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A Performance Evaluation of an Improved Palm Kernel Cracker from Locally Sourced Materials

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Abstract

This paper presents the design and fabrication of an improved palm kernel cracker using available local materials and evaluate its performance. In designing and selecting of materials for the machine, consideration was given to the techno-economic status of micro and small-scale palm kernel processors who would be the intended users of the machine. The convectional palm kernel cracker which uses long rotating hammer for cracking nuts were discovered to be less efficient since it misses any nut that are not in line of action or axis of rotation. Also, by virtue of its design, cracked shell continually hint the drum (cracking house) that would lead to wear of the drum. Hence, this paper modified palm kernel cracker with a cracking equi-angularly space of three hammers welded to the rotor and housed in steel rods constructed into a cylindrical cage that has a gap between successive steel rods such that the whole kernel cannot passed through it. But only allowed cracked shell and kernel itself to pass and as such capable of making contact with every nut and thus cracking nearly all the nuts with an efficiency of74.2%,a throughput capacity of 75.6Kg/hr has been successfully and economically designed and fabricated using locally available sourced materials.

1. Introduction

Palm Kernel (Elaeisguinensis) oil is widely used in food industry as sources of cooking oil. The cracked shell can be used as fuel while the residual cakes from the oil is extracted and used as ingredient in livestock feed production. The products, developing country like ours have a lot of potential for export and therefore serve as foreign exchange earner. This palm kernel oil is referred to as PKO and is used in chemical industries for the production of fatty acids and other products. The processing of palm kernels into palm kernel oil involves the cracking of the palm nut separation of shells from the kernels, washing, cleaning, kernel milling and kernels oil extraction.

The separation of the kernel from the shells is the most labour intensive tasks performed by the people as the method involved the use of stone to crack the nuts and kernel separated by hand picking from the shell at the same time. This method is time consuming, drudgery prone, hazardous, grossly inefficient and very slow to meet the demand of growing industry [1]. It is also not surprised that palm kernel cracker equipment is one of the most frequently requested items by Women's group in the developing countries. Since the existing palm kernel cracker equipment is one of the most frequently requested items by women's group in the developing countries. Since the existing palm kernel cracker equipment technologies however, often fall short of Women's expectations as the process has quite number of deficiencies which include, breaking of kernels in the course of cracking which may be due to insufficient drying of nut as well as high impactation (blow bars) may also result in a number of uncracked [2]. Kernel breakage also results partly because the kernel upon released from the nutshell rebound in the cracking chamber and is subjected to secondary impacts which induced breakage. Also, the interaction between the adjacent nuts may obstruct the direct impingement of the individual nut to the cracking wall so that some of the nuts are discharged uncracked [3].

Consequent upon this, a large number of researched papers on palm kernel cracker exist in literature and notable amongst are: [4] design and development of an improved palm kernel shelling and sorting machine. A palm nut cracking based on hertz theory was mathematically model by [5], while the determination of some properties of palm kernel and shell relevant in nut cracking and product separation was carried out by [6]. Also, [7] design and constructed a palm kernel cracker and a product separation. The knowledge of minimum impact force required for nut cracking is therefore paramount to design improvement of existing mechanical nutcrackers [5]. The challenge of designing and actualizing the successful fabrication of a motorized palm kernel sheller with lesser production time and cost, and also achieving an equivalent purpose as does the existing ones cannot just be over-emphasized. This development is worthy of acceptance by engineers and investors as a result of the benefits derivable from the successful shelling and sorting of palm kernels, especially to countries with greater reliance on agriculture as as their economy's main stay.

However, the objectives of this research paper, is to source for locally available materials, design and fabricate an improved palm kernel cracker machine for cracking palm nut locally that is capable of continuous operation with improved performance of the palm kernel cracker by increasing the through put and percentage of kernel reclaimed without breakage, with relatively lesser production cost and time, and be simple to manufacture and maintain, also not be dependent upon tight tolerances of special material properties for its performance as it must be easily manufactured in a small village-level metal shop.

2.0. Materials and Methods

For this study, the research methodology covered the research design, selection of materials, design of centrifugal force, power requirement, shaft, Angle of twist of the shaft and bearing selection.

