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Effect of Varied Pulleys on A Centrifugal Palm Kernel Cracker

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***Abstract:** This paper is based on the performance evaluation of centrifugal palm kernel crackers for small, medium and large-scale firms that deal with the cracking of palm kernel nuts to meet market requirements. The cracking machine consists of a hopper, a cracking chamber that incorporates a shaft and flange, an outlet, an electric motor, a belt, and pulleys. The performance of the machine was evaluated based on the cracking time and shaft speed. The machine was modified by introducing four pulleys with diameters of 200 mm, 250 mm, 300 mm, and 350 mm, which produced rotor speeds of 936 rpm, 749 rpm, 624 rpm, and 535 rpm, respectively. The rotor speeds were then used to test the designed machine, and its efficiency was evaluated. The machine features a cracking chamber that flaps the palm kernel nuts against a stationary hard surface. A 15hp electric motor operated the designed machine. The results showed that the cracking efficiency was highest at 936 rpm, with an efficiency of 53% achieved in 38 seconds.*

***Keywords:** Cracking Chamber, Cracking Time, Shaft Speed, Cracking Efficiency, Rotor Speed.*

I. INTRODUCTION

Centrifugal Palm kernel cracker refers to the method in which palm kernel nuts are cracked using centrifugal force to fling the palm kernel nuts on a stationary hard surface. According to [1] palm kernel and the shell was stated as the significant wealth creating farm product in Nigeria which the kernels and shells have application in numerous industries such as; soap making, cosmetics, livestock feeds (agriculture), medicine, foundry, civil works, even as a means of energy etc. Local farmers in nearly every part of southern Nigeria face the challenge of cracking and separating the shell from the kernels of their palm kernel nuts with ease and efficiency, while minimising the energy and time required at a relatively low cost. The economic importance of palm kernel is indicated by its wide use as food, traditional medicines and in industries [2].

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Palm kernels are cracked in the local mills for the extraction of palm kernel oil and kernel cake, the kernel oil is used for the production of glycerin, margarine, edible oil, confectionery, candle, soap, oil paint and medicines and the kernel cake is used as an ingredient for livestock feeds in the livestock industries [3].

In recent times, cracking is achieved by placing the nut on top of the stone and striking it with another stone, applying an impact force that causes the shell to split. However, the industries and local farmers need a palm kernel machine to aid their production to meet the market requirement (Patrick, *et al.,* 2004) [10]. Due to technological advancements, palm kernel machines were developed to crack palm kernels and remove their shells. It was discovered that the palm kernels used are intended for rural areas and local farmers, rather than the industrial sector. One of the devices that can produce this requirement of the industrial sectors is called a centrifugal palm kernel cracker [4].

Centrifugal palm kernel cracker comprises some fundamental components, such as the hopper through which the palm kernel nut is fed into the machine, the chamber which consists of the flange which flaps the palm kernel nut on the hard surface with the use of impact force, and the shaft that rotates. The pulley is driven by the electric motor, which then makes the shaft rotate [5]. Oluwole *et al. (2016) investigated the dynamics of a* vertical-axis centrifugal nut cracker. The cracker consists of a feed hopper with a flow rate control device, a cracking unit, a separating unit, and a power system that includes a single-phase three-hp, 1500-rpm electric motor with a belt and pulley system. The cracking unit consists of an impeller with four vanes mounted on a vertical shaft and an impeller casing that serves as the cracking surface. The working principle of the cracker is similar to that of a centrifugal pump. The nuts to be cracked are rotated and pushed by the vanes of the impeller in the direction of the vanes' motion, thereby imparting mechanical energy to the nuts. [6]

When leaving the impeller, the nuts gain kinetic energy (velocity), and the velocity components are studied graphically using velocity vectors. The results of the analysis showed that the radial velocity is 0.66 m/s, the tangential velocity is 15.71 m/s, and the resultant velocity is 15.72 m/s. In comparison, the cracking velocity is 10.41 m/s, which gave an impact (cracking) energy of 0.55 J. The cracker was evaluated using sheanut at four moisture levels (6, 13, 22.7, and 27.9% db) and nut feed rates of 11.4, 15.5, 23.1, and 45.2 kg/h. Furthermore, the study demonstrated that at a nut moisture content of 22.7% (db) and a feed rate of 11.4 kg/h, a 100% cracking efficiency was achieved. [7].

