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PERFORMANCE EVALUATION OF A PALM KERNEL CRACKER WITH INTEGRATED SEPARATING UNIT

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ABSTRACT

Nigeria as a country has not met the demand for palm kernel oil production because of the constraint involved in the processing operation especially, cracking and separation of shell from the nut. In this study, a palm kernel cracker (PKC) with a separating unit was developed. The separating unit consisted of three chambers where separation takes place: the first chamber removes the particles attached to the kernel and the shell, the second and central chamber removes the broken kernel and shell while the final chamber separates the cracked and uncracked kernel in a discharge chute by means of an attached blower. The developed PKC was tested using *tenera* and *dura* varieties of palm kernel. Performance indices for evaluation were cracking efficiency, throughput capacity and percentage losses using three moisture contents (A: 7.0 - 9.0; B: 10.0 - 12.0 and C: 14.0 - 16.0% d.b.) and four speeds of operation (1600, 2200, 2400 and 2600 rpm). The results showed that the highest cracking efficiency and output capacity for *tenera* were 87.3% and 51 kg/h respectively at 10 - 12% (d.b.) moisture content and speed of 2200 rpm while the highest cracking efficiency and output capacity for *dura* were 78.8% and 45 kg/h respectively at 10-12% (d.b.) moisture content and speed of 2200 rpm. The highest percentage loss (18%) obtained for *tenera* was at (14 - 16% d.b.) moisture content with an operating speed of 2400 rpm, while *dura* variety was 21% at same moisture content and operating speed. It could be concluded that the optimal performances of the PKC was at moisture content level 10 - 12% (d.b.) and operating speed of 2200 rpm for the two varieties of palm kernel tested.

Keywords: Cracking Efficiency, Percentage Loss, Throughput Capacity, Moisture, Operating Speed, Varieties

1.0 INTRODUCTION

Oil Palm (Elaeis guineensis Jacq) is an indigenous plant to West Africa (*Poku and Kwasi, 2002)*. It is the highest oil yielding crop per hectare in the plant kingdom (Kurki *et al.*, 2008). The palm tree bears its fruit in bunches which vary in weight from 10 to 40 kg. The individual fruit which varies from 60 to 70g, is made up of an outer skin (epicarp), a pulp (mesocarp) containing oil in fibrous metric, a center nut consisting of a shell (endocarp) and the kernel which itself contain oil different from palm oil, resembling coconut oil (FAO, 2004). Palm kernel oil, a major viable oil in Nigeria is obtained from the kernel of a palm tree after cracking palm nut; the kernel is not useful until the shell is separated from the kernel (Oke, 2007). The usual way of cracking the nuts is a labour-intensive and time-consuming process (Stork, 2007). The traditional palm kernel oil extraction starts with the shelling of the palm nuts. The shelling used to be performed using two stones to crack each nut and separating the kernel and shell simultaneously (Gbasouzor *et al.,* 2012). The kernel/shell separation is usually performed in a clay-bath, which is a concentrated viscous mixture of clay and water (plate 1). The density of the clay-bath is such that the shells sink while the lighter kernels float to the top of the mixture. The floating kernels are scooped in baskets, washed with clean water and dried. Periodically, the shells are scooped out of the bath and discarded. This method is applicable to the local farmers that have few oil palm bunches to process; it cannot be fully commercialized (Okoronkwo et al., 2013). This manual operation has been largely superseded by the use of nut-cracking machines. The mechanical nut-crackers deliver a mixture of kernels and shells that must be separated (FAO, 2004).

Plate. 1: Traditional method of separating kernel from shell using clay bath method (Local Oil Palm Processing Mill at Ovia North East, Edo State, 2013)

2.0 MATERIALS AND METHODS

2.1 Operational Principle of the Machine

The machine (Fig. 1) was used to perform two major operations; cracking the nuts as well as separating the kernel from the shell.

2.1.1 The Cracking Unit

The cracking unit is made up of the hopper which serves as receptacle, impeller shaft, cracking drum and impeller blade or beater. The nuts were introduced into the hopper through gravitational means to the cracking chamber where the cracking operation took place; this was achieved through the aid of impeller blades that flap the palm nuts against the wall of cracking drum. The impeller blade also facilitates the discharge of the cracked nuts into the preliminary separating unit.