2.1. Materials

The criteria for the material selection the materials for the various components of the machine was based on the type of force that will be acting on them, the work they are expected to perform, the environmental condition in which they would function, their useful physical and mechanical properties, the cost, toxicity of materials and their availability in the local market environment.

2.2. Method

Thein-feed hopper, support frame, sorting tray, shaft and cracking drum used for this study was really designed and fabricated at Department of Mechanical Engineering Workshop. The components was fabricated using manufacturing methods such as machining, welding, drilling and turning operations. Basic design parameters were done which was used to develop the isometric view of kernel cracker as shown in fig 1, 2 and table 1 shown the component parts nomenclature.

2.3. Design Consideration

(i) Centrifugal Force: The centrifugal force (F_e) developed by the hammers is given as:

$$F_c = m\,\omega^2 r \qquad (1)$$

Where,

m = inertia mass of the hammer (kg)

ω= angular speed of rods

r = radius of the hammer from the shaft axis of rotation

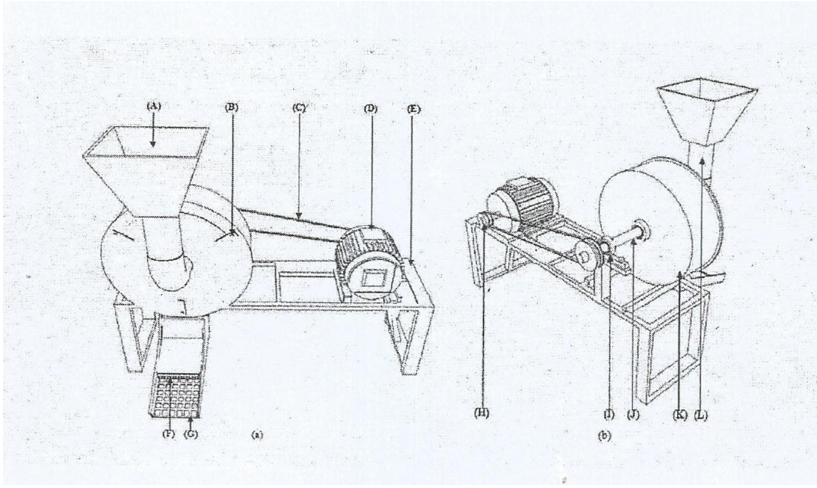

Fig1. Isometric view of kernel cracker

Table 1: Parts Nomenclature (List and names)

S/N	Part	Part Name
1	A	In-feed Hopper
2	B	M12 Bolt and Nut
3	C	V-Belt
4	D	Electric motor
5	E	Support frame
6	F	Speed Breaker
7	G	Sorting Tray (Metallic Mesh)
8	H	Drawer Pulley
9	I	Ball Bearing
10	J	Metallic Shaft
11	K	Cracking Drum
12	L	In – Feed Elbow

Now, $\omega = (\frac{2\pi N}{60})^2 r$ (2)

Where, N= number of revolutions per minutes

Thus, $F_c = M(\frac{2\pi N}{60})^2 r$ (3)

(ii) Torque: The torque developed was estimated from

$T = F_c r$ (4)

Where,

F_e = Centrifugal force (N)

r = radius perpendicular to the axis of rotation of the hammer

(iii) Power: The power required was calculated using the following relation.

$$P = \frac{2\pi NT}{60} \quad (5)$$

Where,
P = Power (Watts)
T = Torque (Nm)

2.4. Design Calculations

The following specifications enable us to calculate the necessary parameters that helped to select suitable prime mover for the cracker.

2.5. Specifications

(i) The means of the hammer = 0.5kg by 3 hammers equiangular space about the shaft axis
(ii) Hammer distance from axis = 250mm
(iii) Input speed (after pulley reduction) = 750 rpm.

