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Design and Fabrication of Thevetia Peruviana Nut Cracking Machine

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Abstract: A thevetia peruviana nut cracking machine was designed, fabricated and tested for it performance in the department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria. The cracking machine consists of the following components parts: hopper, cracking unit, outlet, main frame and the transmission unit. The design of the machine was based on the engineering properties of thevetia peruviana nut while making use of locally available materials for the fabrication. The machine requires a five horse power (5hp) electric motor to operate. The average throughput capacity and cracking efficiency of the machine were 31Kg/h and 97% respectively. The machine is therefore suitable for cracking thevetia peruviana nut and recommended for adoption by small scale processors.

Keywords: Thevetia Peruviana, Cracking, Nut, Machine, Design, Testing.

1. INTRODUCTION

Thevetia peruviana also known as physic plant, milk bush, allamanda plant, yellow oleander and “Olomi Ojo” in Yoruba is an ever green ornamental dicotyledonous shrub or small tree that belongs to the order apocynales and Apocyanaceae family. It is among the notable non-edible less known seeds in Nigeria after castor and jatropha (Usman et al; 2009). It is commonly found in the tropics and sub-tropics but it is native to Central and South America. It is a drought resistant plant, with yellow trumpet like flowers and grows well in all parts of Nigeria. Thevetia peruviana made its way to Nigeria over fifty years ago and has been grown as an ornamental plant in homes, schools and churches by missionaries and explorers (Ibiyemi et al., 2002).
The Thevetia peruviana plant flowers and fruits all year round providing a steady supply of seeds. A tree can produce between 400-800 fruits per annum depending on the rainfall pattern and plant age. It grows to about 10-18 feet high; the leaves are spirally arranged, linear and about 13-15cm in length (Olisakwe et al., 2015). The fruit contains a nut which is longitudinally

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and transversely divided. The fruit contains between one to four seeds in its kernel, and the plants bears milky juice in all its organs. All parts of the plant, especially the seeds are toxic due to the presence of glycosides. It contains a milky sap containing a compound called thevetin that is used as a heart stimulant but in its natural form is extremely poisonous. The physicochemical properties of Thevetia peruviana oil makes it suitable for the preparation of oleo chemicals such as soap, shampoos, alkyd resin and biodiesel (Usman et al; 2009).

Harvested thevetia peruviana fruit undergoes different processing operations among which are: drying, cracking, oil extraction and shell as residue. Cracking as one of the unit of its processing can be achieved through the application of forces in various forms such as impact, compression and attrition or a combination of two or more. Traditional method of cracking involves the use of stones or mortar and pestle which is time consuming, stressful, damages the kernel and low output. Hence there is a need for mechanical method to remove the drudgeries involved in the cracking operation

2. MATERIALS AND METHODS

2.1 Description of the Machine

The Thevetia peruviana nut cracking machine plate 1 consists of the following components parts: hopper, cracking unit, outlet, main frame and the transmission unit. The hopper is the part through which the thevetia peruviana nut is fed into the machine. It is made from mild steel sheet in the form of a truncated inverted pyramid. It is slightly bent to one side to prevent the escape of seed during operation. The cracking units consists of a stationary and a rotating drum. The stationary drum encloses the rotating drum and has abrasive rod in its lower part. The cracking takes place when the rotating drum rubs the nut against the abrasive rod on the stationary drum. The main frame is the main unit of the machine on which all other parts are rested upon. The transmission unit consists of the pulley, electric motor and the belt. The electric motor powers the machine by transferring rotary motion via the belt and pulley drive. The out let is the part through which the cracked kernels are collected.

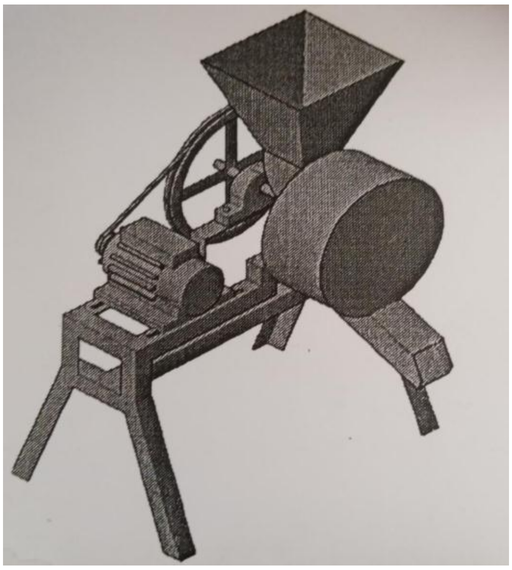

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Plate 1: Thevetia Peruviana Cracking Machine

2.2 Material Selection

The materials used for fabrication of the Thevetia peruviana nut cracking machine were carefully selected based on the following factors:

i. Cost: the materials used were selected based on the fact that it does not inflate the total cost of the machine.
ii. Durability: the materials used were also selected based on its ability to stand the test of time.
iii. Size and Weight: the materials used were also selected on the basis that the machine does not becomes too heavy to be easily moved from one place to another.
iv. Availability: the materials used were also those that could be locally sourced should in the case of servicing or replacement of worn out parts.
v. Strength: the materials were also selected on the basis of being able to withstand the stress of the machine during operation without failure.

