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Performance evaluation of two palm kernel nut cracker machines

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Abstract

In this study performance evaluation of centrifugal impact approach and vertical palm kernel nut cracker machine was carried out. The results of the study show that the vertical centrifugal palm kernel cracker is more efficient than the centrifugal impact approach palm kernel cracker. The efficiency of Vertical centrifugal palm kernel cracker is 71.3% and that of centrifugal impact approach is 50.38%. Apart from this, the vertical centrifugal machine though has low speed but it produces clean and neat nut cracked output.

Key words: *Palm nut, centrifugal nut cracker, vertical nut cracker machine, performance evaluation, racking efficiency, kernel breakage.*

1. Introduction

Palm kernel industry had remained very popular in third world because of the dependency of many companies on palm kernel oil as raw material, which is quite inadequate (Hartley, 1987). Nigeria is one of the world largest exporters of palm kernel product in early sixties, providing about 400,000 metric tons amounting to 65% of the world trade. Nigeria palm kernel nut export reduced drastically within seventies, from 65 to 15% when there was an oil boom (Ndegwe, 1987). Based on high dependent of many companies like soap, vegetable oil and body cream industries on palm kernel oil, an efficient palm kernel-processing machine is therefore not only necessary but also important to revitalize the production of palm kernel in other to meet up with ever increases industrial demand (Oke, 2007).
The processing of the palm kernels into palm kernel oil involves the cracking of the palm nut, separation of the shells from the kernels, washing, cleaning, kernel milling and kernel oil extraction. The separation of the kernels from the shells is a very difficult process and an issue which continues to be of great importance within the industry (Akubuo and Eje, 2002). Cracking palm nuts to release the kernels is a critical step that affects the quality of kernel oil. There are two widely methods commonly used for these processes: Manual (traditional) method and Mechanical method.

The manual method of palm nut processing is the traditional way of cracking and separating palm kernel. It is a method in which nuts are cracked using stone and kernel separated by hand picking from the shell at the same time. This method is labour intensive, time consuming, cumbersome and very slow to meet the demand of growing industry (Oke, 2007). Preserving the kernel embedded in the palm nut when cracking the nutshell is important in the subsequent palm kernel and shell separation and, in enhancing the quality of the palm kernel oil.
There are two basic mechanical methods that can be used to crack the shell of the nut. The shock caused by an impact against a hard object and the application of direct mechanical pressure to crush, cut or shear through the shell. Palm nut cracking machine are developed on the principle of hurling of the palm nuts at a fairly high speed against stationery hard surface (Okoli, 1997). Generally, two types of nutcrackers are used in palm oil mill; roller crackers and centrifugal impact crackers. In rollers cracker the nuts are cracked in between two fluted rollers revolving in opposite directions. The clearance between the rollers is invariable but the nuts are of different sizes, which make the machine to be operating at reduced efficiency. The other cracker is a centrifugal impact cracker that used principle of centrifugal force to flap the palm kernel nuts on the stationary hard surface. This method involves using a shock

caused by an impact against hard objects to shear, crush or cut through the shell.

Currently, locally manufactured centrifugal nutcrackers are used for the cracking step in the oil-mill in Nigeria. Although, this has high productivity, the process has quite a number of deficiencies which include; breaking of kernels in the course of cracking which may be due to insufficient drying of nut as well as high rotor speed. Inappropriate spacing of the impactors (blow bars) may also result in a number of uncracked nuts in the finished product as well as the feeding rate of the nut into the cracking chamber (Ofei, 2007). Kernel breakage also results partly because the kernel upon release from the nutshell rebound in the cracking chamber and is subjected to secondary impacts which induce breakage. Also the interaction between the adjacent nuts may obstruct the direct impingement of the individual nut to the cracking wall, so that some of the nuts are discharged uncracked (Koya, 2006). The level of Free Fatty Acids (FFA) is higher in broken kernels than in whole kernels, therefore breakage of kernels should be kept as low as possible according to Poku (2002).