2.1.2 The separating unit

The gear reduction box reduces the speed from the power source from ratio one to twenty (1:20), this allows the preliminary separator to turn at desired speeds of 2,600, 2,400, 2,200 and 1,600 rpm. The separating unit consists of two sections; preliminary separating unit comprising three chambers where the separation takes place and the final separating unit

2.1.2.1 Preliminary separating unit

This unit consists of three sub-sections for separation of impurities of the mixture (the kernel and shell). The first section separates with the aid of a cylindrical basket whose wire mesh has orifices less than the geometric means diameter of kernel and shell. The second section is made of mild steel with orifices that are less than the geometric means diameter of nuts. The third section has the orifices that were to separate the fully cracked nuts from the un-cracked. The separator angle is less than the angle of repose of the shell but far greater than that of the kernel. It comprises of mild steel rods of about ¼ inch woven round with galvanized wire mesh of diameters that would not allow the ejection of the kernel.

2.1.2.2 Final separating unit

The unit consists of a centrifugal blower that separates the kernel from the shell at the discharge chute of the machine.

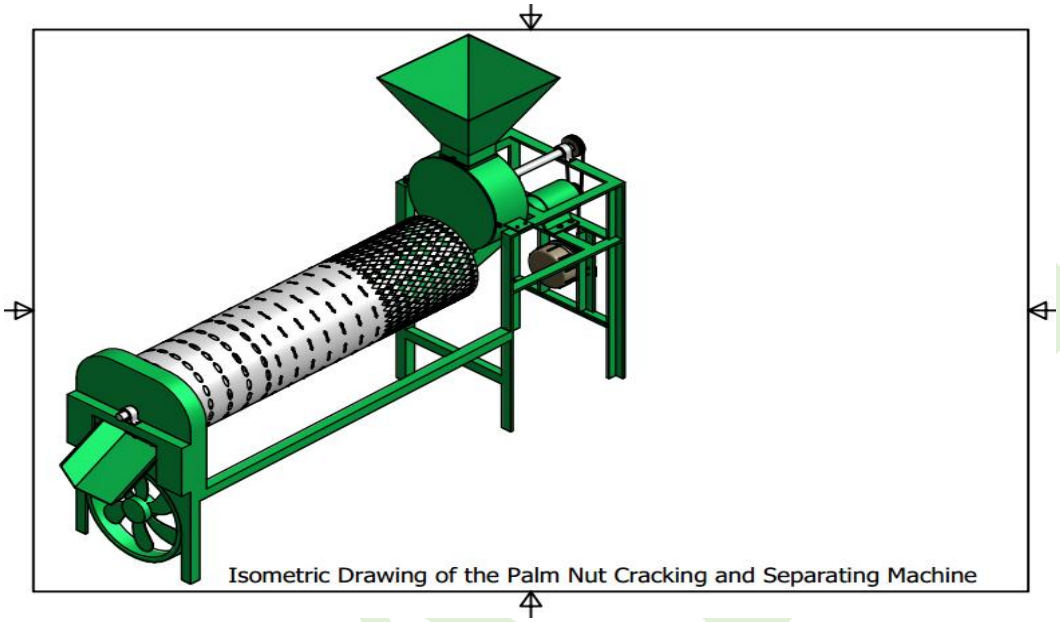

Fig. 1: Isometric Diagram of the Palm Kernel Cracker with Separator

2.2 Evaluation of the Machine Performance

The machine was tested at the College of Engineering Central Workshop, Federal University of Agriculture, Abeokuta at No load and loading using the selected factor levels.

2.2.1 No Load Test

The performance of the machine was tested for about five minutes to ensure smooth running of the component parts, the operational shaft speed was set at 2600 rpm using appropriate pulley, this enabled the general observations to be taken before subjecting the machine to load test.

2.2.2 Load Test

Tenera and *Dura* kernel samples were used for the study. The samples were introduced into the hopper which serves as a receptacle to the cracking drum, As the samples of palm kernel gradually fell into the cracking drum and the stopper removed, the beater of the impeller hit the kernels to the wall of the drum through the rotating effect of the shaft speed thereby causing the cracking of the kernels. The cracked kernels passed through the discharge chute, and were received by the separating chamber, Here, the first filtering of the particles/dirt was done (first chamber), the second chamber caused the shell to be separated from the kernel while the last chamber at the rear of the basket separated the cracked kernel from the un-cracked and the partially cracked ones. The un-cracked kernel and other materials that could not be separated by any of the chambers in the rolling basket were finally separated through the aid of a blower attached to the discharge chute of the basket.

