitted 345 kg CO<sub>2</sub> equiv, which indicated a high potential of global warming impact from rice production in Lokoja, Nigeria.

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