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# Development and Performance Evaluation of Indigenous Palm Kernel Daul Processing Machine

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**Abstract:** In an attempt to ease the production of palm Kernel Oil, a palm Kernel dual processing machine has been developed to crack effectively various sizes as well as to separate the palm Kernel from the shell. This palm kernel dual processing machine was fabricated and designed with locally available materials from the opinion of a new idea which aims at easing the pain, stress, intensive labour, time consuming, unduly cost and cumbersome operation encountering in the traditional/existing processes of cracking and separating palm kernel from the nut. The machine was tested to ascertain its performance and it has efficiency of 98% with processing rate of 95 nuts per second with just one 4hp electric motor which is an improvement over existing ordinary palm kernel cracking machine that has 90% efficiency of cracking with processing rate of 89 nuts per second without separation.

**Key words:** Palm kernel, processing, dual and machine development, evaluation

## INTRODUCTION

Palm kernel oil, a major viable oil in Nigeria is obtained from the kernel of the palm tree after cracking the palm kernel nut. The kernels are not useful until the kernels are separated from the shell but usual way of Cracking palm nut to get the kernel is a time consuming and labour intensive process (Stork, 1962). A safer and more efficient method of cracking palm kernel and separating kernels from shells is desired. Therefore, cracking and the separating processes are two major operations that need serious development for drastic improvement in quality and quantity of palm kernel oil produced in Nigeria. Kernel contains 46 to 54% oil with a Free Fatty Acid, (FFA) of about 4 % and this oil is more stable than palm oil (Derek and Wiberley, 1997) . The by-product after extraction of palm kernel oil can also be used as a valuable substitute for cocoa butter as well as palm kernel cake, animal feed, soap, candle and varieties of industrial used.

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 with in 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 what within and outside this country, 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.

Removal of palm kernel form its shell basically involves cracking and separating processes. 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 typical business venture for local youth and old women in the villages 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 (Badmus, 1990).

There are two basic mechanical effects 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 (Badmus, 1990).

Mechanical method will only crack the nuts and leave the product as a mixture of shells and kernels, which needs to be separated before it can become a useful product. Picking by hand is too cumbersome at this stage, the separation processes is done using a pot containing viscous mixture of water and clay. The purpose of the clay is to aid the shells to sink while the kernels float on top of the water clay mixture. This method consumes a lot of time in washing and drying the kernel and make the palm kernels to be liable to quick infection of fungal thereby reduces the quality of oil produced. Another mechanized wet method of separation is the hydrocyclone where the principle of flow resistance is applied (Oguoma *et al.*, 1993). This method of separation has wide industrial applications but is capital intensive.

Having understudied the problems of cracking and separating processes in the existing methods, palm kernel dual processing machine actually incorporate the solution of the identified problems in the design and development using local available raw material such as discarded automobile spare parts to produced the machine.

## MATERIALS AND METHODS

In the existing cracking machine the different sizes of nuts were not put into consideration. When a mixture of different nuts are fed into the existing cracking machines some are too small or too big cracked which is the major reason for the low efficiency of the machine. Base on the above findings an experiment was carried out to determine the average size, average mass, moisture content, strength and coefficient of friction of shell and kernel to aid in the design and fabrication of the machine.

**Apparatus and experimental procedure:** Apparatus that were used in the experiment are weighing balance, venire caliper, pins, standard masses, flexible cord, meter rule, scissors, resort stand and palm kernel shell of different sizes. The masses of palm kernel nut were measured and the major and minor diameters were also determined. The strength of palm kernel nut was also determined by allowing a kilogram weight to fall from varying elevated height on palm kernel until the weight actually cracked the palm. kernel nut by cutting cord with a scissors.

**Physical characteristic of shell and kernel:** The physical characteristic of palm kernel that needs to be taken into consideration, include: the size of palm kernel nut, shell and kernel, the mass of palm kernel and coefficient of friction for shell and kernel with respect to steel.

**Size of palm kernel nut, shell and kernel:** Measurement of sizes of the nuts was taken from 5 samples of 500 dura nuts. Fifty nuts were measure in each sample, the average size of diameter of the palm kernel nuts ranged from 12.20 to 29.60 mm and the size of shell thickness ranged from 2.20 to 8.60 mm. The size of diameter of kernel ranged from 9.7 to 17.00 mm

**Mass of palm kernel:** Measurement of masses of the nuts was taken also from 5 samples of 500 nuts. Fifty nuts were weight in each sample. The masses of the nuts ranged from 2.4 to 10.8 g.