The performance evaluation of the developed palm nut cracker was carried out at different moisture contents levels as well as various motor speeds and the results are presented in Table 1. The cracking efficiency, capacity of the machine, cracking and separating efficiencies and percentage loss were calculated from equations 1 to 4. Table 1 also shows the levels of factors used in the performance evaluation. Cracking Efficiency (%): This determines how efficient the machine performs, when operated according to Oguoma *et al.*, (1993)

$$\text{Cracking efficiency} = \frac{mass\ of\ cracked\ kernel}{total\ mass\ of\ kernel} \times 100 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Capacity of the Machine: The capacity of the machine was calculated using the formulae:

$$\text{Output Capacity} = \frac{mass\ of\ output\ (kg)}{Duration\ of\ operation\ (h)} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Cracking and separating efficiencies

$$= \frac{completely\ cracked\ and\ separated\ Average}{Total\ Feed} \times 100 \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Percentage Loss

$$= \frac{Average\ mechanical\ damage}{Total\ \ palm\ kernel\ introduced\ into\ the\ machine} \times 100 \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Table 1: Levels of Factors Used in Performance Evaluation

Varieties of nut	Moisture Content Level (%d.b.)	Speed (rpm)
Dura and *Tenera*	7 – 9 10 – 12 13 – 16	1600 2200 2400 2600

2.3 Statistical Analysis

Data obtained for the various levels of factors was analyzed using Analysis of Variance (ANOVA) and differences between means for mean separation of factors were made at 5% significant.

3.0 RESULTS AND DISCUSSION

3.1 Results of Performance Evaluation of the Machine

The results of separating the efficiency of the machine are presented in Tables 2 and 3. The highest values of separating efficiency ranged from 56.3 to 62.7% for palm kernel samples at 10.0 – 12.0% d.b. moisture content. The lowest values of separating efficiency ranged from 23 to 35% for palm kernel samples at 10.0 – 12.0% d.b. moisture content. A speed of 2200 rpm produced the highest separating efficiency of 62.7%.

Table 2: Summary of Machine Performance at Various Speed Levels for *Tenera*

Variables	Moisture Content %(db)	Prime mower Speed (rpm)	Cracking efficiency (%)	Mechanical damage %	Output Capacity kg/min	Percentages Losses %
I	7.0 -9.0	1,600	70.10±0.05^{c}	15.00±0,50^{b}	37.00±0.88^{bc}	11.±0.88^{b}
		2,200	72.20±0.01^{a}	17.00±0.77^{b}	37.00±0.57^{c}	10.00±0.47^{c}
		2,400	71.10±0.07^{b}	25.33±0.88^{a}	39.00±0.33^{ab}	14.33±0.67^{a}
		2,600	69.4± 0.58^{c}	24.00±0.57^{a}	40.00±0.57^{a}	13.00±0.77^{ab}
II	10.0 -12.0	1,600	82.30±0.663^{c}	14.00±0.577^{a}	45.00±0.57^{c}	7.00±0.57^{b}
		2,200	87.33±0.000^{a}	13.00±0.577^{a}	51.00±0.47^{a}	4.00±1.15^{ab}
		2,400	85.10±0.333^{b}	16.00±1.15^{a}	48.33±0.33^{b}	3.00±0.57^{b}
		2,600	82. 20±0.000^{c}	14.00±1.15^{a}	47.00±0.88^{b}	5.00±1.15^{ab}
II	14.0 -16.0	1,600	58.7.00±0.00^{a}	39.00±0.57^{b}	32.00±0.57^{ab}	13.00±0.57^{b}
		2,200	50.40±0.333^{b}	40.30±0.33^{ab}	31..00±0.33^{c}	16.00±0.02^{a}
		2,400	45.00±0.000^{c}	42.00±0.33^{a}	33.00±0.00^{b}	18.00±0.51^{a}
		2,600	41.20±0.333^{d}	40.00±1.15^{ab}	30.00±1.15^{b}	17.33±0.88^{a}

***** Values with different alphabets are significantly different @ $P < 0.05$

Table 3: Summary of machine performance at various speed levels for *Dura*

Variables	Moisture Content %(db)	Prime mower Speed (rpm)	Cracking efficiency (%)	Mechanical damage %	Output Capacity kg/min	Percentages Losses %
I	7.0 -9.0	1,600	61.33±.33^{b}	30.00±0.67^{b}	34.00±0.7^{b}	11.00±0.01^{b}
		2,200	66.00±0.03^{a}	30.00±0.58^{b}	39.33±0.34^{a}	15.30±1.46^{a}
		2,400	60.00±1.73^{b}	34.00±1.50^{a}	37.00±1.54^{a}	16.00±1.73^{a}
		2,600	62.00±1.71^{ab}	35.00±0.77^{a}	38.00±1.16^{a}	14.00±1.07^{ab}
II	10.0 - 12.0	1,600	72.00±1.15^{c}	18.00±1.15^{a}	40.00±0.14^{b}	9.00±1.170^{a}
		2,200	74.20±1.17^{bc}	16.00±1.14^{a}	43.000±1.15^{ab}	8.00±.15a
		2,400	78.8.00±0.01^{a}	15.00±1.45^{a}	45.00±1.17^{a}	10.00±1.05^{a}
		2,600	76.10±0.06^{b}	17.00±1.14^{a}	44.000±1.70^{a}	12.00±1.44^{a}
III	14.0 - 16.0	1,600	50.30±0.33^{ab}	20.00±1.15^{c}	34.00±1.15^{a}	18.00±0.22^{a}
		2,200	52.6±0.88^{a}	22.00±1.14^{bc}	32.00±1.18^{a}	20.00±0.12^{a}
		2,400	50.20±0.44^{b}	24.00±1.5^{ab}	32.00±2.31^{a}	21.0±2.03^{a}
		2,600	51.10±0.05^{ab}	26.00±1.17^{a}	30.00±1.11^{a}	20.00±1.7^{a}

