Design, Construction and Testing of a Palm Kernel Shelling Machine

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Abstract

The methods employed by rural dwellers and small-scale companies who are in the palm kernel nuts production business ranges from the use of shelling stones, mortar and pestles and palm kernel nut grinders. However, these methods are stressful and inefficient. Therefore, this work focuses on the design and construction of a motorized shelling machine which is less stressful and more efficient. The materials used for the construction of the machine were mild steels and cast iron which were locally sourced. After the construction, the machine was tested to evaluate its efficiency. The machine shelling time was 2.5 minutes to shell 1 kg of the nuts. The test was repeated 10 times and the average shelled nuts in 2.5 minutes was 0.88kg. It was established that in one hour the machine shelled approximately 21.2 kg of palm kernel nuts and thus, in a day (8 working hours) it will shell about 170 kg. The efficiency of the machine was 88%. The cost of fabrication was one hundred and fifty-six thousand, six hundred and forty naira only (N156,640:00) which was found to be cheaper than the foreign one of similar size and capacity as well as some of the locally produced types. Therefore, this machine is more economical and efficient for small and medium scales industries in the production of palm kernel nuts. In addition, the machine is simple to use and maintained and separate the cracked nuts from the shells and un-cracked nuts.

Keywords: Shelling, Palm Kernel Nut, Shelling Chamber, Shelling Arms

I. INTRODUCTION

A lot of works have been done by various researchers in the area of designing and fabrications of palm kernel cracking machines, especially in the tropical regions where palm oil trees predominantly grow. However, they have one deficiency or the other such as high cost of production, low machine efficiency and non-portability. Thus, this research work seeks to address these deficiencies. The oil palm is a bunch of fruits attached at the upper part of the palm tree in bunches. The outer skin of the palm is known as exocarp a pulp called mesocarp which contains the palm oil in the fabriurm matrix. A central nut containing a shell call endocarp and the kernel which itself contains oil that is quite different from the palm oil, but resembles the coconut oil [1]. Palm Kernel is the seed of palm oil nuts. The oil palm (elaesisguinensis) belongs to the palmate family. Palmate contains about 225 family members with over 360 species. Among the oil producing plants, the oil palm is the richest vegetable oil plants [2]. Palm kernel is the seed of the popular oil palm tree which is commonly found in the tropical forest region of Africa and the World. It is found in the tropical Rainforest of the Western African Region [3]. The oil palm tree is the one of the greatest economic assets a nation has, only if its usefulness and the importance is fully realized and harnessed [4]. Malaysia is the leading palm oil producing country in the world. It contributes immensely to the growth of its economy [5]. The palm kernel nuts and the shells are very important wealth creating farm produce in Nigeria, most especially in the southern part of the country. The kernel cakes used as one of ingredients in livestock feeds which is highly rich in the essential nutrients needed by livestock [6,7]. In addition the shells are for brake pads and as source of energy for blacksmith and domestic use [8]. The palm and kernel oils are used for different applications such as soap making cosmetics, medicine, oil paint margarine, polish etc. [6]. There were several methods employed for shelling the palm kernel over six decades now, but basically, they can be classified into traditional and modern methods.

The traditional methods include shelling stones, mortar and pestle, smashing propelling against hard surface (rock) for the purpose of shelling. These methods are usually employed mostly in the rural areas. The shelling efficiency using the aforementioned methods is very low, it is time and energy consuming and less productive. Due to the continuous increase in demand for palm kernel nuts and the shells for soap, cream, livestock feeds, medicinal purpose etc, in the tropical regions where palm trees are mostly found, various efforts and contributions were made in the design and fabrications of palm kernel shelling machines [9, 10]. Other works include but limited to the work done by Udo et al. [11]. The machine efficiency was higher (92.5%) than this one which is (88%), but the cost of the machine was (USD 909) which is high compared to this one that was about (USD150), it does not sort out the shells from the nuts and also not portable compared to this one. It also uses higher horsepower (9 hp) unlike ours that uses only 3 hp. The cracking efficiency of the machine produced by Ibrahim et al. [12] was only 75.5% in comparison with this one that is 88% and also it does not sort out the nuts from the shells. The machine produced by Ismaila et al. [3] has an overall efficiency of 70%, even though it can sort out the nuts from the shells. In addition, all the foreign palm kernel shelling machines are sophisticated and very expensive that rural dwellers cannot use or afford. Therefore, this work focuses on the design, construction and testing of motorized palm kernel shelling machine using locally available materials which is not only more efficient and portable than some traditional ones, but simple in operation and affordable by the local dwellers, small & medium scale businesses.

