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## PERFORMANCE EVALUATION OF A PALM KERNEL NUT CRACKING MACHINE

**S. B. UDO\*<sup>1</sup>, S. B. ADEJUYIGBE<sup>2</sup>, S. O. ISMAILA<sup>2</sup> AND A. F. ADISA<sup>3</sup>**

<sup>1</sup>Industrial Maintenance Engineering Department, Yaba College of Technology, Yaba, Lagos, Nigeria.

<sup>2</sup>Mechanical Engineering Department, Federal University of Agriculture, Abeokuta, Nigeria.

<sup>3</sup>Agricultural Engineering Department, Federal University of Agriculture, Abeokuta, Nigeria

\*Corresponding author: [udosundaybassey@yahoo.com](mailto:udosundaybassey@yahoo.com) Tel: +2348083821702

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### ABSTRACT

Palm kernel, which is one of the by-products of palm tree is of great importance to the human race and highly sought for, because it contains oil which could be consumed directly or used as raw materials for other products. The plant is mostly found in the rain forest of Nigeria where the production of palm kernel is not the major challenge, but the production of clean and unbroken kernel (high grade) to be sold to the palm kernel merchants who buy and supply to companies. The development of mobile palm kernel nut cracking machine was made to reduce drudgery, to enhance processing capacity and to determine processing loss. Palm kernel nut cracking occurs when nuts are loaded to rupture without crushing the embedded kernel. The aim of this research work was to assess the performance of the developed mobile palm kernel nut cracking machine. Total sample of four thousand (4,000) palm kernel nuts were divided into five groups of eight hundred palm kernel nuts and each group was further divided into four sub-groups of two hundred (200) palm kernel nuts. Each group of five was fed into the hopper and cracked at different shaft speeds in revolutions per minute (rpm). The shaft speeds were determined with a tachometer and it was varied on the engine by adjusting the throttle lever. In a group of five, it was replicated for four different times at the same speed. The cracking efficiency and throughput capacity were calculated. The research work showed that the cracking efficiencies at speeds of 1200, 1800, 2200 and 2400 rpm were  $98 \pm 0.3$ ,  $98.5 \pm 0.08$ ,  $98.5 \pm 0.01$  and  $99 \pm 0.04\%$  respectively. The throughput of the machine increased from 10.91 to 38.00 g/s as the speed of the machine increased from 800 to 2400 rpm. Also the performance efficiencies of the developed machine were 93, 94, 95, 94.5 and 94% while the overall efficiencies were 90.86, 92.12, 93.58, 93.08 and 93.06% for the set speeds. It was concluded that the overall performance of this developed palm nut kernel cracking machine were effective because it fell within the range of between 90 to 98% overall efficiency.

**Key words:** cracking, palm kernel nut, efficiency, throughput, tachometer

## INTRODUCTION

Palms are classified in the family Palmae, lacking the aboreal characteristic of wood, bark and cambium, though they are still frequently referred to as trees (Thomas, 2000). The oil palm is a monocotyledon, which grows from the center. It produces one leaf at a time, emerging from the apex, with the leaflets folded against each other. It then spreads its leaflets as photosynthetic ability of the individual leaf develops. A palm can live up to sixty-five years and reach a height of 20 meters (Hertley, 1988). There have been claims for the origin of the oil palm in both Africa and the Americas. The discovery of deposited fossil *Elaeis* pollen grains deep in the Niger River Delta, however, seems to point towards a West African origin (Schultes, 1990). In West Africa, oil palm is found from Senegal along the coast of West Africa to Nigeria and beyond. The palm is an early success tropical plant, which grows in climates which are suitable for high tropical forest. Therefore, oil palms are only able to establish in the forest climate either on river banks or where an opening is created to allow sufficient sunlight.

### Palm Kernel Nut

The residue from the press consists of a mixture of fibre and palm nuts. The nuts are separated from the fibre by hand in the small-scale operations. The sorted fibre is covered and allowed to be heated up, using its own internal exothermic reactions, for about two or three days. The fibre is then pressed in spindle presses to recover second grade (technical) oil that is used normally in soap-making. The nuts are usually dried and sold to other operators who process them into palm kernel oil. The sorting operation is usually reserved for the youth and elders in the village in a deliberate effort to help

them earn some income. Large-scale mills use the recovered fibre and nutshells to fire the steam boilers. The superheated steam is then used to drive turbines to generate electricity for the mill. In the large scale kernel recovery process, the nuts contained in the press cake are separated from the fibre in a depericarper. They are then dried and cracked in centrifugal crackers to release the kernels. The kernels are normally separated from the shells using a combination of winnowing and hydro cyclones. The kernels are then dried in silos to a moisture content of about seven percent before packing. During the nut cracking process some of the kernels are broken. The rate of Free Fatty Acid (FFA) increase is much faster in broken kernels than in whole kernels. Breakage of kernels should therefore be kept as low as possible, given other processing considerations (FAO, 2004).