2.6. Centrifugal Force (F_c)

From equation (3)

$$F_c = M\left(\frac{2\pi N}{60}\right)^2 r = 3 \text{ x} 0.5 \left(\frac{2\pi x 750}{60}\right)^2 \text{x } 0.25$$

F_c = 2.313kN

2.7. Torque (T)

From equation (4)
T = F_er = 2313 x 0.25
T = 578.297Nm

2.8. Power Requirement (P)

From equation (5)

$$P = \frac{2\pi NT}{60}$$

$$= \frac{2x750x578.297}{60}$$

P = 45.419KW (60HP)

2.9. Shaft Design

The diameter of the shaft was determined from equation given by [8] and [9] as

$$d_s = \frac{16T}{0.27\lambda\partial o} \quad (6)$$

Where,
d_s = diameter of shaft
T = torque transmitted by the shaft
$\partial 0$ = Yield stress for mild steel
Given that,
T = 578.297Nm, and ∂o = 200N/mm^2
Hence,
ds = 54.53mm
Therefore a mild steel rod diameter 55mm was used for the shaft.

2.10. Angle of twist of the shaft

The angle of twist of the shaft was, calculate from the equation given by [9]

$$Ø = \frac{584MtL}{Gd2} \quad (7)$$

Where,
Ø = deflection angle
M_t = torsional moment (Nm)
L = Length of shaft (mm)
G = modulus radius (Gpa)

2.11. Selection of Bearing

Using an expected life of 24,000 hours with a dynamic load factor of 0.9, [10].The radial load.

$$T = 2 (T_1 + T_{2)} \quad (8)$$

The axial load and radial load was determined by taking moment of forces acting on the shaft Axial load = 0, while radial load = F_r = 1KN Using the SKF Chart 1989 manufacturer's catalogue and basic ratio life equation as in [10]

$$L = ((\frac{Ck}{W}) \times 10^6 \text{ revolution} \quad (9)$$

$$L = W (L/10^6)^{1/K} \quad (10)$$

Where,
L = basic life rating (hrs) = 24,000hr
C = basic dynamic load rating
W = equivalent dynamic load = 1kN
K= exponent of life equation

The exponent K is 3 for ball bearing and $\frac{10}{3}$ for roller bearing [10]

2.12. Design Summary:

Table 2.0 shows the design summary for the palm kernel cracker fabricated.

Table 2.0 Design Summary for Cracker

S/N	Parameters	Value
1	Power required	45.42kW (60HP)
2	Torque developed	578.3Nm
3	Diameter of shafts	55mm
4	Revolution per minutes	750 rpm
5	Mass of each hammer	0.5kg
6	Number of hammers	3

2.13. Performance Tests

The machine was tested with different varieties of palm nuts of difference machine speeds. The effect of these different varieties on machine parameters such as feed rate (kg/h) throughput capacity (kg/h) cracking efficiency (%) and kernel breakage ration (KBR) were determined.

2.14. Feed Rate (Kg/h)

The nut cracker was regulated to get different feed rate. The regulation was done by adjusting the feed rate control (gate) to four points to reduce the diameter of feeding chute into cracking chamber.

The hopper was completely filled with palm nuts (10.5kg) and leveled to the brim. The stop watch was used to evaluate the time to completely empty the nuts into the cracking chamber, while the feed rate was calculated as follows:

$$FR = \frac{WT}{t} \quad (11)$$

Where,
WT = Weight of the palm kernel that filled the hopper (kg)
t = time taken to empty the whole palm kernel into cracking chamber (kg)
the four feed rates that was selected for use were 450, 600, 750 and 900kg/h

2.15. Throughput Capacity

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

$$TC = \frac{WT}{T} \quad (12)$$

Where,
WT = Total weight of palm nut feed into the hopper (kg)
T = total time, taken by cracked mixture to leave the chute (L)

3.2.3. Cracking Efficiency

This is the ration of completely cracked nuts to the total nuts feed into the hopper. It is given by

$$CE = \frac{WT - X}{WT} \quad (13)$$

Where
WT = Total weight of the palm nuts fed into the hopper (kg)
X = Weight partially cracked and uncracked palm nuts (kg)

2.16 Kernel Breakage Ratio

This is a factor that quantifies the amount of damaged and cracked kernel received from the cracked nuts it is given by:

$$KBR = \frac{CD}{CD + CU} \quad (14)$$

Where
CD = Cracked and damaged kernel
CU = Cracked and undamaged kernel

3.0. Results and Discussion

Table 3 shows the performance evaluation results for the improved developed palm kernel nuts cracking machine, with speed of 1400rpm. The experimental tests show that of the same speed. The un-cracked palm nuts, cracked palm nuts and partially cracked palm nuts were 0.21kg, 0.742kg and 0.048kg.