II. MATERIALS AND METHOD

2.1 Design Calculations and selection of materials

2.1.1 Determination of the centre distance of the pulley.

v-belt of cross section 16 mm wide and 13 mm depth weighing 2.1 x 10^{-4} Nm^{-1}

was selected from a standard table of belt selection.

C=3r + R. (eqn 1.)

where, r and R are the smaller and bigger pulley diameters and C – centre distance.

R = 0.08 m (80 mm), r = 0.03m (30 mm)

∴ C=3(0.03) + 0.08 = 0.170 m

2.1.2 Determination of the Length of Belt

Length of the Belt: $L=2C+\pi[r+R]+\frac{[R-r]^2}{C}$ (eqn 2)

∴ $L= 2(0.170) + 3.14\ (0.03+ 0.08) + \frac{[0.08-0.03]^2}{0.170}$ = 0.340 + 0.3454 + 0.01471 = 0.70011 m.

Therefore, a belt of 0.73 m was chosen which corresponds to a pitch length of 0.7003 m

2.1.3 Determination of angle of lap

θ = π-2rad (eqn 3)

By using $\sin\alpha = \frac{R-r}{C}$ (eqn 4)

Sin α = $\frac{0.08-0.03}{0.170}$ = 0.2941, α = $\sin^{-1}(0.2941)$ = 17.10°

∴ θ = 180 – 2 x 17.10 = 180 – 34.2 145.8

Angle of lap (θ) = 2.55 rad

2.1.4 Determination of the speed of the machine Shaft

From literature (Reference book) an engine of 3 hp (2,238 kW) power and a speed of 2600 rpm were chosen to adequately cater for the force needed for shelling the palm kernel whether wet or dry.

The speed of the machine shaft is calculated using the equation (5)

$N_m/N_S = D_S/D_m$ [12] (eqn. 5)

Where, N_m = speed of the motor (smaller pulley); N_s – Speed of the machine Shaft (larger pulley), D_s – diameter of the machine shaft (larger pulley), D_m – diameter of the motor shaft (smaller). N_m = 2400 rpm, D_s = 165 mm, D_m = 65 mm.

∴ $N_s = \frac{Nm.Dm}{Ds} = \frac{2400 \times 65}{160}$ =975 rpm

2.1.5 Determination of output shaft torque (T_2)

$P = T_2\omega_2$, (eqn. 6)

where P – power of motor, T_2 – output shaft torque, ω_2 – angular velocity

∴ $T_2 = P/\omega_2$

P = 2.238 kW = 2238 W

$\omega_2 = \frac{2\pi N}{60} = \frac{2 \times \pi \times 975}{60}$, (N = 975); ω_2 = 102.05 rad/sec.

∴ T_2 = 2238/102.05 = 21.93 Nm

2.2 Selection of the materials and Fabrication

The Pulley angle β is taken to be 18°, since β ranges from 17° – 19° and assumed that co-efficient of friction (μ) will not be less than 0.2 [13]

A three horse power (3.0 hp) motor was selected. But 3.0 hp = 2.23 kW. The speed of the motor is equal to 2600 rpm.

The materials selection was done according the design calculations and the mechanical properties of the materials.

The underlisted materials were used for the construction of the machine.

- Mild steel
- V- Belt
- Bearings (bronze

- Cast iron (shelling arms)

The equipment used are:

- welding machine, and electrodes,
- the power hacksaw,
- grinding machine,
- stop watch and
- electronic weighing machine.