Ndukwu *et al.* (2017) evaluated the functional performance of a vertical-shaft centrifugal palm nut cracker.
In the research, the cracker efficiency and kernel breakage ratio are two key parameters used to evaluate cracker performance. The results indicated that for the lowest speed of 1,650 r/min and the highest feed rate of 880 kg/h, and all moisture contents, the cracking efficiency was not above 65%. Therefore, the obtained result showed that the efficiency increases with an increase in machine speed and a decrease in feed rate. Furthermore, the kernel breakage ratio ranged from 0 to 0.18 (0–18%) for all feed rates and moisture contents.
Oke (2007) worked on the development and performance evaluation of an indigenous palm kernel dual processing machine. In the work, the machine was tested to ascertain its performance. The research results showed an efficiency of 98% with a processing rate of 95 nuts per second, achieved using a single four-hp electric motor. This improvement is over the existing ordinary palm kernel cracking machine, which has an efficiency of 90% with a processing rate of 89 nuts per second, but without separation. [8]
Udo *et al. (2012) researched the* performance evaluation of a palm kernel nut cracking machine. This research work aimed to assess the performance of the developed mobile palm kernel nut cracking machine. So, a total sample of four thousand (4,000) palm kernel nuts was 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. The research work showed that the cracking efficiencies at speeds of 1200, 1800, 2200, and 2400 rpm were 98.0±0.3%, 98.5±0.08%, 98.5±0.01%, and 99.0±0.04%, respectively. Additionally, the performance efficiencies of the developed machine were 93%, 94%, 95%, 94.5%, and 94%. The overall efficiencies were 90.86%, 92.12%, 93.58%, 93.08%, and 93.06% for the set speeds. It can therefore be concluded that the overall performance of the developed palm nut kernel cracking machine was effective, as it achieved an overall efficiency range of 90 to 98%. [9]

II. METHODS

Palm nuts are fed into the feed hopper with the discharge control plate closed. The machine is then powered through a Vee-belt drive arrangement between an electric motor and a pulley keyed to the cracking disc shaft. The machine is allowed to attain a steady speed for about five (5) minutes before the feed control plate is opened to allow nuts to fall into the cracking chamber. As the palm nuts enter the chamber, they are then rotated. The impact force between the palm nut and the chamber casing causes it to crack, thus releasing the kernels and shell nuts, which are then discharged through the outlet provided at the machine into an optional collection sack. Four pulleys with diameters of 200 mm, 250 mm, 300 mm, and 350 mm were used, respectively. The pulleys were then used to test the machine's efficiency, and the results were evaluated. The curve casing, which directs the palm kernels to the cracking chamber, was introduced to prevent splashing or flying back of palm kernels during the cracking process.

III. TEST RESULTS

Table 1: Result for 30kg Palm Kernel Cracked with a pulley of 200mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	29.6kg
Time taken to crack the palm kernel	38sec
Weight of the palm kernel cracked	15.9kg
Un-cracked palm kernel	1.3kg
Weight of the kernel shell	12.4kg

Table 2: Result for 30kg Palm Kernel Cracked with a pulley of 250mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	29.3kg
Time taken to crack the palm kernel	1min
Weight of the palm kernel cracked	14.3kg
Un-cracked palm kernel	2.1kg
Weight of the kernel shell	12.9kg

Table 3: Result for 30kg Palm Kernel Cracked with a pulley of 300mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	29.3kg
Time taken to crack the palm kernel	1min 37sec
Weight of the palm kernel cracked	13.8kg
Un-cracked palm kernel	2.9kg
Weight of the kernel shell	12.3kg

Table 4: Result for 30kg Palm Kernel Cracked with a pulley of 350mm

Initial weight of palm kernel	30kg
Weight of palm kernel after cracking	28.7kg
Time taken to crack the palm kernel	2mins 29sec
Weight of the palm kernel cracked	12.6kg
Un-cracked palm kernel	4.2kg
Weight of the kernel shell	11.9kg

Table 5: Shows the Result for the Time taken to Crack the Palm Kernel at Different Speeds of (936r.p.m, 749r.p.m, 624r.p.m and 535r.p.m)

Speed (rev/min)	Time taken to Crack the Palm Kernel
936r.p.m	38sec
749r.p.m	1min
624r.p.m	1min 37sec
535r.p.m	2mins 29sec

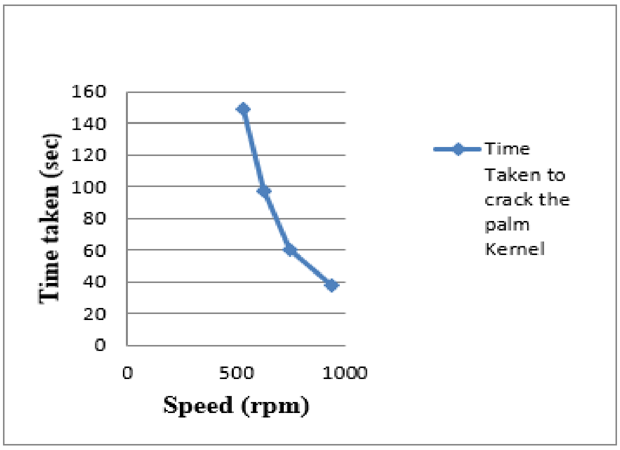

Figure 1: Time taken to crack the palm Kernel

From Figure 1 above, it was deduced that as the speed reduces, the time taken to crack the palm kernel increases.