Every unit operation in farm has specific objective and this calls for special machines. Attempts have been made worldwide to develop perfect machines for each operation. Unfortunately there is a widening gap between the developed world and developing world. This low performance of locally fabricated machines were compared with the foreign ones could be as a result of adoption impossibility of modern techniques and the high cost of machines involved (Kaul and Egbo 1985). Having critically examined this complicated problem, we acknowledge the needs to embark on comparison and performance evaluation of two existing indigenous palm kernel nut cracking machines to know the best of the machines for adequate agricultural yields at affordable price and one that gives better efficiency. These machines are electrically powered, parts are mechanically fabricated and assembled together to allow for necessary relative motion, feeding process, discharge operation as well as ease of maintenance. Electric motor is required to drive the cracker.

Having discussed the problems associated with local means of cracking palm kernels, this study aims at the followings: (i) to test and ascertain the performance of existing palm kernel cracking machines using common palm kernel species for the machines, (ii) to compare the efficiency of each palm kernel nut-cracking machines and which is to be adopted by farmers for easy operation, high maintainability and optional output and (iii) to know the time taken to crack a measured amount of palm kernel nut.

2. Materials and Method

2.1 D*esign consideration and material selection for the two palm kernel cracker machines*

2.1.1 Design of the Machine

In the design of a palm kernel cracker the following factors affect its design, material selection and manufacture (Badmus, 1990).

a. Velocity of the palm kernel nuts towards the hard wall.
b. Rotor speed
c. Varieties of the palm kernel nut (size, weight etc)
d. Clearance between the rotor and the cracking wall
e. Feed rate of the palm kernel nut.

In the existing cracking machine the different sizes of nut were not put into consideration experiments were carried out to determine the average size ,average mass ,Velocity require to crack the kernel nut and the average volume of the kernel nut to aid design and fabrication of the machine.

2.1.2 Mass of the Kernel Nut

Samples of palm kernel nuts were collected from various Ondo State, Nigeria. The nut's nominal diameter was measured using a venire caliper; the mass of each nut was measured using an electronic weighing balance.

Table1: Mass and diameter of palm kernel samples

S/NO	MASS (KG)	DIAMETER (M)
1.	0.0035	0.0135
2.	0.0028	0.0200
3.	0.0030	0.0200
4.	0.0038	0.0145
5.	0.0031	0.0145
6.	0.0037	0.0123
7.	0.0035	0.0130
8.	0.0036	0.0134

9.	0.0039	0.0135
10.	0.0040	0.0141

Cracking was done manually by placing each not at the center of a rig base. The rig consists of a 1.5kg weight (15N) that was moved along a wooden vertical scale. The weight was raised to a pre-determined height by means of a rope attached to it.

2.1.3 Determination of velocity required to crack a palm kernel nut

A rig apparatus was set up where a kernel nut was placed on a hand steel plate. The kernel nut was gently loaded with weights. It was observed that over 200N was not able to crack the nut.

A different method was then adopted, basing it on the Conservation of Energy Theory which states that energy is neither created nor destroyed but can be transformed from one form to another in this method, a small pre-determined height was placed between the kernel and the weight. It was observed that as little as 10N was able to crack the kernel nut satisfactorily. Different weights were tried, but by the time the weights reached 20N they started smashing up the kernels which was unacceptable.

The experiment employed analysis of potential and centrifugal force models. The potential energy model postulates that the kernel absorbs the potential energy of a falling hammer or weight (M) due to the height (h-d) through which it falls, making the nuts kinetic energy to be equal to the potential energy of the falling weight. While the centrifugal energy model postulates that, it is the force with which the nut is thrown that will aid its cracking and also the distance between the rotor and cracking.

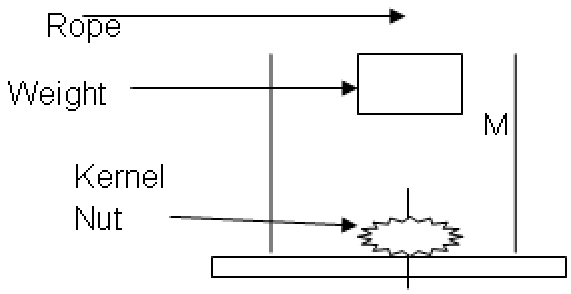

Figure 1: Determination of force to crack kernel nut

The mathematical Expression used is

$$P.E. = Mgh$$

$$= Mg(h-d) \qquad 1$$

Force = Work done W

$$F = Ma = Mwv = Mv(v/r)X \qquad 2$$

Where

P.E. = Potential energy (Joules)