2.3 Fabrication and Assembly

The fabrication of the machine components was done using various machining processes except the electric motor, bearings, belts and the pulleys. The pulley centre was calculated.

The electric motor, the bearings, pulleys, V-belt were selected and purchased.

The following fabrication processes were employed: welding, drilling, turning and grinding. A combination of two or more processes were used to construct a component.

After the components were fabricated, they were assembled into one single unit by means of bolts and nuts and welding. The assembled machined is shown in Figure 1.

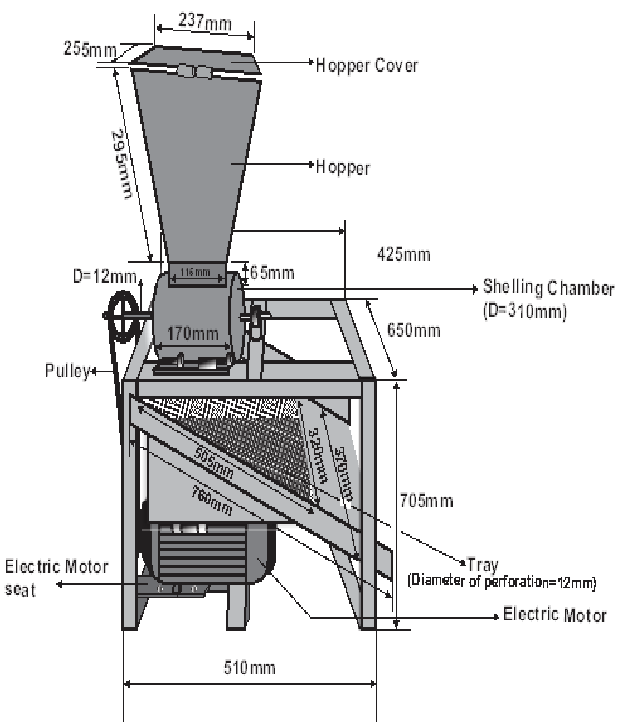

Figure 1. Palm kernel shelling machine

2.4 Description of the components

2.4.1 The Hopper

The hopper is made of mild steel plate of 2.5 mm thickness. This material is chosen, because the hopper is part of the machine that have contact with palm kernel nuts always and mild steel has good wear resistance and hardness. The nuts are fed to the shelling chamber through the hopper

2.4.2 Shelling Chamber

The shelling chamber is made of mild steel plate of 3.5 mm thickness. It has drum like shape which is divided into two semi-circular parts, the upper and the lower parts. The lower part houses the shelling arms and the shaft. The nuts are shelled in the chamber through high impact force generated via the shelling arms.

2.4.3 The machine shaft

The shaft is made from mild steel rod. It is used for driving the shelling component (shelling arms) in the shelling chamber so as to generate the required speed that will in turn create a high impact force needed to shell the palm kernel nuts.

2.4.4 The pulley and V-Belts

The pulley is the component that transmits power from the electric motor shaft (prime mover) via the v-belts to the shelling mechanism shaft. The two pulleys are of different diameters, the smaller pulley has a diameter of 65 mm and the larger pulley is 160 mm which is attached to the machine shaft.

2.4.5 The shelling arms

The sheeling arms consist of three flat circular plates made of cast iron with diameter of 143 mm and thickness of 5 mm. The three flat circular plates are welded to the centre of the shaft at a distance of 54 mm from each other in such a way that the shaft passes through the centre of the three plates. These three circular plates are connected to each other by a hollow pipe of diameter 12 mm. the shelling arms also made from cast iron (11 pieces) are connected to these pipes.

2.4.6 The Machine Tray

The machine has two trays which are positioned under each other at right angle. The upper tray is perforated to a length of 505 mm out of a total length 760 mm. it collects the nuts and sieve the shells and some broken nuts into the tray underneath and the shells and the broken nuts are collected and sorted out. The breath of the down tray508 mm and its length is 580 mm

2.4.7 The machine base

All the other components of the machine rest the machine base (stand). The machine base was made of cast iron angle bar with high shock absorbing capacity and strength.