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Table 6: Shows the Result for the Weight of Cracked Palm Kernel at Different Speeds of (936r.p.m, 749r.p.m, 624r.p.m and 535r.p.m).

Speed (rev/min)	Weight of Cracked Palm Kernel
936r.p.m	15.9kg
749r.p.m	14.3kg
624r.p.m	13.8kg
535r.p.m	12.6kg

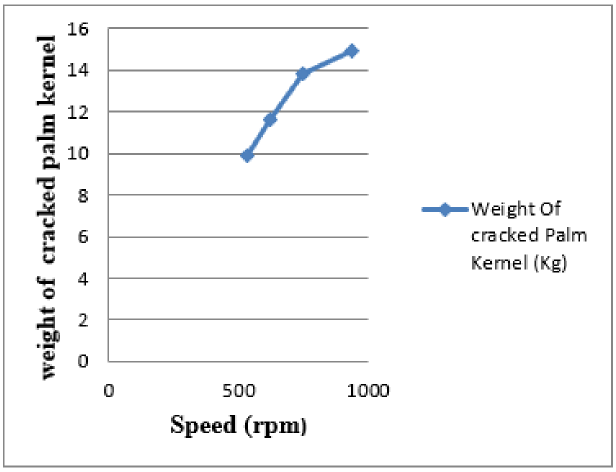

Figure 2: Weight of Cracked Palm Kernel

Figure 2 above shows the result of the weight of cracked palm kernel at different speeds. It was observed that the weight of the cracked palm kernel reduces as the speed also reduces, which implies that the higher the diameter of the pulley, the lower the speed and the higher the torque.

Table 7: Shows the Result for the weight of Un-Cracked Palm Kernel at Different Speeds of (936r.p.m, 749r.p.m, 624r.p.m, and 535r.p.m)

Speed (rev/min)	Un-cracked palm kernel (kg)
936r.p.m	1.3kg
749r.p.m	2.1kg
624r.p.m	2.9kg
535r.p.m	4.2kg

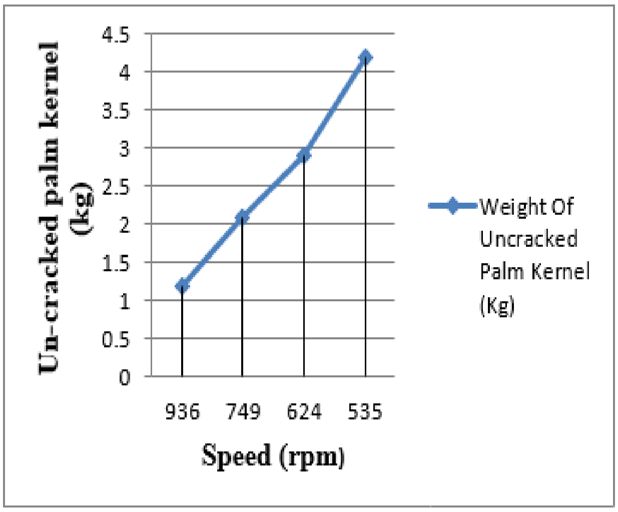

Fig 3: Weight of Un-Cracked Palm Kernel (Kg)

Figure 3 above shows the result of the weight of the uncracked palm kernel. It was observed that the weight of the un-cracked palm kernel increases as the speed reduces.

Table 8: Shows the Comparative Analysis of the Result for the performance evaluation.

Speed(rpm)	Weight of cracked palm kernel(kg)	Weight of uncracked palm kernel(kg)	Weight of Kernel shell (kg)	Time taken (sec)	Weight after cracking
936	15.9	1.3	12.4	38	29.6
749	14.3	2.1	12.9	60	29.3
624	13.8	2.9	12.3	97	29.0
535	12.6	4.2	11.9	149	28.7