W = Work done on kernel nut (Joules)

X = Distance between rotor and cracking wall (meter)

M = Mass of weight (kilogram)

m = Mass of kernel nut (kilogram)

h = Height between weight and base plate (meter)

d = Diameter of kernel (meter)

g = Acceleration due to gravity $(m/5^2)$

f = Velocity of the nut (M/S)

$$V = \frac{[Mgr(h-d)]^{½}}{(Mx)^{½}} \qquad 3$$

Table 2: Parameter to determine velocity required to crack palm kernel nut

S/NO	MASS (M) (KG)	DIAMETER (D)	h-d(M)	Mx (M)	√Mgr(h-d)/mx(m/s)
1.	0.0035	0.0136	0.1365	0.00070	0.4841
2.	0.0028	0.0200	0.1481	0.00056	0.5042
3.	0.0030	0.0200	0.1300	0.00060	0.4727
4.	0.0038	0.0145	0.1358	0.00076	0.4828
5.	0.0031	0.0134	0.1366	0.00062	0.4843
6.	0.0037	0.0123	0.1377	0.00074	0.4862
7.	0.0035	0.0130	0.1370	0.00070	0.4717
8.	0.0036	0.0134	0.2366	0.00072	0.6378
9.	0.0039	0.0135	0.1365	0.00078	0.4841
10.	0.0040	0.0141	0.1359	0.00080	0.4830
TOTAL	0.0349	0.01478	1.6938	0.00698	4.9909

Using the data above velocity for each mass of kernel nut is obtained.

Velocity (V) = V/10 = 4.9909/10 = 0.4991 m/s

Mass (M) = M/10= 0.0349/10 = 0.00349 kg

Diameter (d)= D/10 =0.1478/10 = 0.01478m

2.1.4 Determination of average volume of a kernel nut

The volume of a dried palm kernel nut displaced using up-thrush method was investigated. The beaker was filled with water and reduced to an exact level; a kernel nut was then dropped into the beaker of water. The kernel nut displaces a particular volume of the water equal to its own volume. This volume was read directly from the graduate scale. The original volume of the water was then subtracted from the water volume after immersion to determine the volume of the kernel nut. The experiment was repeated for other kernel nut of different size and shapes.

The results of measurement of palm kernel volume are shown in the Table 3.

Table 3: Data to show Volume of average kernel nut

s/n	1	2	3	4	5	6	7
Volume of nut (ml)	10.0	5.0	6.9	8.6	4.0	6.2	4.5

Volume of kernel used =6.4 ml

1ml=1/10 x m^3

:. Volume=$6.45/10^6$ = $6.45 \times 10^{-6} M^3$

2.2 Design Calculation of Centrifugal Impact Approach Cracker

2.2.1 Determination of the Force Required for Cracking the Nut and the Horse Power Rating of the Required Electric Motor

From the equation $V = wr \qquad 4$

$W = v/r \qquad 5$

Force $F = mw^2r \qquad 6$

Where M = Mass of kernel

Power $P = FV \qquad 7$

Horse power (hp) = 0.0015hp

2.2.2 Estimation of Time Taken to Crack Measured Mass (Kg) of Kernel Nut.

According to Newton's law of motion: impulse produces changes in motion and is equal to change in momentum

Ft = MV 8a

t = MV/F 8b

For 1kg 2.07sec. → 0.0349kg

T → 1kg

t=13.2 sec.