**Coefficient of friction:** The coefficient of friction for shell and kernel with respect to steel were determined experimentally. The coefficient of friction for shell and kernel is 0.50 and 0.26, respectively. The shell has higher coefficient of friction than kernel with respect to steel surface. This is an important factor in designing the separating unit of palm kernel processing machine.

**Design procedure and machine development:** Palm kernel dual processing machine has two distinct parts and the parts include cracking unit and separating unit.

**Cracking unit:**

b = Bread of the blade = 80 mm
t = Thickness of the blade = 10 mm
r = Height/radius of blade = 120 mm
$\rho$ = Density of steel = $7.85\times10^3$ kg m$^{-3}$
$\omega$ = 2ΠN/60 = angular velocity of the disk = 61.09 rad s$^{-1}$
N = Angular speed of disk = 583.33 rpm
fc = 337.49N
$V_c$ = Peripheral velocity of the

$$= \omega r \quad (2)$$

$$= 7.33 \text{ m s}^{-1}$$

**Force to crack palm kernel nut (F):** The cracking strength of palm kernel as determined from an experiment was 1423.25N m$^{-2}$.

$$F = A\times S \quad (3)$$

Where,

A = Area of palm kernel cracking = 0.000843m$^2$
S = Strength
F = 1.28N

**Power Require to drive the shaft of cracking unit ($P_c$):**

$$\text{Power} = (fc + w_p)V_c \quad (4)$$

In the design of palm nut cracker of horizontal shaft type, the following factors were considered in the design, material selection and construction of palm nut cracker viz: Impringing velocity of palm nut with which it strikes the drum, sizes of palm nuts, moisture content of palm nut and clearance between rotor and cracking drum (John and Owoniho, 2004).

**Cracking force of the impeller blade:** Basically, there are two forces that exist on impeller blade depending 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 (Olakanmi, 2004). But the one that is responsible for cracking is centrifugal force (fc)

$$fc = M\omega^2 r \qquad (1)$$
$$= \rho V \omega^2 r$$

where,

V = Volume of the blade =
$b \times t \times r$ = 0.0000 96

where

$w_{p,}$ = weight of the pulley =12N
= 2561.54W
= 2.56kW(3.433hp)

**Separate unit:** Differences in the sizes and coefficient of friction of the shells and kernels as determined in the experiment were exploited in the design, material selection and development of palm kernel separator unit.

**Angle of repose (ϕ) of shells and kernels:** Angle of repose (ϕ) is the angle at which the separating tray is tilted for kernel and shell to move down with uniform velocity.

Where,

$$\mu = \tan \_\phi$$

μ = Coefficient of friction,ϕ = Angle of response ,$\phi_s$ = Angle of response of shell ,$\phi_k$ = Angle of response of kernel, $\mu_s$ = Coefficient o friction of shell = 0.50 and $\mu_k$ = Coefficient of friction of kernel = 0.26.

$$\phi_s = \tan^{-1} \mu_s = \tan^{-1} 0.5 = 26.6^0$$

$$\phi_k = \tan^{-1} \mu_k = \tan^{-1} 0.26 = 14.57^0$$

**Vibration force:** The vibration of screening tray is result of periodic disturbing force $F_t$ applied to the screening tray by mean of camshaft and returning spring. The disturbing force $F_t$ is therefore

$$F_t = S\times + M\omega^2 r \qquad (5)$$

Where ,

S = Stiffness of spring = 2 N mm$^{-1}$,M = Mass of screening tray = 16. 94 kg, N = Angular speed of the screening = 69 rpm, $\omega_t$= Angular velocity of tray vibration = 7.23 rad s$^{-1}$, r = Radius of the pulley rotating the camshaft. = 120 mm and x = Amplitude = 40 mm.

$F_t$ = 82.10N.

**Power require to vibrate the separating Tray ($P_t$):**

$$P_t = (F_t + wp_v)\, V_t$$

Where,

$wp_v$ = Weight of the pulley =12N
$V_t$ = $\omega_t$
r = Peripheral velocity of the cam
$F_t$ = Vibrating force
$P_t$ = (82.1+12)×0.876 = 81.64116W

**Total power required to drive the palm kernel processing machine ($P_T$):** Power Require to vibrate the separating tray ($P_t$) + Power require to vibrate the cracking unit ($P_c$)

$P_T = P_t + P_c$
$P_T$ = 81.6412 +2561.54
= 2644.18W(3.54hp)

**Machine development:** The palm kernel dual processing machine is made up of following named units:

- Cracking unit
- Separating unit

Shown in Fig. 1, is exploded isometric view of palm kernel dual processing machine with the identify parts.