2.3 Design Consideration

The design of Thevetia peruviana nut cracking machine was based on the following factors:

i. Engineering properties of the nut
ii. Quantity of nut to be processed
iii. Availability of fabrication materials
iv. High cracking efficiency
v. Simplicity in the design

2.4 Design Calculations and Analysis

The design analysis and calculation is necessary to determine the parameters of all the component parts of the thevetia peruviana nut cracking machine.

2.4.1 Design for the Hopper

The hopper was designed to allow easy flow of the thevetia nuts into the cracking unit. The shape of a truncated inverted pyramid which opens directly into the cracking unit allows the thevetia to fall by gravity unto the cracking unit. The hopper was designed using the relation given by Uthman et al; 2022 below:

$$\text{Volume of thevetia, } V = \frac{\text{mass of thevetia}}{\text{bulk density of thevetia}} \quad (1)$$

2.4.2 Design for Shaft

The shaft which is the rotating element of the thevetia nut cracking machine was designed for to prevent structural failure during operation. The diameter of the shaft was designed based on Maximum direct stress of 1.2 x 10^8pa using ASME code equation given below:

$$d^3 = \frac{16}{\pi S_S} M_b + \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (2)$$

Where;

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d= diameter of the shaft
$S_S = 1.2 \times 10^8$pa
M_b= maximum bending moment
M_t= torsional moment
K_t= 1.5
K_b=1.5

2.4.3 Design for the Power Requirement of the Machine

The power requirement of the machine was derived by the equation given by Khurmi and Ghupta, 2005 below:

$$P = \frac{2\pi NT}{60} \quad (3)$$

Where;
T = Fr
P is required power
N is machine speed
T is torque
F = weight of shaft
r = radius of shaft

2.4.4 Design for Belt Drive

The belt drive was designed using the relation given by Khurmi and Ghupta, 2005 below:

Determination of belt tension

$$P = (T_1 - T_2)V \quad (4)$$

Where;
P = Design power in watts
T_1 = Belt tension at tight side in Newton
T_2 = Belt tension at slack side in Newton
V = Speed of belt in M/S

Also, $N_1D_1 = N_1D_2$

Where;
N = Speed
D = Diameter of pulley
1 = Electric motor
2 = Machine

Determination of Angle of Wrap

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$$\vartheta = [180 - 25\ \text{in}^{-1}\ x\,]\frac{\pi}{180} \tag{5}$$

Where;
ϑ - angle of wrap in rad
$2.3 \log\left[\frac{T_1}{T_2}\right] = \varphi\vartheta\cos\beta$
ϑ - frictional coefficient of belt
β - frictional coefficient of pulley

Determination of Length of Belt

$$L = 2x + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} \tag{6}$$

Where;
L = Length of belt
C = Centre distance between two pulley
D_1& D_2 = Diameter of driver & driven pulley

2.5 Fabrication Procedure and Assembly

2.5.1 Fabrication of Hopper

The hopper was made from mild steel sheet of 2.5mm thickness. It was cut with a guillotine shears according to the size and bent to the shape with a manual bending machine. It was welded with an electric arc welding machine using gauge 12 electrode as a joining medium.

2.5.2 Fabrication of Main Frame

The mainframe of the machine was made from 50 X 50 X 5 mm 'H' iron. The length and breadth was marked and cut to the required size using an angle grinder. It was then joined using an electric arc welding machine using gauge 12 electrode as a joining medium.

2.5.3 Fabrication of Shaft

The shaft was made from 30mm mild steel machine rod. It was machined on the lathe to the appropriate size while the key way slot was cut with a vertical milling machine.

2.5.4 Fabrication of Cracking Unit

The outer drum of the cracking unit was made from 2.5mm mild steel sheet. It was measured with a measuring tape and marked with a steel chalk. It was then cut using a guillotine shears and then rolled into a cylindrical shape using a manual rolling machine. The end was then joined with an electric arc welding machine using gauge 12 electrode as the joining medium. Iron rod of 16mm diameter were also welded horizontally on the wall of the outer drum. The internal rotating drum of the cracking unit was made from mild steel flange and ion rod. The flange was attached to the shaft with an electric arc welding machine and the rod was in turn attached around the circumference of the flange.

2.5.5 Fabrication of Outlet

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The outlet was made from 2.5mm mild steel sheet. It was measured with a steel tape, marked with a steel chalk and then cut with a guillotine shears. The shape was formed by bending it with a manual bending machine and then attached to the outer drum of the cracking unit with an electric arc welding machine.

