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Design and Fabrication of a 1.4kg/hr Dry Groundnut Peeling Machine

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ABSTRACT

The design and fabrication of a 1.4kg/hr dry-groundnut peeling machine using locally sourced materials is presented in this paper. The design of the machine shaft, power of electric motor, total volume occupied by seeds and the maximum number of seeds in the cylindrical peeler barrel were carried out. 257 dry groundnut seeds were prepared and tested on the modified machine, measuring the mass of seeds to be peeled and unpeeled, testing for peeling effectiveness, peeling rate and groundnut material loss from peeling. A graph of the peeling efficiency was plotted against the number of seeds fed into the machine. Results showed that, the peeling machine has an average peeling efficiency of 83.04% and unpeeled efficiency of 16.96%.

1. Introduction

Groundnuts (Arachis hypogaea) also known as peanuts or earthnuts, or jack nuts is a species in the legume or beans family. Originated in South America (Southern Bolivia /North West Argentina region) where it was cultivated as early as 1000 BC. Dissemination of the crop to Africa, Asia, Europe and the pacific islands occurred presumably in the sixteenth and seventeenth centuries with the discovery voyage of the Spanish, Portuguese, British and Dutch [1]. Today, it is grown in areas between 40 degrees south and 40degrees north of the equator, where average rainfall is 500 to 1200mm and mean daily temperatures are higher than 20^{o}C. The groundnut is cultivated in 108 countries on about 22.2 million hectares of which 13.69 million has are in Asia (India 8 million hectares; China 3.84 million hectares), 7.39 million has in Sub-Saharan Africa, and 0.7million hectare in Central and South America. Average pod yield on a global scale increased slightly from 1.08million tones/ hectares in the 1980s to 1.15mt ha^{-1} in the 1990s and the global production is 29 million tons of pods [2]. India, China and the United states are the leading producers and grow about 70% of the world's groundnuts [3]. Nigeria was a major producer of groundnut which was exported to other countries for foreign exchange. At that time, large pyramids of sacks of groundnut could be seen in Kano. For some years now, these pyramids of sacks have disappeared because our production of the crop has declined.

The uses of groundnuts are diverse. The nut is a rich source of edible oil, containing 36 to 54% oil and 25 to 32% protein [4]. About two thirds of world production is crushed for oil, which makes it an important oil seed crop [5]. The oil is used primarily for cooking, manufacture of margarine, shortening and soaps. Seeds are consumed directly either raw or roasted, chopped in confectionaries, or ground into peanut butter. Young pods may be consumed as a vegetable while young leaves and tips are utilized as a cooked green vegetable [6]. Peeling is the last operation that is carried out in the processing of groundnut before extraction. Peeling could be carried out traditionally (manually) by hand, mechanically by existing and recently developed machines

whose inherent and observed drawbacks call for further development. Traditional method especially by manual hand peeling is tedious, slow, require high labour input and incur high processing losses when large scale is involved [7, 8].
Mechanization of the peeling process has imposed the greatest engineering challenge because groundnut seeds vary widely in size and shape, texture, colour and strength of adhesion of the skin to the groundnut seed, the physical and mechanical properties of the groundnut seeds vary significantly with maturity time and season of harvesting.
Several groundnut peeling machines based on different techniques have been developed over the years. Recent efforts include the groundnut peeling machine (Wet method) and (dry method) and the groundnut rubber roller peeling machine [9, 10]. These machines are very expensive and out-of- reach by the small-scale producers and farmers.
This research aimed at designing and fabricating an efficient portable groundnut peeling machine from locally sourced materials.

2. Materials and Method

2.1 Materials

Plastic and solid foam were locally obtained from Benin City, Nigeria. The selection of these materials was based on reliability, cost, portability, Maintenance and servicing, safety, weight, friction and availability.

2.2 Description of the Groundnut Peeling Machine

Various components were put together in the fabrication of this machine. These parts are: the peeling chamber, discharge chute, electric motor, electric motor casing, shaft and control unit.

i. Peeling Chamber

It houses the rotary peeler and the peeling drum. The peeling operation is done inside it.

ii. Discharge Outlet

The shelled groundnut seed is collected through this outlet. The seeds fall under gravity from the shelling chamber into its tray. It must have good strength and high resistance to impact loads. Also the chaff is removed through this outlet.

iii. Electric Motor Casing

The packaging is done using plastic to avoid electric shock and to allow for portability. The dimension (220mm x 160mm x 40mm) was chosen after carefully considering the size of the electric motor.

iv. Electric Motor

The electric motor was used to rotate the shaft. A 1 hp electric motor was used.

v. Control Unit

The control unit is attached to the electric motor casing. It is used to vary the speed of the motor when the machine is in operation. It has a plastic casing of dimension 90mm x 45mm x 13mm to prevent electric shock.