2.2.3 Estimation of Volume of Hopper for Kernel Nuts.

The geometrical shape of the hopper to be used is shown below

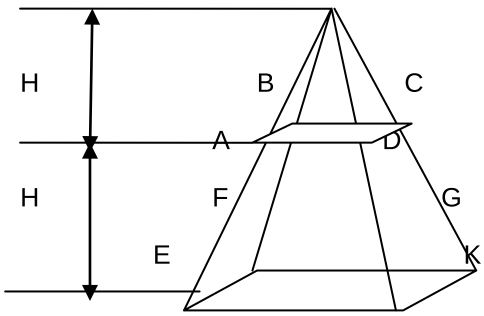

Figure 2: Geometrical shape of hopper

L = EF=FG =320mm= 0.33m

H = 305m= 0.305m

L = AD=DC=85mm=0.085m

H = 90mm = 0.09m

Volume of entire Pyramid $=1/3L^2 (H + h)$

Volume of imaginary Pyramid = $1/3 L^2h$

Volume of truncated part required $=V^1-V^2$

$=0.01328m^3$

Now considering the volume of the rectangular box bolted to the bottom of the hopper, we have

Rectangular box bottled to the bottom of the Hopper

Volume of cuboids=L x B x H 9

Total Volume = Vol. of Hopper + Vol. of cuboid

$=0.013422m^3$

Discharge Compartment

Area of discharge (small Opening) to the cracking section is given by:

Area = L x B 10

For an average size of kernel nut with diameter 14.78mm, the volume to be occupied by kernel nut in cracking compartment is given by:

Volume $=5.2764 \times 10^{-4}$ m^3

2.2.4 Capacity of the Cracker

Average volume of kernel = 6.45ml

$= 6.45 \text{ X } 10^{-6}m^3$

If 6.45×10^{-6} m^3 is the volume occupied by 1 Kernel, then $1m^3$ will be occupied by $1/6.45 \times 10^{-6}$ kernel. Therefore, number of kernels entering cracking compartment is found by:

Number of kernels in cracking compartment =Volume of kernel X Volume occupied by kernels in cracking section i.e

$(1/6.45 \times 10^{-6}) \times (5.2764 \times 10^{-4}) = 81.8$ kernels.

That is 81 kernels will be in the cracking section at a time

Number of kernels to be occupied by the hopper is evaluated as:

Total Volume =(Vol. of hopper + Vol. of cuboids + Vol. of cracking compartment) x 1/6.45 x 10^{-6}

(V_1-V_2) +lbh +lbd= 2181.6 kernels

Total mass passing from hopper for cracking = Number of kernels in cracking sector x mass of kernel nut(in Table 2)

Capacity of the cracker =0.2855 X 3600

=1027.75 Kg/hr

2.2.5 Belt Selection

2.2.5.1 Determination of belt tension

Determination of the appropriate power that may be transmitted to nut cracking machine is a pre-requisite for belt selection and is a function of the belt tension and belt speed.

Power = $(T_1 - T_2)$ V 12

From the formula for V - belt in the grove, we have.

$(\sigma_1 - M_1V_2) / (\sigma_2 - M_1 V_2) = e^{(N\ Ø1/Sin\ Q/2)}$ 13

Where

T_1 =Belt tension in tight side (N)=0.1063

T_2 =Belt tension in loose side (N)=0.0505

V =Belt speed m/s= D_1N_1 /60 =20.23 M/S

$Ø_1$ =angle of wrap of smaller puller=3.367rad

$Ø_2$ =angle of wrap of larger pulley=2.915rad

r =Radius of small pulley = 0.064

R =Radius of large pulley=0.07

C =Centre distance between pulleys =0.35m

B = Sin^{-1} (R-r/c)

σ_1 = Maximum allowable stress =12 MN/m^2

σ_2 =Stress on Black of the belt=0.563MN/m^2

M1=Density of 1m belt (1m Cross Section) - 1250 Kg/m^3

Q=Groove angle =38^0

N=Constant =0.25

It can be seen from above that the angle of wrap of the smaller pulley governs the design.

The required cross sectional area of the belt is given by:

Area = $(T_1 - T_2)/ (\sigma_1- \sigma_2)$ =8.857 X 10^{-8} m^2

2.2.6 Shaft Design

Motor installed horizontally, so all the belt pull on shall is horizontal, for solid shaft having little or no axial loading, the equation reduces to

$d^3 = 16Ss\ (K_bM_b)^2 + (K_1m_1)^2$

For a belt drive, the torsion Moment is gotten by:

Torsion moment M_1 = 3.55 NM

Bending of moment M_b = 687.89NM

Shock and fatigue factor applied to bending moment M_b = 1.5

Shock and fatigue factor applied to Torsion Moment M_1 = 1.0

Allowable Stress for shaft with key way S_S = 40 x 10^6 MN/m ^{2} (Holowenko, 1980)

From above Formula Considering the factor of safety of 1.5

d=1.5 x 0.05096m =0.0764

=76.4mm

Therefore a shaft diameter of 76mm is recommended.