2.6 Principle of Operation of the Machine

The thevetia nut cracking machine use the principle of rubbing in the cracking of the thevetia nuts. The machine is coupled with a 5Hp electric motor and its power is transmitted to the machine via belt drive. The dried thevetia nuts are fed into the machine via the hopper into the cracking unit where it comes in contact with the rotary drum. The rotary drum rubs the thevetia nut against the wall of the outer drum which has been lined with iron rod which causes the nut to split into two. The cracked nut and the kernel is then ejected from the machine via the outlet.

2.7 Cost Analysis

The cost of fabricating the thevetia peruviana nut cracking machine were presented in table 1 below.

Table 1: Bill of Engineering Measurements and Evaluation (BEME)

S/N	Material Specification	Quantity	Rate(₦)	Amount (₦)
1.	2.5mm mild steel sheet	1	30,000.00	30,000.00
2.	50 x 50 x 5mm ‘L’ iron	2	10,000.00	20,000.00
3.	16mm mild steel rod	1/2	5,000.00	2,500.00
4.	30mm shaft	1m	10,000.00	10,000.00
5.	M10 Bolts And Nuts	2dozen	750.00	1,500.00
6.	Pillow bearing	2	5,000.00	10,000.00
7.	200mm pulley	1	4,000.00	4,000.00
8.	50mm pulley	1	2,000.00	2,000.00
9.	5hp motor	1	75,000.00	75,000.00
10.	Gl2 electrode	1pack	3,500.00	3,500.00
11.	Cutting disc	1	1,200.00	1,200.00
12.	Grinding disc	1	1,000.00	1,000.00
13.	Machining	Lump	10,000.00	10,000.00
14.	Painting	Lump	5,000.00	5,000.00
15.	Transportation	Lump	5,000.00	5,000.00
16.	Workmanship	Lump	15,000.00	15,000.00
	Total			195,700.00

2.8 Testing of the Machine

2.8.1 Sourcing of Test Materials

Thevetia Peruviana nuts were harvested from the campus of Kwara State Polytechnic, Ilorin, Kwara State, Nigeria.

2.8.2 Sample Preparation

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The thevetia peruviana nuts were cleaned and sorted manually to remove the bad or damaged nuts from the bulk of the samples. The good nuts were then sun dried for two weeks to achieve a moisture content safe for storage and also good for cracking. The nuts were then measured into samples of 500g in three places respectively using a digital weighing scale. Each of the samples were replicated thrice and placed in a labelled container prior to the testing of the machine.

2.8.3 Output Parameters
The output parameters were determined using the following equations:

i. Machine Throughput Capacity (Kg/h): $M_{Tc} = \frac{m_s}{T} \times 3.6$ (7)

ii. Machine Cracking Efficiency (%): $M_{Ce} = \frac{m_{s-m_d+m_e}}{m_s} \times 100$ (8)

Where;
M_{Tc}: Machine througput capacity
M_{Ce}: Machine cracking efficiency
m_s: mass of sample fed into the machine
m_d: mass of damaged or partially cracked nut
m_e: mass of whole or escaped nut
T: time taken to crack the sample

2.9 Experimental Procedure
The thevetia peruviana cracking machine was cleaned and dried prior to its usage. The electric motor was connected to 240V A.C electric supply and the switch was put on. The machine was allowed to run for a minute before the samples were then introduced into the hopper. The samples were collected at the outlet and time taken for each sample to be cracked was taken with a stopwatch and recorded accordingly. The procedure was repeated for all the samples.

3. RESULTS AND DISCUSSION

The summary of the result obtained from the testing of the thevetia peruviana nut cracking machine were presented in table 2 below.

Table 2: Summary of Result Obtained from the Machine

S/N	Feed Rate (g)	Whole Kernel (g)	Broken/ Damaged Kernel (g)	Whole/ Escaped Nut (g)	Shell (g)	Loss (g)	Time (s)	Throughput Capacity (Kg/h)	Machine Cracking Efficiency (%)
1.	500	78	21	3	385	13	58	31.03	95

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2.	500	73	10	-	392	25	63	28.57	98
3.	500	68	15	-	404	13	55	32.72	97
Average	500	73	15	1	394	17	57	31	97

The result of the test conducted on the thevetia peruviana nut cracking machine is as presented in table 2 above. Samples of 500g each were fed into the machine three times and the average of the kernel recovered, broken/damaged kernel, whole/escaped nut, shell and loss were 73, 15, 1, 394 and 17 g respectively while the machine was able to process the sample at an average of 57secs. Therefore, the average throughput capacity and cracking efficiency of the machine were 31Kg/h and 97% respectively.

4. CONCLUSION

A thevetia peruviana nut cracking machine was designed and fabricated in the department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria. The machine was tested for its performance in terms of throughput capacity and cracking efficiency. The machine has an average throughput capacity of 31Kg/h and cracking efficiency of 97%. Therefore, the machine is suitable for cracking thevetia nut on a small scale.

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