

## DEVELOPMENT AND PERFORMANCE EVALUATION OF SMALL-SCALE PALM KERNEL CRACKER

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**ABSTRACT:** Cracking of palm kernel is a common process in order to separate the palm seeds from the kernel. Though, the palm kernel has been cracking with the aid of stone, ever since, due to the technological advancement there has been various palm kernel cracker machine on which there has been an improvement on them from time to time. It was observed that most people engage in palm kernels cracking were rural dweller, even some that are living in urban city are facing with incessant supply of electricity, therefore there should be a means of addressing the aforementioned shortcomings. This work aimed at producing a portable palm kernel cracker machine powered by gasoline motor with easy mobility that will reduce cracking time and human energy from local materials. The machine has main components: hopper, cracking chamber, bearing cover, frame assembly and puller. The Palm kernel nuts are mechanically cracked with the aid of centrifugal rotating three arms hammer that beats the Palm kernel from the seed. The machine optimum performance gave a throughput capacity of 401.4 kg/hr, cracking efficiency of 95.6%, split losses of 9.3% and uncracked losses of 6.2%. With the aforementioned capacity of the machine, the associated problems and difficulties in the traditional method will be culminated. With these attributes, this machine is suitable for both small and medium scale processors.

KEYWORDS: Palm Kernel, Cracking, Mobility, Cracking Efficiency, Gasoline Motor

# INTRODUCTION

The Oil Palm tree is one of the greatest economic assets a state or nation has, provided its importance is realized and potentials fully harnessed. Oil Palm products include Palm Oil, Palm Kernel Oil, Palm Kernel Cake amongst other products. Some other by-products of the Oil Palm include Palm wine, fatty alcohols as well as intermediates. They are also known as sweet oils. Palm kernel oil is a white to yellowish oil of vegetable origin which is solid at normal temperatures and is obtained from the kernels of the oil palm (Elaeis guineensis). Palm kernel oil is different from palm oil, which is obtained from the flesh of the fruit. Four products namely palm kernel oil, palm kernel cake; palm kernel sludge and palm kernel shell which is used as a biofuel can be *gotten from palm kernel nuts*. Palm kernel oil is processed to yield edible fats, soaps and candles and is used in the confectionery, pharmaceutical and perfume industries. There are great differences between palm oil and palm kernel oil in physical and chemical



characteristics. Palm oil contains mainly palmitic and oleic acids, the 2 common fatty acids and about 50% saturated, while palm kernel oil contains mainly lauric acid and is more than 89% saturated, Ayhan, (2003). Palm kernel production potentials of several countries are far from been fully exploited. At present, many countries are operating below expected capacity and this research effort is to develop an appropriate machine for quality production of palm kernel. The performance of the machine shows that throughput capacity increases from 625-1270 kg/hr for 'Dura' variety and also increases from 750-1200 kg/hr for 'Tenera' variety, Jimoh and Olukunle, (2013a).

There are many different varieties of palm kernel, resulting in a wide range of average sizes. For one particular variety, the cracker may crack the palm kernel so much that they crumble into many small pieces leaving few or no halves; whereas with a different variety, the cracker may barely crack the shell and the palm kernel leaves the machine unscratched, Akinoso and Raji, (2011). Lack of appropriate technology for palm fruit processing has been described as one of the major problems militating against Nigeria's oil palm agro-industrial development, Owolarafe and Oni, (2011) and Adetan, et al., (2007). This traditional method is not only labour intensive and time consuming, but also associated with pains, drudgery and wounds that are usually sustained when the finger is hit with a stone or other part of the body is hit by the flying shells. Although, the hand-cracked kernel attracts high costs due to high grade quality oil recovered since the level of breakage is low. Separation of cracked mixture to recover the kernels is one of the most important activities in PKO production process. Research has led to the invention of the clay-bath and hydro-cyclones for the recovery of kernels from the cracked mixture, Okoronkwo, et al., (2013).