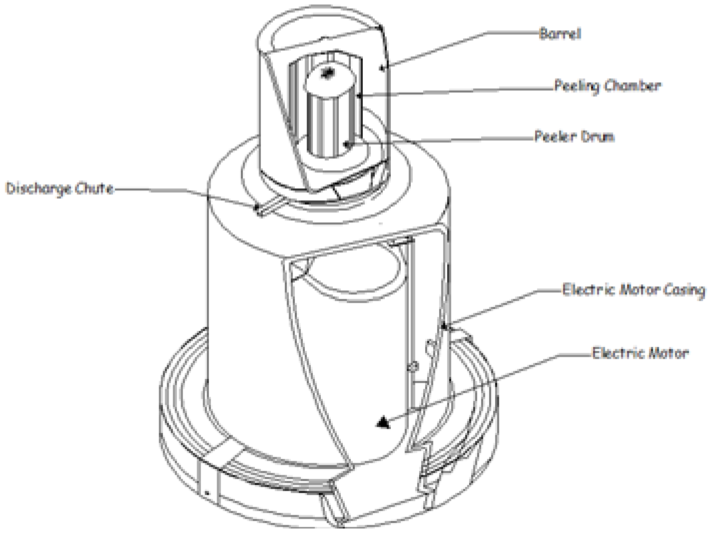

Figure 1: Isometric cut-away view

2.3 Design Analysis and Calculation

2.3.1 Design procedure

The design procedure for this project is as summarized below:

i. Calculation of total volume occupied by seeds and maximum number of seeds in the barrel
ii. Power determination equations
iii. Shaft design

2.3.2 Calculation of Total Volume Occupied By Seeds

In commercial operations, it is necessary to estimate the total volume occupied by seeds in order to calculate the amount of production that can be achieved per hour or per day.
Assuming the groundnut seed to be a sphere, the volume occupies by a seed of groundnut can be obtained using the formula:

$$V_s = \frac{4}{3}\pi r_s^3 \quad (1)$$

The total volume occupied by seeds is found using:

$$V_{TS} = \overline{\Lambda}\left(r_c^2 h_c - r_p^2 h_P\right) \quad (2)$$

The total number of groundnut seeds that can be contained in the cylindrical barrel is found using:

$$n_{TS} = \frac{V_{TS}}{V_S} \quad (3)$$

The mass of the groundnut seeds in the barrel is determined by using:

$$M_{TS} = M_s \times n_{TS} \quad (4)$$

2.3.3 Power Determination

In order to determine the power require to drive the maximum load in the peeler barrel, the following equations have been put forward:
The peeling strength of a seed is:

$$P_S = \frac{F_P}{A_G} \quad (5)$$

Assuming the groundnut seed to be a sphere, the area is found as:
follows:

$$A_g = 4\overline{\Lambda} r_g^2 \quad (6)$$

The peeling force of groundnut is the force required o peel the dry red skin from the seed bonded to it and it is found using the equation:

F_p = Ps x Ag (7)

Total peeling force for the groundnut seed, is found using

$F_{PT} = P_S$ x A_g x n_{TS} (8)

The torque transmitted to the rotary peeler is found using

T_{pt} = F_{pt} x L_p (9)

The angular speed of shaft is found using the equation:

$$\omega = \sqrt{\left(\frac{g}{l_p}\right)} \quad (10)$$

The power required for peeling is found using the equation:

$P_P = T_{PT}$ x ω (11)

2.3.4 Power Determination Analysis

In accordance with the American society of Agricultural Engineers (ASAE), the peeling strength of dry groundnut seed is O.0035N/mm2.

The area of groundnut seed is found using Equation (6).