2.3 Design Calculation of Vertical Palm Kernel Cracker

2.3.1 Determination of the Force Requires for Cracking Kernel Nut and the Horse Power Rating of Electric Motor

V =wr (13)

W =v/r=38.74rev/min

Force $F = mw^2r$ =1.833N

Power P= FV =0.0009149

Horse Power (hp) =0.00122hp

2.3.2 Estimation of Time Taken to Crack Measured Mass (Kg) of Kernel Nut

Ft = MV

t = MV/F

For 1kg $t = \frac{0.00349 \times 0.4991}{1.833}$

=0.057 Sec.

2.3.3 Estimate of Volume of the Hopper for Kernel Nuts.

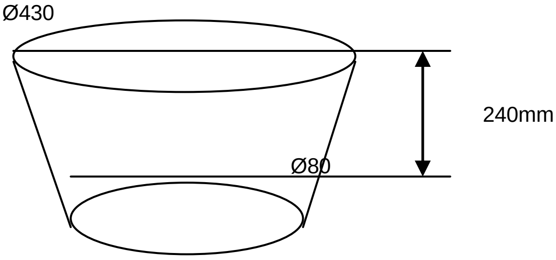

Figure3: Volume of Hopper

Height h=240mm

Inner diameter d_1= Ø80 =0.080mm

Radius r_1=0.04

Outside diameter d_2= Ø430=0.430

Radius r_2=0.215

Volume $V_1 = 1/3\pi r^2 h = 0.402 \times 10^{-3}$ m^3

Volume $V_2 = 1/3\pi r^2 h = 11.617 \times 10^{-3}$ m^3

Volume of truncated part required $= V_2 - V_1$

$= 11.22 \times 10^{-3}$ m^3

To determine the Volume of the rectangular box bolted to the bottom of the hopper, we have

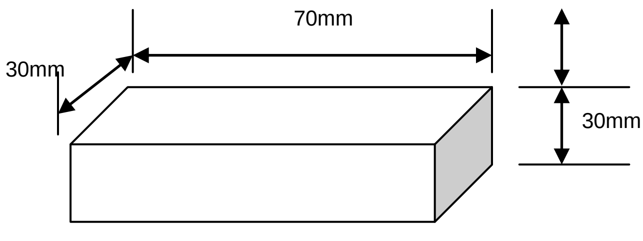

Figure 4: Rectangular box bolted to the bottom of the hopper

Volume of cuboids=LXBXH

L=0.070m, B=0.030m, H=0.030m

Volume=0.630×10^{-4} m^3

Discharge Compartment

Area =l x b=0.070 x 0.030 =0.00211m^2

For an average size of kernel nut with diameter 14.78 mm, the volume to be occupied by the kernel nut in cracking compartment is given by

Volume = area X 14.78 =$3.10 \times 10^{-5} m^3$

2.3.4 Capacity of the Cracker

Number of kernel going to cracking compartment is found by multiplying volume of kernel with volume occupied by kernel in cracking section, that is

Total Volume x $1/6.45 \times 10^{-6}$ = (3.10×10^{-3}) $1/6.45 \times 10^{-6}$ =4.812 kernels

That is 4 kernels will be in the cracking section at a time.