The basic features of the machine are hopper, cracking chamber, horizontal shaft with beaters, discharge outlet and the prime mover. The machine was evaluated at three different moisture content of palm nuts and four levels of machine speed at an average feed rate of 450kg/hr. Test result showed that the machine gave its best work performance at 1480 rpm machine speed and with palm nuts of 9.81% (db) moisture content. The cracker efficiency and kernel breakage ratio are some of the most important parameters for evaluating the cracker performance. From the result of this work, the two parameters are function of cracking speed, moisture content and feed rate. The kernel breakage ratio ranged from 0 - 0.18 (0 - 18%) for all feed rates and moisture contents. It increased with moisture content and cracking speed, but decreased with feed rate, Ndukwu and Asoegwu, (2010). A palm nut and fibre separator was designed, fabricated and tested. The basic features of the separator are feeding chute, pulverizing unit, separating unit, discharge outlets and the prime mover. The machine was tested at three different machine angles of tilt, two different levels of moisture content termed and three levels of fibre discharge openings. Test results showed that the machine gave its best work performance with dry mixture at 10mm fibre discharge opening and  $20^0$  machine angles of tilt. The cost of producing one unit of the palm nut and fibre separator as at the time of fabrication was estimated to be twenty thousand, four hundred and sixty naira not including the cost of electric motor, and the power required for operating the machine was 2.25kW, Ologunagba, et al., (2010).

An improved automated palm nut cracker of model was used for the experiment and results shown that the highest throughput, functional efficiency and quality performance efficiency were 1,260 kg/hr, 99.07% and 98.80% respectively while



mechanical damage reduced to 0.20%, Jimoh and Olukunle, (2013b). Due to the lack of electricity supply in some rural areas in Nigeria in which the production of Palm kernel thrives, this work aimed at construction of portable palm kernel cracker suitable for small and medium processor user in other to ameliorate the welfare and economy situation there.

# **DESIGN THEORY**

## **Types of Palm Kernel Cracker**

Manual palm kernel cracker: traditionally, cracking of the nuts is done by placing the nut on top of a stone and striking it with another stone with an impact force, causing the shell to split along the line of impact and the nut let out. This traditional method is not only labour intensive and time consuming, but also associated with pains, drudgery and wounds that are usually sustained when the finger is hit with a stone or other part of the body is hit by the flying shells, Badmus, (1990); Ologunagba, (2012). However, due to the global demand of palm kernel and it's by products, an effort has been geared towards an improved method of palm kernel extraction.

## **Mechanical Palm Kernel Cracker**

This is modern crackers and of two types: Hammer-impact, and Centrifugal-impact types. The hammer-impact type breaks or cracks the nut by impact when the hammer fall on the nut, while the centrifugal-impact nut cracker uses centrifugal action to crack the nut. The nut is fed into the hopper and it falls into the housing where a plate attached to the rotor is rotating. According to some researchers shelling has always posed a major problem in the processing of biomaterial and they attributed this to the shape and the brittleness of the kernel. A vertical shaft is fitted into the cracking chamber from the bottom and is attached to a channel for directing the palm nut falling on it. The centrifugal action of the shaft flings the nut on the cracking ring with the nut cracking on impact. Ologunagba, (2012) designed a cracking chamber which consists a circular housing made from mild steel rod attached with 4 beaters made of mild steel flat bars arranged at intervals of 90° to one another. Oguoma, et al; (1993), Adebayo, (2004), Oladejo, et al., (2008), stated that palm kernel extraction can be clarified as roller, hammer impact and centrifugal - impact crackers. The roller cracker has two rollers revolving in opposite directions which subject the palm nuts to compressive force as the nuts move through the rollers being constant any preset condition while the nut sizes vary made the efficiency very low. The hammer -impact cracker breaks or cracks the nuts by impact when the hammer falls on the nuts, but kernel breakage is a major setback.

The centrifugal impact cracker involves the hurling of the palm nuts at a fairly high speed against a stationery hard surface; this design has high productivity. Jimoh and Olukunle, (2013b), Abu, et al., (2014), designed a cracking chamber consists of a pair of hammers made from mild steel which are arranged at 180° to each other, but the shortcoming is that some palm kernel was uncracked. Olakanmi, (2004), stated that there are two forces that exist on impeller blade depending on its state of motion. These include the centrifugal force in the rotor blade associated with dynamic motion of the



blade and weight of the blade association with static state of blade. But the one that is responsible for cracking is centrifugal force.