### Cracking of the Palm Kernel Nut

Ologunagba et al. (2010) stated that cracking is the process of breaking materials without entire separation. Palm kernel nut cracking occurs when nuts are loaded to rupture without crushing the embedded kernel. Rural dwellers' traditionally in the study areas are used to breaking the palm kernel nut with two stones when is at rest position, lies longitudinally so that the impact is applied along the lateral axis. The method of cracking palm kernel nuts are divided into two groups

- (a) Traditional Methods
- (b) Modern Methods
- (c)

**Tradition methods:** The most common practice of cracking palm kernel nuts in Africa most especially Nigeria, there are hand-operated mills. In these areas and beyond, the kernel is recovered by hand-cracking usually done by women and children. The

traditional cracking of the palm nuts is carried out manually in one of the following ways:

- i. Stone Arrangement method
- ii Mortar and pestle method

**Modern Methods:** The development of mobile palm kernel nut cracking machine is a major effort made to reduce drudgery on nut cracking in rural areas. Palm kernel nut cracking occurs when nuts are loaded to rupture without crushing the embedded kernel. Researchers around the world especially in the tropics where palm trees are found have made various contributions to the design of cracking devices. Some have designed and tested various cracking machines. Eric et al. (2009) and Oke, (2010) worked on the determination of some design parameters for palm nut cracker. Others have investigated the effects of the existing crackers on the quality of recovered kernel and showed that certain factors affect the cracking efficiency of the nut cracker. These factors are:

- (i) The size of the nut which ranges from 2-4 cm in length,
- (ii) The moisture content of the nuts (16% as recommended by Koya (2006)
- (iii) Cracker rotor speed and feeding rates (to be determined for this machine design)

Some past researchers as mentioned above designed machine that worked on crushing and cracking principles and similar to traditional methods which uses the impact principles in cracking the nuts. The reciprocating ram was designed with enough energy to break kernels at one stroke by using the impact energy that is required to crack a kernel with a load dropped from a height (Eric et al., 2009 and Oke, 2007).

Ndukwu and Asoegwu (2010) also designed a machine which was made up of a cracking chamber which contains the reciprocating ram that serves to crack the nuts against a solid block at either end of its motion. Directly above the cracking chamber is the feeding mechanism made up of a pawl whose movement rotates the nut container above it to drop nuts into the cracking chamber.

The required force to effect cracking was provided by a hand drive, this was made possible by a bar that sticks out from the bottom of the machine, pivoted between the ram and pawl that activates the container (Adebayo, 2004). The bar has a slot through which the pin, the ram and the pawl acting as the bar was oscillated. It was noticed that the efficiency of the machine was about 80.2% but the percentage of the broken palm kernel or crushed kernel nut was high. These differences were attributed to the nut sizes and moisture content of the nut.

Most of the locally made palm kernel nut cracking machine found in the rural areas are built based on intuitive technology and most of the parts were produced without justification for size from the appropriate engineering calculation, resulting in failure of major parts due to over loading. Because no design concept was considered before fabricating these locally made palm kernel nut cracking machines, this led to materials wastage, high rate of kernel breakage, poor machine performance and cost (similar machine of this capacity range cost between N250,000 to N300,000) which actually made the machines un-affordable for rural dwellers. With all the aforementioned problems, performance evaluation of a developed vertical shaft type cracker was carried out for this study.

## MATERIALS AND METHODS

### Materials

Four thousand palm kernel nut samples, a developed mobile palm nut cracking machine and an electronic tachometer to measure the machine speeds were used in this study.

### Experimental Procedure

The four thousand (4,000) palm kernel nuts were divided into five groups of eight hundred and each group was further divided into four sub-groups of two hundred (200). Each group of five was fed into the hopper for test running and cracked at different shaft speeds in revolution per minute (rpm). The shaft speeds were determined with a tachometer and it was varied on the engine by adjusting the throttle lever. In a group of five, it was replicated for four different times at the same speed. The cracking efficiency and throughput capacity were calculated, using different speeds of 800, 1200, 1800, 2200 and 2400 rpm. The cost estimate of this machine was carried out from design to production stage it was N150,000.