Where,

r_g = 7.2mm

substituting into Equation (6) gives

A_g = 651. 44mm^2

The peeling force from Equation (7) is

$F_P = P_S$ x A_g

Where

P_s = O.0035N/mm^2

A_g = 651.44mm^2

Therefore,

F_p= 2.28N

Total peeling force for the groundnut seed is found using Equation (8)

$F_{PT} = P_S$ x A_g x n_{TS} (8)

Where,

N_{ts} = 257 seeds

F_{PT} = 585.96N

The total torque transmitted to the peeler is found using Equation (9)

$F_{tp} = F_{pt}$ x L_p (9)

Where,

L_p = 0.12m

$\therefore$ T_{pt} = 585.96x0.12

= 70.315 N-m

The angular speed of shaft is found from Equation (10)

$$\omega = \sqrt{\left(\frac{g}{L_p}\right)} \quad (10)$$

Where,
g = 9.80 m/s^2
L_p = 0.12m

$$\therefore \quad \omega = \sqrt{\left(\frac{9.80}{0.12}\right)}$$

ω = 9.04 rad/sec
The power required for peeling is found from Equation (11)

$$P_p = T_{PT} \times \omega \quad (11)$$

P_p= 635.65 watt
But power required for peeling in horse power (h.p) is

$$P_p = \frac{635.65}{746}$$

P_p = 0.85hp
Since there are friction losses and electrical losses due to heating, a 1 hp electric motor to drive the machine was selected.

2.3.5 Shaft Design

Shaft design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Shafts are usually circular in cross-section and may be either hollow or solid. Shafting is usually subjected to torsion, bending and axial loading.
Total mass of seeds on the shaft is equal to the total mass of seeds in the barrel.

$$\therefore M_{TS} = 301g$$

Total weight can be found from the equation,

$$W_{TS} = \frac{M_{TS} \times g}{1000} \quad (12)$$

W_{TS} = 2.95N

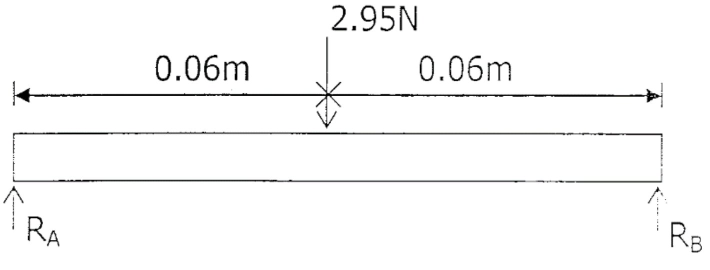

Figure 2: Free body diagram (FBD) for the shaft loading.

Considering the about point figure,

$$R_A + R_B = 2.95N \quad (13)$$

Taking moment about point A gives $\sum M_A = 0$

$0.12R_B - 0.06(2.95) = 0$
R_B= 1.475N
Substituting the value of R_B into Equation (13), we have that,
R_A = 1.475N

The reaction at the supports are $R_A = R_B = 1.475N$
Figure 2 shows the shear force and bending moment diagrams of the shaft

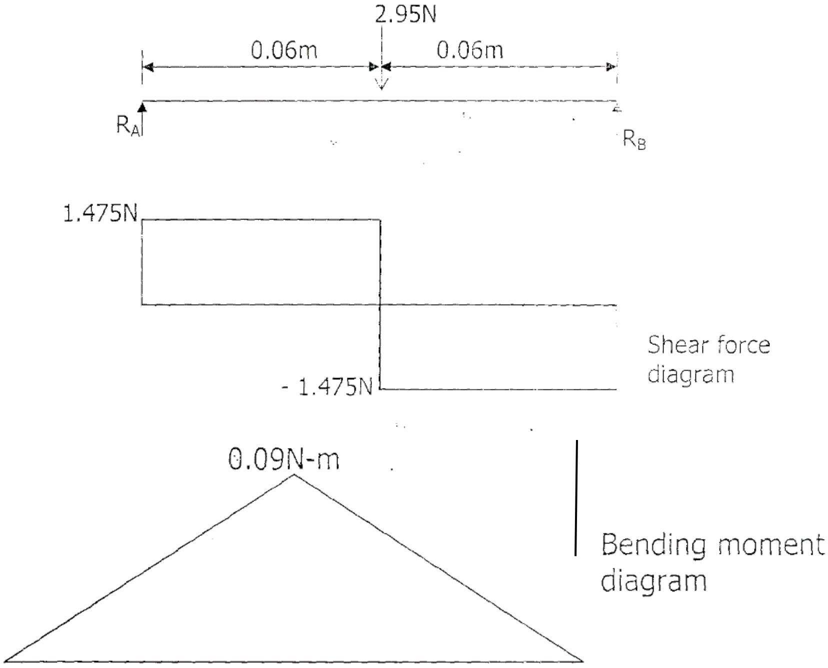

Figure 3: Shear force and bending moment diagram for the shaft

From the bending moment diagram above the maximum bending moment is given as:
Mb = 0.09N-m
From the American society of mechanical engineering (ASME) code for shafting, the diameter is found from the equation.

$$d^3 = \frac{16}{\Lambda s_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (14)$$