## MATERIAL AND METHOD

#### **Design Consideration and Specifications**

This work aimed at producing a portable cracker with easy mobility that will reduce cracking time and human energy from local materials. The main components of the machine are: *Hopper*, *Cracking Chamber*, *Bearing Cover*, *Frame assembly and Puller*. *Hopper*: this is the part in which the palm nuts are held while being fed into the cracker. It is made of mild steel, trapezoidal in shape and welded to the cracking chamber. *Cracking chamber*: this is the chamber where the palm nut is cracked. It is made of steel with 360mm diameter having three-arms hammer arranged in 120° to another in the chamber. The three-arm hammer hits the palm nut with the wall of the cylinder during cracking. *Frame Assembly*: this made of angle iron (45x45x6.25) mm. It holds and supports the remaining parts of the machine. *Bearing cover*: this is made up of sheet metal plate; it covers the bearings and rotor compartment.

#### **Machine Operation**

The palm kernel nuts are fed into the cracking chamber through hopper. Power is transmitted to the rotor from an electric motor through the V-belt. As the rotor rotates, the centrifugal rotating three arms hammer beats the palm kernel from the seed. The kernel and the seeds passed into the lower circumference of the cracking chamber.

# Estimation of Cracking Efficiency, Percentage Broken Kernel and Whole Nut in Shell

A kernel yield  $(m_1)$  and shell fraction  $(m_2)$  in grams from the sample were collected for each of the varieties and sieve size combination and analyzed to find the cracking efficiency. The kernel yield samples were separated into un-cracked nut  $(m_3)$  and broken kernel  $(m_4)$ . The shell samples were also separated into the shell  $(m_5)$  and the whole nut  $(m_6)$ . The cracking efficiency,  $(\sigma)$ , is defined as the fraction of the quantity of non-defective kernel over the total kernel sample. This can be computed as,

$$\sigma = \left[1 - \left(\frac{\mathbf{m}_3 + \mathbf{m}_4}{\mathbf{m}_1}\right)\right] 100\% \tag{1}$$

The percentage broken kernel is defined as the fraction of the broken kernels in the kernel sample. This is expressed as

$$\alpha = \frac{\mathrm{m}_4}{\mathrm{m}_1} \times \ 100\% \tag{2}$$



The percentage whole nut in the shell sample is also defined as quantity of whole nuts in the shell sample. This is expressed

$$\beta = \frac{m_6}{m_2} \times 100 \%$$
 (3)

#### **Power Requirement**

The power requirement of the machine was determined with the expression by, Kurmi and Gupta, (2005), Oladejo and Oriolowo, (2015),

$$P = \frac{2\pi nT}{60}$$
(4)

Where,

n shaft speed, (rpm),

T torque required to turn the shaft at the circumference of the driven pulley, (Nm),

Power required to drive the shaft=1.91kW. Therefore, an electric motor of 2.25KW (3h.p) was selected.

## **Pulley and Belt Drive**

The mechanisms and systems in the machine are driven through the V-belt and pulley arrangement with the nibbler shaft taken its drive directly from 2.25kW electric motor of 1420rpm speed. With the power rating, a belt of type A- cross-sectional symbol was selected. Thus, recommended minimum pulley pitch diameter, d = 75mm.