### Performance Evaluation

#### Throughput capacity (kg/h)

This is the quantity of the nuts fed into the hopper divided by the time taken for the cracked mixture to completely leave the collecting chute. It is given by:

$$\text{Throughput} = \frac{Tw}{T}$$

where:  $Tw$  = total weight of the palm nuts fed into the hopper (kg)

$T$  = total time taken by the cracked mixture to leave the chute (h)

#### Performance Efficiency ( $\epsilon_p$ )

The performance efficiency  $\epsilon_p$  is given by:

$$\epsilon_p (\%) = \frac{\text{Total weight of un - broken}}{\text{Total weight of expected kernel}}$$

$$\epsilon_p (\%) = \frac{W_{UN}}{W_{UB} + W_{BN} + W_{PK} + W_{UC}} \times 100$$

#### Percentage of Broken Nuts (PD)

The percentage of broken nuts, PD is given by:

$$PD (\%) = \frac{\text{Weight of Broken Nuts}}{\text{Total weight of expected kernel}}$$

$$PB (\%) = \frac{W_{BN}}{W_{UB} + W_{BN} + W_{PK} + W_{UC}} \times 100$$

#### Cracking Efficiency ( $\epsilon_c$ )

Cracking efficiency (%): This is the ratio of completely cracked nuts to the total weight of nuts fed into the hopper. It is calculated as:

$$\epsilon_c (\%) = \frac{\text{Weight of cracked nuts}}{\text{Total weight of the nut feed in}}$$

$$\epsilon_c (\%) = \frac{W_{TN} - W_{UB}}{W_{TN}} \times 100$$

#### Overall Efficiency, ( $\epsilon_o$ )

Overall Efficiency ( $\epsilon_o$ ) is the product of the performance efficiency and that of cracking efficiency:

$$\epsilon_o (\%) = \epsilon_p \times \epsilon_c$$

where:  $W_{UB}$  = weight of un-broken kernel from the chute

$W_{BN}$  = weight of broken nuts from the chute

$W_{PK}$  = weight of partially cracked kernels

$W_{TN}$  = Total weight of the nut feed into the hopper  $W_{UC}$  = weight of the un-cracked nuts

## RESULTS AND DISCUSSION

### Evaluation Performance of the Machine

Table 1 shows the performance tests on the

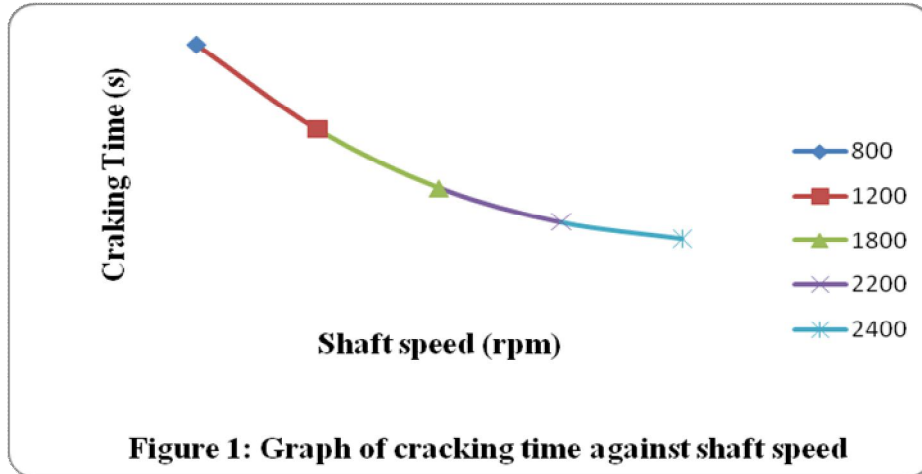
fabricated machine and it was noticed that at the highest speed of 2400 rev/min had the least number of un-cracked nuts and number of partially cracked nuts of 1.0% and 1.5% respectively.

As shown in Figure 1, the least speed of 800 rev/min required an average of thirty-five seconds while highest speed of 2400 rev/

min of the machine required the least average time (ten seconds) to crack 200 palm kernel nuts. The speed of 800 rev/min had the highest number of broken kernels because the cracking time decreased as the shaft speed increased translating to the kernel nuts lesser time of contact with cracking unit or increased angular velocity in equation 3.

**Table 1: Performance Tests on the developed Palm kernel nuts cracking machine**

Number of palm kernel nuts (4Reps)	Shaft speed (rev/min)	Cracking time taken (s)	Number of un-cracked nuts (%)	Number of partially cracked nuts (%)	Number of un-broken kernels. (%)	Number of broken kernels. (%)
200	800	33	2.5	2.5	93.0	2.0
200	1200	23	2.0	2.5	94.0	1.5
200	1800	16	1.5	2.0	95.0	1.5
200	2200	12	1.5	1.5	94.5	2.5
200	2400	10	1.0	1.5	94.0	3.5



**Figure 1: Graph of cracking time against shaft speed**

**Throughput of the Machine**

Table 2 shows the relationship between the shaft speeds and the throughput, there exists a linear relationship between the speed of the shaft and the throughput of the machine. The significance of this is that

as the machine shaft speed (800rpm) increases to (2400rpm) the machine throughput also increases as shown in Table 2 at slightly increase in broken kernel increase from 2.0% to 3.5% respectively as shown in Table 1.