**The cracking unit:** The cracking unit is made up of feed hopper, impeller shaft, cracking drum, impeller blade. The nut fall by gravity through the hopper channel into the cracking drum where the cracking process take places through the help of impeller blade that flap the palm kernel nut against the walls of cylindrical cracking drum. The three blades are at 120° to each other and the blades have clearance of 15 mm from cracking drum, this is based on the result of design calculation. The impellers are made up of high carbon steel and are removable to ensure adequate maintenance and replacement in case of wears after being used for long period.

**The separating unit:** The separating unit is made up of camshaft, returning spring and separating tray, inclined at angle 20° which is less than angle of response of shell but is far greater than that of kernel, to enhance free fall of kernel.

The tray has two sections; the first section of the tray is shell screener, which is made of 10 mm rods lined at equidistance of 9.00 mm in the tray. This distance is base on the experimental result of the average size of the shell thickness and kernel; this section separates the shell from the kernel. The second section is kernel screener that separates cracked from uncracked palm kernel and is made

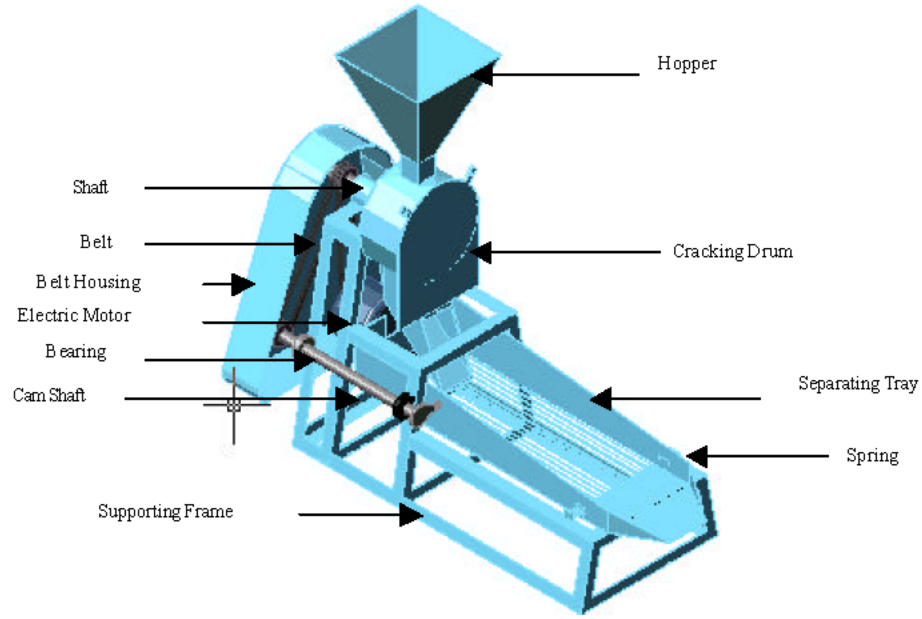


Fig. 1: Isometric drawing of indigenous dual kernel cracker processing machine

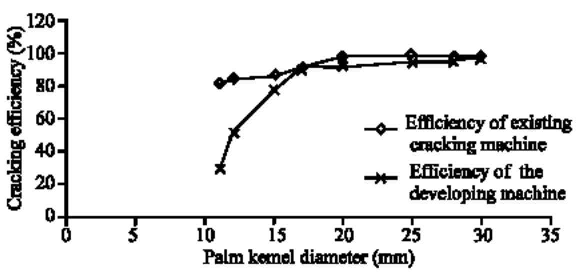


Fig. 2: Graph of cracking efficiency against diameter of palm kernel

up of tray perforated with size of 16.00 mm base on the size range of kernel determined in the experiment.

The tray is subjected to vibration with the aid of three camshaft rotated by 4hp electric motor and three the returning spring. Cracking unit and separating unit are powered by 4 hp with 2500 rev $min^{-1}$ with two pulleys. One of the pulleys is connected with v-pulley of the cracking unit, the other one to separating unit.

**Performance evaluation:** The performance of the machine is determined by evaluating the efficiency of the developed machine (Fig. 2).

**Machine efficiency:** Comparative evaluation was done between developed palm kernel dual processing machine, existing palm kernel cracking machine and manual way of cracking and separation. Ten samples were prepared for evaluation and each sample contains 5000 pieces of palm kernel nut. Each sample was poured into the palm kernel dual processing machine and the record of the cracked and un-cracked palm kernel nuts with time of processing were taken. The same thing was repeated for exiting cracking machine. Ten other samples containing 5000 pieces of palm kernel nuts were prepared for manual cracking and separating process for 10 persons.