Belt speed, is given by

 $S = \pi dn \tag{5}$ 

Where,

- d shaft diameter, (m),
- n shaft speed, (rpm),

$$\frac{\mathrm{D}}{\mathrm{d}_2} = \left[\frac{\mathrm{n}_2}{\mathrm{n}_1}\right]_{\aleph} \tag{6}$$



## Where,

- D diameter of the driver (nibbler) pulley, m,
- d<sub>2</sub> diameter of driven (pulverizer) pulley, m,
- $n_1$  speed of driver pulley,
- n<sub>2</sub> speed of driven pulley,

## **Shaft Selection**

The pulverizer and nibbler shafts were selected using the ASME code equation for solid shaft having little or no axial loading, Oladejo and Oriolowo, (2015),

$$d^{3} = \frac{16}{\pi s_{s}} [(K_{b}M_{b})^{2} + (K_{t}M_{t})^{2}]^{\frac{1}{2}}$$
(7)

Where,

- $S_s$  ultimate stress of mild steel without key way = 55MN/m<sup>2</sup>.
- $K_b$  combined shock and fatigue factor applied to bending moment = 1.5,
- M<sub>b</sub> maximum bending moment, (Nm),
- $K_t$  combine shock and fatigue factor applied to torsional moment = 1.0, and
- M<sub>t</sub> maximum torsional moment, (Nm).

## Cracker

Having research into the various types of cracking mechanism in palm kernel cracker, this work adopted the centrifugal-impact designed cracker which has 3 arm centrifugal mild steel hammer arranged in  $120^{\circ}$  radially with the rotating sheet in the cracking camber. The action of these 3 arms crackers enables it to hit the kernel laterally which let out the seed from the palm nut in a neat form. Also, the centrifugal impact force by the rotating hammer is optimum for all varieties of palm nut to be cracked.





Figure 1: Palm Kernel Cracker



Figure 2: Schematic Diagram of the Palm Kernel Cracker

(1) Frame Assembly, (2) Hopper Cover, (3) Hopper, (4) Bearing Cover,
(6) Cracking Chamber, (7) Bearing, (8) Shaft, (9) Pulling Iron, (10) Rolling Tyre, (11) V-Belt, (12) 3HP Gasoline Motor, (13) Cracker



#### **TEST AND PERFORMANCE EVALUATION**

After design and construction, the machine was tested and the following parameters were investigated: *Effective capacity, Cracking efficiency, Split losses, Un-cracked losses and Seed breakage.* 

Effective capacity is the quantity of palm kernel that the machine can crack per unit time. It is derived by the expression,

E.C. = mass / time (kghr<sup>-1</sup>).

Cracking efficiency is the percentage weight of the palm kernel cracked to the uncracked palm kernel. It is derived by the expression,

C.E. = mass cracked / total mass of palm kernel x 100%.

Cracked loss is the percentage mass of the palm kernel seed split to that originally present on the cobs. It is derived by the expression, C.L. = Split mass / total cracked mass x 100%.

Un-cracked loss is the percentage mass of palm kernel that is un-cracked to the total mass of palm kernel cracked. It is derived by the expression, U.L. = Un-cracked mass / total mass of palm kernel x 100%.

#### RESULTS

From figure 3, it was observed that any mass of Palm kernel less than 1000kg fed into the cracker at a time will lead to the emanation of (i) split loss (PKS) and (ii) uncracked loss of Palm kernel (PKU) during operation; the percentage of split and uncracked loss of Palm kernel during the operation decreases as the mass of Palm kernel fed into the machine increases at a time during operation. The machine optimum performance gave a throughput capacity of 401.4kg/hr, cracking efficiency of 95.6%, split losses of 9.3% and un- cracked losses of 6.2%, (See appendix).

Test No	Time (sec)	Mass of PKC (g)	Mass of PKS (g)	Mass of PKU (g)	Total Mass of PKC* (g)	Total Mass of PKF (g)
1	15	1562	316	122	1878	2000
2	20	2021	311	168	2332	2500
3	27	2452	288	260	2740	3000
4	31	3026	240	233	3267	3500
5	37	3344	226	230	3570	3800
6	41	3576	231	193	3807	4000
7	46	4088	216	196	4304	4500