Table 3 Performance Tests on improved developed palm kernel nuts cracking machine at 1400rpm

Mass of Palm Kernel nuts (kg)	Cracking Time (s)	Mass of Uncracked Nut (Kg)	Mass of Cracked Nut (Kg)	Mass of Partially Cracked nuts (Kg)
1	46.13	0.30	0.64	0.06
1	50.02	0.20	0.76	0.04
1	48.26	0.27	0.66	0.07

1	44.21	0.18	0.80	0.02
1	49.27	0.10	0.85	0.05
Average	47.58	0.21	0.74	0.05

From Table 3, The experiments carried out in evaluating the machine show that 1kg of palm kernel nut cracks at an average time 47.58s. This implies that in 1 seconds, the machine will crack 0.021kg of palm kernel, that is 0.021kg/s. This is estimated through put value of the machine as shown in Table 4. The hopper has the shape of a frustum of a pyramid. The total mass of the palm nuts that can be accommodated in the hopper is 10.8kg. since 1kg of palm nut takes 47.58 second, therefore 10.8kg will take 514 seconds. Based on the average amount of cracked palm nuts obtained after the cracking operation from supplied palm nuts into the machine, it can be said that the average efficiency of the machine is about 74.2%.

The efficiency of the machine which is not too high might be due to so many factors. This could include error in design and fabrication when there is no precision welding. It can be stated that the size of the nuts has little or no effect on the efficiency of the cracking machine developed. The average amount of palm nuts cracked per day by the cracking machine is about 1872kg. This will take an average farmer about 144kg per day to achieve this

Table 4. Cracking and Through Put of the Palm nut cracking machine at 1400rpm

Mass of Palm Kernel nuts (kg)	Cracking time (s)	Through put Kg/s
1.0	46.13	21.678
1.0	50.02	19.992
1.0	48.26	20.721
1.0	44.21	22.619
1.0	49.27	20.296
Average	47.58	21.061

In Table 4, it can be deduced that the lower the cracking time at constant speed of 1400rpm, the higher the throughput of the machine. Table 4-6 show the obtained values of cracking time and throughput capacity of the machine at different shape speeds.

Table 5. Cracking time and throughput of the Palm nut cracking machine at 1200rpm

Kg	(s)	Throughput Kg/s
1.0	59.53	16.798
1.0	60.03	16.658
1.0	58.13	17.203
1.0	59.77	16.730
1.0	60.22	16.606
Average	59.54	16.799

As shown in Table 5, averages cracking time and throughput value at 1200rpm shaft speed are 59.54 seconds and 16.799kg/s respectively. Cracking time is a determinant in obtaining higher or lower throughput which also depend largely on the speed of rotation of the shaft carrying the hammer.

Table 6. Cracking time and throughput of the Palm nut cracking machine at 800rpm

Mass of Palm kernel nut (Kg)	Cracking Time (s)	Throughput (Kg/s)
1.0	86.52	11.558
1.0	85.23	11.733
1.0	85.47	11.700
1.0	87.11	11.479

1.0	86.49	11.562
Average	86.14	11.606

The average cracking time and throughput value at 800 rpm shaft speed at 86.14 seconds and 11.606kg/s respectively as shown in Table 6.
While the average cracking time and throughput of the machine at different shaft speed was obtained as shown in Table 7.

Table 7. Average cracking time and throughput of the machine at different shaft speed

Shaft Speed (rpm)	**Average Cracking time (s)**	**Throughput (Kg/s)**
800	86.14	11.606
1,200	59.54	16.799
1,400	47.58	21.061

It was observed that the cracking time reduces as the shaft speed increases and throughput increases as shaft speed increases.
This implies that the lower the shaft speed, the higher the cracking time and lower the throughput of the machine.