**Table 2: Relationship between the shaft speed and the throughput**

Shaft Speed (rpm)	Throughput (g/s)
800	10.91
1200	16.52
1800	23.13
2200	30.00
2400	38.00

**The Efficiency Performances of the Machine**

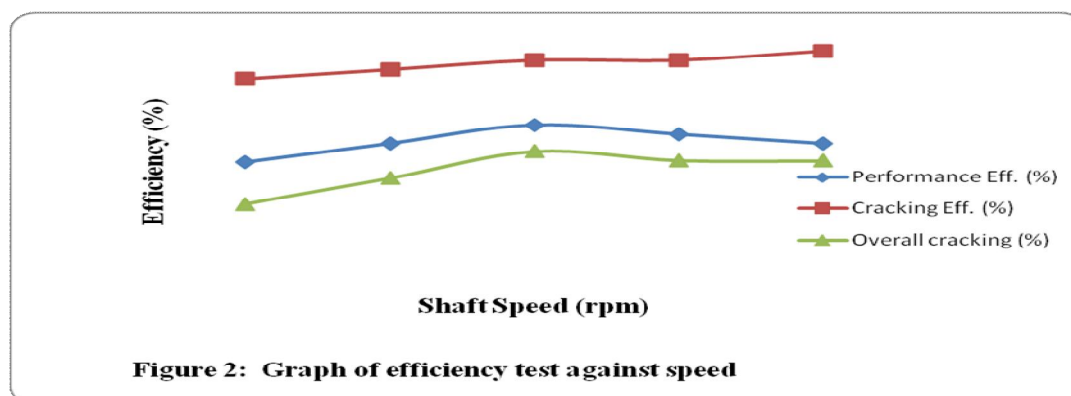
Table 3 shows the shaft speed with machine efficiencies, the highest cracking efficiency of 99.00% was noticed at a speed of 2400 rev/min while the least cracking efficiency of 97.00% was observed at lowest speed of 800 rev/min.

Figure 2 shows that efficiencies increased as the speed increased while performance and overall efficiencies increased as the speed increased from 800 to 1800 rev/min but declined while it increased in speed from

1800 to 2400 rev/min. Tables 1 and 3 shows that machine critical speed at best performance occurred at 1800rpm where centrifugal force in equation 3 was in support until it began to fall at higher speed. In the graph of efficiency against the shaft speed, it was noticed that both performance efficiency and overall efficiency increased from the shaft speed of 800 to 1800 rpm and declined as from speed of 2200 rpm while cracking efficiency increased at the same shaft speed. Generally, cracking performance and overall efficiencies increased at the highest level of the shaft speed

**Table 3: Shaft speed with efficiencies of the designed cracking machine**

Shaft Speed (rpm)	Performance Efficiency	Cracking Efficiency	Overall Efficiency
800	93.00	97.50	90.68
1200	94.00	98.00	92.12
1800	95.00	98.50	93.58
2200	94.50	98.50	93.08
2400	94.00	99.00	93.06



## CONCLUSIONS

The results of the work implied that the cracker efficiency and the kernel broken ratio are some of the most important parameters for determining the optimal performance of the cracker. The research also showed that increase in the speed of the shaft which reduced the time of cracking operation led to an increase in damage of the kernels. The research work showed that the cracking efficiencies at speeds of 1200, 1800, 2200 and 2400 rpm were  $98 \pm 0.3$ ,  $98.5 \pm 0.08$ ,  $98.5 \pm 0.01$  and  $99 \pm 0.04\%$  respectively. The throughput of the machine increased from 10.91 to 38.00 g/s as the speed of the machine increased from 800 to 2400 rpm. Also the performance efficiencies at speeds 800, 1200, 1800, 2200 and 2400rpm of the developed machine were 93, 94, 95, 94.5 and 94% while the overall efficiencies were 90.86, 92.12, 93.58, 93.08 and 93.06% respectively. It was concluded that the overall performance of this developed palm nut kernel cracking machine were effective because it fell within the range of between 90 to 98% overall efficiency. The machine cost N150,000 compared with those of similar capacity costing between N250,000 to N300,000 with lesser performance efficiencies in the rural areas. It can then be concluded that the performance of this developed palm nut kernel cracking machine was effective as well as of better efficiency.

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