 Table 1: Analysis of Machine operation during Performance Evaluation





Figure 3: Performance Evaluation Analysis

# CONCLUSION

With the level of present technology and by considering the untold hardship coupled with long hours people used in palm kernel cracking through conventional method, the usage of this palm kernel cracker which was designed from locally sourced material will over ruled all problems being experienced by the people. This will help to boost the production of palm kernel oil, palm kernel and palm kernel seed etc. The user's standard of living will be improved. The machine maximum performance and long service life is ensured when there is proper maintenance and operations among which are: preventing the machine from having contact with water or rainfall, regular lubrication of bearings, retightening of any loose bolts and nuts must be done before each operation, operation of the machine on a level ground in order to prevent excessive vibration. With the machine performance of throughput capacity of 401.4kg/hr, cracking efficiency of 95.6%, split losses of 9.3% and un- cracked losses of 6.2%, the machine will culminate the associated problems and difficulties in the traditional method of separation. It is, therefore, recommended for both small and medium scale processors. In case of future research on this machine, the separator of palm kernel and seed should be incorporated.

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## APPENDIX

#### Calculation

Effective Capacity = Total Mass of palm kernel fed / Time (Kg hr<sup>-1</sup>)

E.C.<sub>1</sub>= 2 x 3600 /15 = 480kghr <sup>-1</sup>,

E.C.<sub>2</sub> =2.5X3600 / 20 = 450kghr<sup>-1</sup>,

 $E.C._3 = 3.0x3600 / 27 = 400 kghr^{-1}$ ,

E.C.<sub>4</sub>=3.5X3600 / 3 = 406.5kghr-1,

E.C.<sub>5</sub>= 3.8x3600 / 37 = 369.7kghr<sup>-1</sup>,

 $E.C._6 = 4x3600 / 4 = 351.2 kghr^{-1}$ ,

 $E.C._7 = 4.5 \times 3600 / 46 = 352.2 \text{kghr}^{-1},$ 

Average Effective Capacity= 480+450+400+406.5+369.7+351.2+352.2/7 = 401.37kghr<sup>-1</sup>

Cracking Efficiency = Mass cracked / Total mass of palm kernel fed x100%

C.E.<sub>1</sub> = 1.878 / 2x100 = 93.9%, C.E.<sub>2</sub> = 2.332 / 2x100 = 93.3%, C.E.<sub>3</sub> = 2.740 / 3x100 = 91.9%, C.E.<sub>4</sub> = 3.267 /3.5x100 = 93.3%, C.E.<sub>5</sub> = 3.570 / 3.8x100 = 93.9%, C.E.<sub>6</sub> = 3.807 / 4x100 = 95.2%, C.E.<sub>7</sub> = 4.303 /4.5x100 = 95.6%

Average Cracking Efficiency =93.9+93.3+91.3+93.3+93.9+95.2+95.6/7= 93.8%

## Split Losses = Split mass / Total mass of palm kernel broken x100%

S.L.<sub>1</sub>=316 /1878x100 = 16.8%, S.L.<sub>2</sub> = 311 / 2332x100 = 13.3%, S.L.<sub>3</sub> = 288 / 2740x100 = 10.5%, S.L.<sub>4</sub> = 241/3267x100 = 7.4%,



 $S.L._5 = 226/3570 \times 100 = 6.3\%$ ,

 $S.L._6 = 231/3807 x 100 = 6.1\%$ ,

 $S.L._7 = 216/4304 \times 100 = 5\%$ 

Average cracked losses= 16.8+13.3+10.5+7.4+6.3+6.1+5.0/7 = 9.3%

Un-cracked Losses = Un-cracked mass / Total mass of palm kernel fed x 100%

 $U.L._1 = 122/2000 \times 100 = 6.1\%$ ,

 $U.L._2 = 168/2500 \ x100 = 6.7\%,$ 

 $U.L._3 = 260/3000 \times 100 = 8.7\%$ ,

 $U.L._4 = 233/3500 \text{ x}100 = 6.6\%$ ,

 $U.L._5 = 230/300 \times 100 = 6.1\%$ ,

 $U.L._6 = 193/4000 \times 100 = 4.8\%$ ,

 $U.L._7 = 196/4500 \times 100 = 4.4\%$ 

Average Un-cracked Losses = 6.1+6.7+8.7+6.6+6.1+4.8+4.4/7 = 6.2%