Number of kernels that will occupy the hopper is evaluated as:

Number of kernels in the hopper= total volume x Average Volume of kernel

$(11.223 \times 10^{-3}) \times 1/6.45 \times 10^{-6}$=1739.53 kernels

Total mass of kernel passing from hopper for cracking is estimated by multiplying the number of kernels in cracking section with the mass of kernel nut per unit time i.e 0.01396 Kg/s

The capacity of the cracker

= 0.01396 x 3600

= 50.25 Kg/hr

2.3.5 Belt Selection

Where r=Radius of small pulley=0.050m

R=Radius of large pulley=0.10m

C= Center distance between pulley= 0.38m

$Ø_1$ = 180 - 2B=3.205rad

$Ø_2$ = 180 + 2B=3.078rad

β = Sin-1 (R-r/C)=-1.8096

$σ_1$ = $1.2 MN/m^2$

$σ_2$ = $0.341 MN/m^2$

From the formula for V - belt in the grove, we have

$$(σ_1 - M_1V_2) / (σ_2 - M_1V_2) = e^{(NØ1/\sin Q/2)}$$

The required cross sectional area of the belt is given by.

$$\text{Area} = (T_1 - T_2) / (\partial_1 - \partial_2) \quad 14$$

Where power to be transmitted by motor is given by

$$\text{Power} = (T_1 - T_2) V \quad 15$$

$T_1 - T_2 = 0.063N$

From equation

$$\text{Area} = (T_1 - T_2) / (\partial_1 - \partial_2) \quad 16$$

= $7.537 \times 10^{-8} m^2$

T_1 = $σ_1 A$ =0.090444

T_2 = 0.090444 - 0.063 =0.027444

:. $T_1 + T_2$ = 0.090444 +0.027444 =0.117888N

2.3.6 Shaft Design

From equation

$d^3 = 16/\prod Ss\, (K_b m_b)^2 + (k1m1)^2$

For a belt drive

Torsional moment M_1 =7.05Nm

Bending Moment M_b = 11.67Nm

Shock and fatigue factor s applied to bending moment M_b = 1.5

Shock and fatigue factor applied to Torsional moment M_1 = 1.0

Allowable stress=Ss =$40 \times 10^6 N/m^2$

From above formula considering the factor of safety of 1.5

d=20.09mm

Hence, this is the minimum shaft diameter that can be used to transmit this drive. Therefore, 20 mm. shaft diameters used for the design is appropriate.

Table 4: Comparison of Calculated Parameters for Impact approach and Vertical Crackers

PARAMETERS	IMPACT APPROACH CRACKER	VERTICAL CRACKER
POWER	0.00113kw	0.0009149kw
HORSE POWER	0.0015hp	0.00122hp
CRACKING TIME	13.2sec.	16.33sec.
CAPACITY	100.5kg/hr	50.25kg/hr
SHAFT DIAMETER	76mm	20.09mm

From the calculated parameters, it is discovered that the centrifugal impact approach nut cracker is faster in operation than vertical nut cracking machine because of its high speed and high impact on the kernel nut .

3. Materials Selection

i. **Hopper:** The hopper of both machines is made of mild steel plate. The hopper serves as an inlet through which the kernels enter the spinning bow. The top is wide enough to take sufficient kernel at a time. The base of the hopper is bolted to the top of main hosing. This means that the hopper can easily be detached after use for easy transportation of the machine required shape.

ii. **Main Housing:** The main housing was constructed from medium carbon steel with reliable strength, toughness and good weld ability. This is to make the machine easier for servicing and repair when maintenance is necessary.

iii. **Rotor:** The rotor is a rotating part of the machine. The rotor receives palm kernel from the hopper at high speed against the cracking wall.

iv. **Mechanism bed:** The mechanism bed is directly mounted on the top of frame support to support the weight of the engine. Mechanism bed was constructed from 3mm angle iron cut into size and welded together. It has the ability to withstand shocks and vibration.

v. **Mainshaft:** Shaft is a rotating element made from a mild steel rode of which aid the racking of palm kernel nut. The reason for its elections based on its high torsion strength, resistance to wear and low cost.

vi. **Bearings:** Bearings are manufactured to take pure radial loads pure thrust loads or the combination of both bearing has the following advantages.