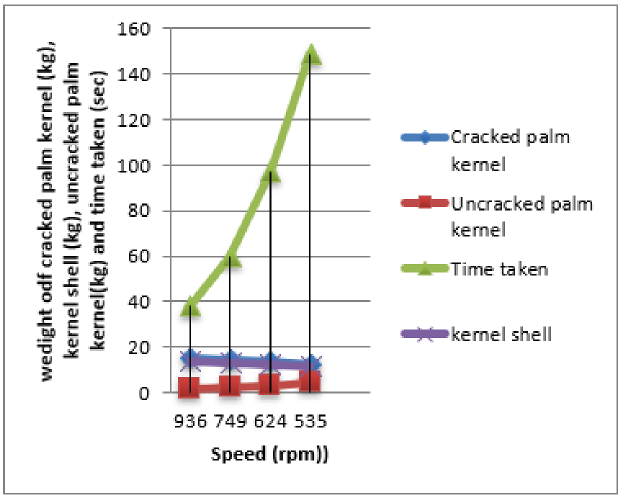

Figure 4: Comparative analysis of the result

Figure 4 above is a graphical representation of the comparison between the volumes of cracked and uncracked palm kernels, along with the time taken to crack at different speeds. The graphical representation implies that as the speed reduces, the un-cracked palm kernel increases, the palm kernel shell decreases, and the weight of the palm kernel after cracking decreases, while the time taken increases.

A. Result:

(i) Cracking rate: $\frac{Total\ palm\ kernel\ fed\ into\ the\ machine\ (kg)}{Total\ time\ of\ cracking\ (sec)}$

$$= \frac{30+30+30+30\ \ (kg)}{129+97+68+56\ (s)}$$

$$= \frac{120\ kg}{350\ s}$$

$$= 0.34\ kg/s$$

(ii) Efficiency: $\frac{Work\ Input}{Work\ Input}$ x 100

Work Input

- At Speed of 936r.p.m
  Work Output = 15.9kg
  Work Input = 30kg
  Therefore; $\frac{=15.9\ kg}{30kg}$x 100
  = 53.0%
- At Speed of 749 r.p.m
  Work Output = 14.3kg
  Work Input = 30kg

Therefore; $\frac{= 14.3kg}{30kg}$ x 100

= 47.6%

- At Speed of 624 r.p.m
  Work Output = 13.8kg
  Work Input = 30kg
  Therefore; $\frac{= 13.8kg}{30kg}$ x 100

  = 46.0%
- At Speed of 535 r.p.m
  Work Output = 12.6kg
  Work Input = 30kg
  Therefore; $\frac{= 12.6\ kg}{30kg}$ x 100

  = 42.0%

Table 9: Shows the result of the efficiency of the machine at different speeds (936rpm, 749rpm, 624rpm, and 535rpm, respectively)

Speed (rpm)	Efficiency (%)
936	53.0
749	47.6
624	46.0
535	42.0

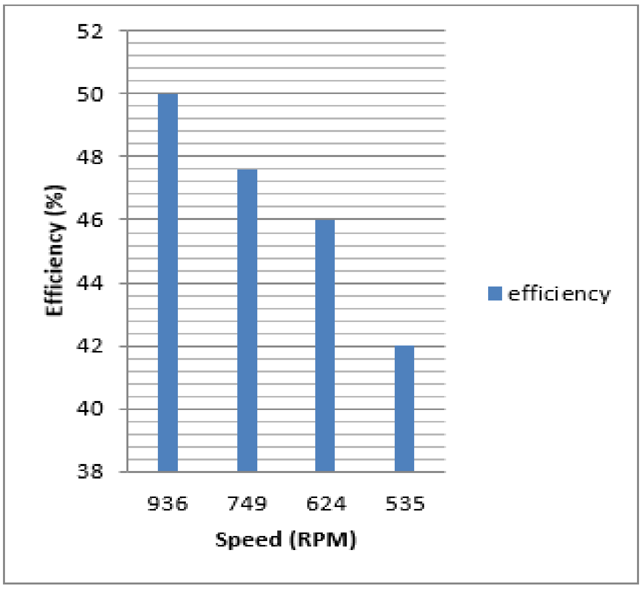

Fig. 5 illustrates the machine's efficiency at various speeds.

Table 10: Sample Size of Palm Kernel

S/N	1	2	3	4	5	6	7	8	9	10	TOTAL
DIAMETER (MM)	19	21	15	22	12	25	19	12	11	15	171

Mean diameter of palm kernel nut = $\frac{Total\ diameter}{No\ of\ palm\ kernel}$

$= \frac{171}{10} \quad = \quad 17.1\text{mm}$

IV. CONCLUSION

Based on the above study, it was concluded that performance evaluation was conducted on a palm kernel cracker to assess the effectiveness of the machine. From the test carried out on the machine, it was deduced that as the speed reduces, the uncracked fraction increases, while the palm kernel shell fraction decreases, and the time taken increases. That means the cracking efficiency has the highest output at 936 rpm, with an efficiency of 50.0%, and a time taken of 38 seconds to crack effectively.

DECLARATION

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Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is not subject to interpretation.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal contributions to this article.

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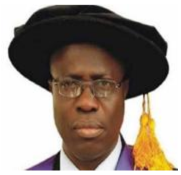

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