III. EVALUATION OF THE SHELLING MACHINE (TESTING)

Experimental Test was conducted to determine the shelling efficiency of the machine.
Shelling time= 2.50 mins
Quantity of palm kernel=1000 g (1 kg)
Speed of machine= 975 rpm.

The testing was repeated for 10 times and the results are presented in Table 1 and 2.

Table 1 Experimental Results

s/n	Time, min	Weight of palm kernel fed (kg)	No. of palm kernel	No. of palm Kernel shelled	No. of palm kernel unshelled	efficiency
1	2.50	1.0	377	337	40	89.4%
2	2.50	1.0	426	374	52	87.8%
3	2.50	1.0	415	351	64	84.6%
4	2.50	1.0	363	328	35	90.4%
5	2.50	1.0	430	379	51	88.1%
6	2.50	1.0	347	307	40	88.5%
7	2.50	1.0	411	372	39	90.5%
8	2.50	1.0	353	311	42	88.1%
9	2.50	1.0	378	326	52	86.2%
10	2.50	1.0	382	340	42	89.0%
Average	**2.50**	**1.0**	**388**	**342**	**46**	**88.3%**

3.1 Determination of the machine (shelling) efficiency

Input = the number or weight of the Initial unshelled palm kernel nuts, (The number or weight of palm kernel nuts before shelling)

Output= The number or weight of the shelled palm kernel nuts.

The total number of palm kernel nuts =3,882.

The total number of nuts shelled = 3425

Machine (Shelling) Efficiency (M_{ef}) = $\frac{output}{input} x\ 100\%$ = $\frac{3425}{3882} x\ 100\%$ = 88.22% = 88%

Average weight of a unit palm kernel nut = $\frac{10000}{3882}$ = 2.58g

The average number of palm kernel nuts shelled in the 2.50 minutes = $\frac{3425}{10}$ = 342.5 pcs.

∴ In 1 minute, $\frac{342.5}{2.5}$ = 137 pcs

In 1hour = 137 x 60 = 8220 pcs x 2.58 g = 21207.6 g = 21.2 kg

∴ in one day (8 working hours), total weight of palm kernel shell will be 21.2 kg x 8 = 169.6 kg

Table 2. Cost analysis

s/n	Material	Quantity	Unit Cost (Naira)	Total cost (Naira)
1.	Galvanized steel plate 2.5mm thickness (2230mm)	1	10,200	10,200
2.	Steel Plate 5mm thickness (1000mm)	1	4,500	4,500
3.	Angular Bar (60 x 60) mm; 6000mm	1	8,100	8,100
4.	Flat bar (60 x 3) mm	1	5,400	5,400
5.	Shaft (20.5) mm diameter; 1000 mm	1	4,500	4,500
6.	Steel Rod (3mm); 6000 mm	1	2,700	2,700
7.	Electrodes	2 Packets	1,620	3,240
8.	Bolts & Nuts	12	210	2,520
9.	Paint (4litres)	1	2,700	2,700
10.	Ball Bearing	2set	1,440	2,880
11.	Electric Motor (3hp)	1	51,300	51,300
12.	Labour			48,600
13.	Miscellaneous			10,000
	GRAND TOTAL			**156,640**

IV. CONCLUSION

This case study research focuses on the design, construction and testing of a palm kernel shelling machine. The following conclusions were drawn from the study:

i. The palm kernel shelling machine was successfully designed, constructed and tested.
ii. The performance evaluation of the machine shows that the machine is efficient to meet the demand of the local farmers and small-scale industries involved in palm nuts production.
iii. The efficiency of the machine was 88% which is comparable to similar imported machines, but a lot higher than the traditional methods of shelling palm kernel nuts in the rural areas.
iv. The machine is more affordable compared to foreign machines and some locally produced shelling machines.

In addition, the study recommended the following:
A regulator should be incorporated in future design to regulate the amount of palm kernel nuts falling from the hopper into the shelling chamber for better shelling results
The machine should be installed in a reinforced concrete to reduce vibration and noise.

Conflict of Interest

The Authors declare no conflicts of interest.

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