3.1. Bill of Engineering Materials and Evaluation for Palm Kernel Cracker

S/N	**Part Name**	**Part Description**	**Qty**	**Unit Cost ₦**	**Total ₦**
1	Machine Housing	Steel shell (Cylindrical) 10mm thick, Ø 600mm Length	1	30,000	30,000
2	Hopper	Pyramid shape Top: 460mmsq Bottom: 127mmsq	1	25,000	25,000
3	Power shaft	Ø55mm, 707mm long	1	15,000	15,000
4	Rotor	Three arm hammer rotor hub Ø70mm, hammer length 250mm	1	12,000	12,000
5	Stator	Squirrel cage steel rod Ø500mm by 416mm	1	10,500	10,500
6	Big Pulley	Cast iron steel pulley Ø 150mm	1	13,000	13,000
7	Small Pulley	Cast iron steel pulley Ø90mm	1	13,000	13,000
8	V-belt	B-type V-belt	1	2,500	2,500
9	End Cover	Circular disc Ø 600mm	1	3,500	3,500
10	Machine Stand	Steel stand 635mm long	4	2,500	10,000
11	Motor stand	Table frame (steel) (635mm by 355mm	1	8,500	8,500
12	Electric Motor	60HP, 3HP ac electric motor	1	35,000	35,000
13	Bearing	F209KG Bearing	2	3,000	6,000.00
14	Outlet Sprout	Steel construction 20 mm by 60mm	1	5,000	5,000.00
15	Miscellaneous	Lots		30,000	30,000.00
16	Testing and corrections of fault				10,000.00
17	Labour cost				35,000.00
	Total				**₦257,000.00**

4.0. Conclusion

A palm nut cracking machine with an efficiency of 74.2% throughput capacity of 75.6kg/hr has been successfully and economically designed and fabricated using locally available sourced materials. Also, maximum loading of the hopper which is about 10.8kg and $0.02m^3$ in volume will crack in about 9 minutes. The average amount of palm nuts cracked per day by the cracking machine is about 1872kg.

The cracking time decreases and throughput increases as the shaft speed increases. The machine is easy to operate, efficient and affordable. Therefore, the cracking machines using locally sourced materials will help increase productivity and efficiency in the palm nut cracking process in the rural areas.

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References

[1] Oke, P.K, 2007. Development and performance evaluation of indigenous palm kernel dual processing machine. Journal of Engineering and Applied Science, 2(4): 701-705

[2] Ofei, T.N, (2007) Design of Palm Nut Cracker influence of drying time on static force. Journal of Engineering and Applied Science, 2(4):102-125.

[3] Koya, O.A and Faborode, M.O (2006). Separation Theory for Palm Kernel and Shell mixture on a spinning disc. Biosystem Engineering, 95(3): 405-412

[4] Ismali, S.O, Ojolo, S.J Adediran, A.A (2015). Design and development of an Improved palm kernel shelling and sorting machine. European International Journal of Science and Technology. Vol. 4, No. 2 Pp225-240

[5] Koya, O.A and Faborode, M.O (2005). Mathematical Modelling of palm nut Cracking based on Hertz theory, Bio-systems Engineering, 91 (4), 471 – 478

[6] Koya, O.A, Idowu, A and Faborode, M.O (2009). Some properties of palm kernel and shell relevant in nut cracking and product separation. Journal of Agricultural Engineering and Technology, 12, 33-45

[7] Asibeluo, I.S and Abu, A.C (2015). Design and construction of palm kernel Cracker and separator. International Journal of Engineering TrendsAnd Technology (IJETT) Vol. 20 No. 3 Pp 159- 165

[8] Eric, K.G Simons, A. and Elias, K.A (2009). The determination of some design Parameters for palm nut crackers, European Journal of Scientific Research, 38(2), 315-327

[9] Shigley, J.E. and Mischke, C.R (2001).Mechanical Engineering Design. (6thed.). New York McGraw Hill Companies, Inc.

[10] Khurmi, R.S and Gupta, J.K (2008). A Testbook of Machine Design (4thed.)New Delhi Eurasia Publishing House (PVT) Ltd.

[11] Ulman.D.G (1992). The Mechanical Design Process, McGraw Hill, New York