* Values with different alphabets are significantly different @ $P < 0$.

3.2. Performance of Machine On Various Speed Levels of *Tenera*

Results (Table 2) revealed significant differences (p<0.05) in the cracking efficiency, mechanical damage, output capacity and percentage losses of machine at 1,600, 2,200, 2,400 and 2,600 rpm with respect to moisture content (7.0-9.0% d.b.) of palm kennel. However, at 10.0 - 12.0 % mechanical damage, similar significant different (p<0.0%) was recorded in the investigated parameters at moisture content ranges of 10.0-12.0% and 14.0-16.0 % d.b. The study also revealed that the cracking efficiency and percentage losses of the machine increased with increase in prime mower speed of the machine from 1,600 to 2,200 rpm at moisture content range of 7.0-9.0% d.b. while mechanical damage showed no significant difference (P>0.05). Similar significant incense was recorded in the parameters with increase in the speed of the machine from 1,600 to 2,200 rpm. Also, mechanical damage increased with increase in the speed from 1,600 through 2,200 to 2,400 rpm and at moisture content range of 14.0-16.0% d.b. Cracking efficiency of the machine showed significant (p<0.0%) decrease at 14.0-16.0% with increase in the speed of the prime mower. The highest cracking efficiency (67.33 %) and output capacity (51.kg/min) were recorded at moisture content range 10.0-12.0% d.b. at 2,200 rpm while the least cracking efficiency (41.20%) and output capacity (30.00kg/min) were recorded at 14.0-16.0 % d.b. moisture content and 2,600 rpm speed. The highest mechanical damage (42.00%) and percentage losses (18.00%) were recorded at moisture content range of 14.0-16.00% d.b. and prime mower speed of 2,600 rpm while the least mechanical damage (13.00%) and percentage losses (3.00% were recorded at 2,200 and 2,400 rpm speed and at 10.0-12.0 % d.b. moisture content.

3.3. Performance of Machine On Various Speed Levels of *Dura*

The result (Table 3) showed that the cracking efficiency of the machine increased significantly (P<0.0) with increase in the speed from 1,600 to 2,200 rpm. The output capacity and percentage losses increased with increase in speed of the machine at moisture content of 7.0-9.0% d.b. At 10.0-12.0% d.b., similar observations were recorded for the output capacity and percentage losses, except for the mechanical damage of the machine which revealed a non-significant difference (p>0.05) in the speed of the machine at the same moisture content of the palm kernel sample. Also, at 14.0-16.0% d.b. moisture content, the mechanical damage and percentage losses showed significant increase (p<0.05) with increase in the speed of the machine while the output capacity showed a non-significant difference (0<0.0%) with increase in speed of the prime mover. The highest cracking efficiency (78.8%) and output capacity (45.0kg/min) were recorded at 2,400 rpm while the least cracking efficiency (50.20%) and output capacity (30.00kg/min) were recorded at 2,400 and 2,600 rpm respectively, and at 14.0-16.0% d.b. moisture content. Also, the highest mechanical damage (35.0%) was recorded at 2,600 rpm and at 7.0-9.0% d.b. moisture content, the highest percentage losses (21.0%) was recorded at 2,400 rpm and at 14.0-16.0% d.b. moisture content while the least percentage losses (15.0%) was recorded at 2,400 rpm and at 10.0-12.0% d.b. moisture content.

4.0 CONCLUSIONS

The machine had high cracking efficiency when the moisture content of the palm kernel ranged between 10.00 – 12.00% d.b. at 2200 rpm shaft speed. The machine average cracking and separating efficiency was found to be 87.3% and 78.8% at 2200 and 2400 rpm for *Tenera* and *Dura* kernel, respectively. *Tenera* kernel has better cracking efficiency; also, its percentage loss was minimal compared to the *dura* kernel. Speed was observed to be an important factor in this study, it was discovered that the lower the speed, the slower it took for cracking and separation to take place, while the higher the speed, the more the nuts that were cracked and separated but with more damage recorded.

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