- It is a unit that has its own bearing housing
- It has self-alignment ability
- It has longer life than ball bearing
- It is easier to replace because bearing housing is not required.
- It is able to reduce friction to the minimum
- It is able to withstand weight of shaft and can be easily mounted.

vii. **V-belt:** The selected belt for the machine is a single v. belt. A ball provides convenient means of transmitting power from one shaft in another. This belt operates on V - groove pulley. The selection of V belt based on obtaining along and trouble free life and quiet running, the important part in absorbing shock loads and in damping out and isolate the effects of vibration.

vii. **Pulleys:** The recommended pulley for this machine is mild stead. The criterion for selecting mild steel materials is based on comparatively lighter weight than cast iron pulley, higher strength and durability, less tendency of failure or breakage. Both pulleys grooved and the belt runs on v-grooved pulley. The small and large pulleys have dimension of 75mm and 16mm respectively.

ix. Supporting frame: The stand was made of 2 inches angular iron cut into sizes and welded together to form a table0-like structure. The foundation was provided to prevent vibration of the machines. The machines are installed on the required stand through the foundation bolts on the stand. The frame is designed to withstand shock and vibration, to prevent twisting and maintain firm stability.

x. **Electric motor:** The main purpose of the electric motor is to drive the rotor at a very high speed. The combined effect of centrifugal forces and kinetic energy of rotation are employed in palm kernel cracking machines that can be obtained from electric motor of 2 horsepower and revolution per minute. The motor is mounted to the angular bar bolted to the stand for the motor positioning.

3.1 Assembly of the Machine Parts

Parts of the machines were assembled as follows:

- Mounting of the rotor on the main shaft.
- Welding of the main housing to the mechanism bed
- Mounting of the rotor and shaft on the main housing.
- Mounting of the bearings on the shaft by force fit method.
- Mounting of the pulley on the shaft by force fit method.
- Bolting of the hopper on the main housing
- Lubrication of the bearing with grease.
- Mounting of the machine on the mild steel frame
- Mounting of the electrical motor on the base of machine platform.
- Mounting of the belt connecting the motor shaft and the main shaft
- Tightening of the motor belt on its seat to create necessary tension in the belt.
- The palm kernel-cracking machines were completed for testing and evaluation.

4.0 Operation and maintenance

4.1 Operation of the two Cracking Machines

The palm kernel cracking machines are guaranteed for high efficiency of kernel cracking. The machine is designed and constructed to operate in all weathers. It can be used on the farm, in the villages and hamlets.

4.2 Maintenance

The maintenance of the machine is minimal and does not require skilled labour to carry out maintenance exercise. In addition, the cost of maintenance is very minimal. the maintenance is carried out as follows:

-The machine must be clean after use.

- Periodic repainting is recommended for the surface of the bearing.
- The machine can be installed on reinforced concrete to reduce noise and vibration.

4.2.1 Lubrication

The machines has been designed to standard, that most of the components do not require lubrication but the two pillow bearing deserve grease lubrication. The choice of grease is based on the following reasons;

- Unusual protection is required from the entrance of foreign matters.
- Sample bearing enclosures are used.
- Operation of the machine for long periods without attention is desired.

The lubricant achieves the following purposes:

It provides film of lubricant between the sliding and tolling surfaces, it distributes and disputes heats; lubrication prevents corrosion on bearing surfaces and protects the parts from the entrance of foreign matters (Shigley, and Mischke, 1998).

5. Testing and evaluation

The aim of the performance test is to obtain the cracking efficiency of the two machines.

The palm kernel-cracking machines that were design and constructed were connected to the electric motor by V-belt drive and to the power supply which is run for some time, after which it was tested to crack weighted palm kernels to determine cracking efficiency of each machines. The standard set for the testing was the cracking of the kernel without damaging the seed of the kernel.

In performing the test to determine the efficiency, 1000g (1kg) were fed into the hopper for five consecutive times and the output obtained in each operation is tabulated below for each machine.

Table 5 : Computed Efficiency of Vertical centrifugal Palm Kernel nut Cracking Machine

S/N	MASS OF KERNEL FEED	NO. OF KERNEL	NO. OF KERNEL CRACKED	NO. OF KERNEL UNCRACKED	NO. OF BROKEN KERNEL	TIME (SEC.)	EFFIENCY (5)
1.	1KG	530	370	130	30	73	69.8
2.	1KG	531	390	116	25	81	73.5
3.	1KG	528	365	126	37	78	68.2
4.	1KG	526	395	96	35	75	75.1
5.	1KG	532	372	119	41	74	69.9

Efficiency of palm kernel cracking machine =(Output/Input) x100%

Aveξ=(£N/5) %

(i.e. the number of cracked nut divided by total number of kernel nut)