The results were recorded to compare the efficiency of the palm kernel dual processing machine, existing and manual processing operation. Process efficiency $P_E$ (%) was calculated as follows:

$$P_E(\%) = [(P-K)/P]\times 100$$

Where,

P = Total number of palm kernel in the sample.

K = Total number of processed palm kernel nut.

Processing rate ($P_R$) was calculated as follows:

Processing rate in kernel $sec^{-1}$ = $T_c/t_c$

Where,

$T_c$ = Total number of process palm kernel

$t_c$ = Time taken to process palm kernel

Moreover, the efficiency of machine was determined relative to diameter of the palm kernel. Five thousand palm kernels of the same size were sorted out for different diameter. Each sample containing the same size was poured into the machines to known the effect of size of palm kernel on machine efficiency. The same thing was done for existing palm kernel machine.

Table 1: Machine performance and comparative tests data

| S/N | No of nuts introduced into the machine ($N_1$) | No of processed palm kernel nut ($N_2$) | Time Taken (s) | Performance efficiency (%) | Performance rate ($N_3$ $s^{-1}$) | No of cracked palm kernel nut ($N_3$) | Time taken(s) | Performance efficiency (%) | Performance rate ($N_3$ $s^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| | | Palm kernel dual processing machine | | | | Existing cracking machine | | | |
| 1 | 5000 | 4897 | 52 | 97.94 | 94.00 | 4500 | 50 | 90.00 | 90.00 |
| 2 | 5000 | 4905 | 51 | 98.10 | 96.00 | 4505 | 51 | 90.10 | 88.33 |
| 3 | 5000 | 4903 | 51 | 98.06 | 96.00 | 4503 | 50 | 90.06 | 90.60 |
| 4 | 5000 | 4895 | 51 | 97.90 | 95.00 | 4504 | 51 | 90.08 | 88.31 |
| 5 | 5000 | 4907 | 52 | 98.14 | 94.40 | 4495 | 50 | 89.90 | 89.90 |
| 6 | 5000 | 4902 | 52 | 98.04 | 94.30 | 4497 | 50 | 89.94 | 89.94 |
| 7 | 5000 | 4895 | 51 | 97.86 | 95.94 | 4496 | 51 | 89.92 | 88.16 |
| 8 | 5000 | 4898 | 52 | 97.96 | 94.20 | 4504 | 50 | 90.08 | 90.08 |
| 9 | 5000 | 4895 | 51 | 97.10 | 95.00 | 4502 | 51 | 90.04 | 88.27 |
| 10 | 5000 | 4906 | 52 | 98.12 | 94.00 | 4497 | 51 | 89.94 | 8818 |
| AVE | 5000 | 4901 | 51.58 | 98.00 | 94.89 | 4500.3 | 50.50 | 90.00 | 89.10 |

## RESULTS AND DISCUSSION

The evaluation results for the performance efficiency and performance rate for the developed palm kernel dual processing machine and existing cracking machine are presented in Table 1.

The existing palm kernel-processing machine can only crack and the mode of separating the shell from nut is by wet method. This method is faster than manual hand picking but it exposes the kernel to fugal infection due to long time drying period. This long period of drying and the contamination of clay solution used in separating have adverse effect on the quality of oil produced. The new developed palm kernel dual processing machine reduces the tendency of attack by fugal and insect due to low percentage of broken nut and the dry method of separating immediately after cracking process. The quality of palm kernel oil in this case is not affected.

The machine evaluation results shows that this machine is faster with average process rate (cracking and separating) of 95 nuts per sec with higher efficiency of 98% than existing cracking machine with average process rate (cracking) of 89 nuts per sec with 90% efficiency. Palm kernel dual processing machine simultaneously separate the nut from the shell, which is not possible with existing cracking machine. It can also be seen from the above graph that, the size of the palm kernel nut has little or no effect on the efficiency the newly developed machine which is an improvement over the existing cracking.

## CONCLUSION

Results have shown that there is tremendous improvement over manual method of processing palm kernel and the existing palm kernel-cracking machine. This new developed palm kernel dual processing machine make use of one electric motor to serve two proposes thereby saves time, cost and energy more that the existing palm kernel-cracking machine. The machine is easy to operate, efficient and affordable to most Nigerian because of the material used and the cost of production, which is about forty thousand. The product of this machine is more hygienic than the existing palm kernel cracker. Government should grant loan to farmer so that they can afford to buy this relatively cheap machine for mass production of kernel to meet the growing demand of the Nigeria industries for further improvement our economy.

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