Average efficiency = (69.8 + 73.5 + 68.2 + 75.1+ 69.9)/5

=356.5/5

=71.3%

Table 6 : Calculated Efficiency of Impact approach centrifugal Palm Kernel nut Cracking Machine

S/N	MASS OF KERNEL FEED	NO. OF KERNEL	NO. OF KERNEL CRACKED	NO. OF KERNEL UNCRACKED	NO. OF BROKEN KERNEL	TIME (SEC.)	EFFIENCY (5)
1.	1kg	532	270	51	211	76	50.8
2.	1kg	529	250	37	242	62	47.3
3.	1kg	528	265	52	211	70	50.2
4.	1kg	530	27	31	227	69	51.3
	1kg	533	279	38	216	72	52.3

Efficiency of palm kernel cracking machine = (Output/Input) x100%

Aveξ=(£N/5) %

(i.e. the no. of cracked nut divided by total no. of kernel nut)

Average efficiency = (50.8+47.3+50.2+51.3+52.3)

= 251.9/5

= 50.38%

Efficiency of the palm kernel cracking machine = 50.38%

6. Results and discussion

The result evaluation of performance of the two palm kernel cracking machines show that the efficiency of the vertical centrifugal palm kernel cracking machine is 71.3% and 50.38% for impact approach centrifugal palm kernel cracking machine from this it can stated that the two machine are not as such efficient. This is due to many factors among which are error in design and construction.

The impact approach centrifugal palm kernel machine has the highest damage output of the kernel nut due to high impact of the rotor on the kernel nut. Critical examination of the few uncracked kernels reveals that the size of the uncracked kernel nut are smaller than the average mass and diameter of the kernel obtained for the design (refer to experiment 1). By increasing the speed of the motor would cause more damage to the shell of the kernels.

Table 7: Comparison of machine cracking output

S/N	*Vertical centrifugal Palm kernel nut cracker*	*Impact approach centrifugal* palm kernel nut cracker
1	The cracking seeds are very neat	The cracking seeds are damage and rough
2	Slightly slow in operation	Very fast in operation
3	Enough clearance in cracking Spinning bowl	Clearance between the rotor and cracking wall is too tight
4	It have good discharge outlet	Having truncated discharge Outlet.

7. Conclusion and recommendation

The performance test carried out on the two machines shows that both machines needed to be modified. Improvement on the design of the machines is important for higher cracking efficiency. From the result of evaluation, the vertical centrifugal palm kernel cracker has higher efficiency, hence, it is preferred to impact approach centrifugal cracker. Although the vertical centrifugal palm kernel cracker is very slow in operation, but the cracking output is very neat and clean compare to that of impact approach centrifugal cracker is very fast.

In order to boost the efficiency of the kernel nut crackers for the advantages of small - scale industries that use kernel oil, the two machines has to be worked upon to minimize damage to kernel nut and to increase the cracking efficiency. I n order to have relative comparison in term of performance to the imported cracking machine, these two existing machines should be worked upon so as to improve their performance. The following recommendations are made for the two machines.

7.1 Vertical Palm Kernel Nut Cracker

i. Palm kernel nut regulator at the opening of the hopper to cracking chamber has to be included in the design and be constructed to regulate the number of nut going to cracking chamber.

ii. Reducing the hopper discharge opening and position it in a slight form to minimize the number of palm kernel entering to the spinning bowl at a time.

iii. Feeding of kernel nut to the machines has to be gradually drop into the hopper which bring about good cracking output with increase in cracking time.

7.2.2 Impact Approach Centrifugal Cracker

i. Hopper cover with small opening on it must be constructed to avoid scattering of cracked kernel nut.

ii. The machine must be installed on reinforce concrete to reduce noise and vibration.

iii. Enough clearance must be between the rotor and cracking wall in order to allow the free movement of rotor in cracking the palm kernel nut.

iv. Collector must be constructed to the discharge opening to limit the splashing of cracked nut.

Based on the evaluation of the output and performance of these machines, the vertical centrifugal palm kernel is recommended for small-scale industries that make use of kernel oil to increase their productivity.

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