Where,
K_b = combined shock and fatigue factor applied to bending moment for shaft with keyway.
S_s = Maximum allowable stress
S_s= 40MN/mm^2 for shaft with keyway
K_t = combined shock and fatigue factor applied to torsion.
for gradual shaft loading for a rotating shaft,
K_b = 1.5 and K_t = 1
M_b = Maximum bending moment
M_b = Maximum tensional moment For the shaft considered,
M_t = 0
Therefore,

$$d^3 = \frac{16}{\Lambda s_s}\sqrt{(K_b M_b)^2} \quad (15)$$

substituting values into Equation (15) gives

$$d^3 = \frac{16}{\Lambda \times 40 \times 10^6}\sqrt{(1.5 \times 0.09)^2}$$

$$d = 2.58mm$$

Therefore, a shaft of diameter 2.6mm was selected for the design.

2.4 Maximum Capacity of Barrel Analysis

According to American Society of Agricultural Engineers (ASAE), the mass of groundnut seed is between 0.22g – 1.17g.

Assuming the seed to be a sphere having radius 0.72cm, the volume of seed can be determined using Equation (1)

$$V_s = \frac{4}{3}\overline{\Lambda} r_s^3 \quad (16)$$

Where

$r_s = 0.72$cm

by substitution, we have

$V_s = 1.5635\text{cm}^3$

The total volume occupied by seeds can be calculated using Equation (17)

$$V_s = \overline{\Lambda}\left(r_c^2 h_c - r_p^2 h_p\right) \quad (17)$$

Where,

$r_c = 4.5cm$

$h_c = 14cm$

$r_p = 3.6$

$h_p = 12cm$

By substitution, we have

$V_{TS} = 402.061cm^3$

Total number of seeds contained in the peeler barrel is found using Equation (18)

$$n_{ts} = \frac{V_{TS}}{V_S} \quad (18)$$

By substituting values into Equation (18), we have

$n_{TS} = 257.15$

Therefore, maximum number of seeds in the barrel is 257 seeds. Total mass in the barrel is found using Equation (19)

$$M_{ts} = M_S \text{ x } n_{ts} \quad (19)$$

Where,

M_s= 1.17g per seed

$\therefore$ M_{TS} = 1.17 X 257

= 300.69g

Total mass of seed in the barrel is approximately 301g

Time taken to peel 0.301kg of roasted groundnut seeds was 13 minutes (0.2167hrs). The capacity of the machine is therefore:

$Capacity = \frac{Weight}{Time} = \frac{0.301}{0.2167}$ = 1.4kg/hr

2.5 Motor Specification

Shunt motor is selected on the basis of approximately constant speed, adjustable speed and medium starting torque.

Motor rating = 1hp = 746 kw

Speed = 340 rpm

2.6 Fabrication Process

The fabrication was done at Production Engineering workshop of University of Benin , Edo state, Nigeria. The materials used were purchased after designing for the various components of this machine. The manufacturing process employed in the fabrication/ assembling of the machine include drilling, cutting, filing, painting, etc.

2.7 Peeler Assembly

The various parts of the peeler model were precisely constructed. The electric motor is mounted on the main base. The plastic electric motor casing which has a centre hole of diameter 2.6mm was mounted to cover the electric motor so that the electric motor shaft can be seen. The control unit wire and that of the electric motor are connected together at a point inside the casing. The wire was then brought out through a small opening at the side of the base for onward connection to the power source. While the control unit was mounted on the side of the electric motor casing. A pulley of two slots was then fitted on the electric motor shaft.
The rotary peeler was fitted into the peeling chamber having perforations at it sides to allow the peeled red skin to pass through. The unit was then fitted into a dust receiver chamber so that both the peeling and receiver chambers do not rotate as the rotary peeler rotates. A discharge chute was placed at the bottom of the receiver chamber to remove the peeled dust under gravity. This entire unit forms the peeler unit.
The shaft of the peeler unit has a slot which enables the unit to fit perfectly on the electric motor unit to form the peeler machine unit.

3. Results and Discussion

The result obtained from the above test is presented in Table 1.

Table 1: Test Result on Groundnut Peeling

s/n	No of seeds (A_1) fed into machine	No of peeled seeds (A_2)	No of unpeeled seed (A_3)	Efficiency of peeling (%) $\left(\frac{A_2}{A_1} \times \frac{100}{1}\right)$
1	257	220	37	85.6
2	200	170	30	85.0
3	150	124	26	82.6
4	100	82	18	82.0
5	50	40	10	80.0

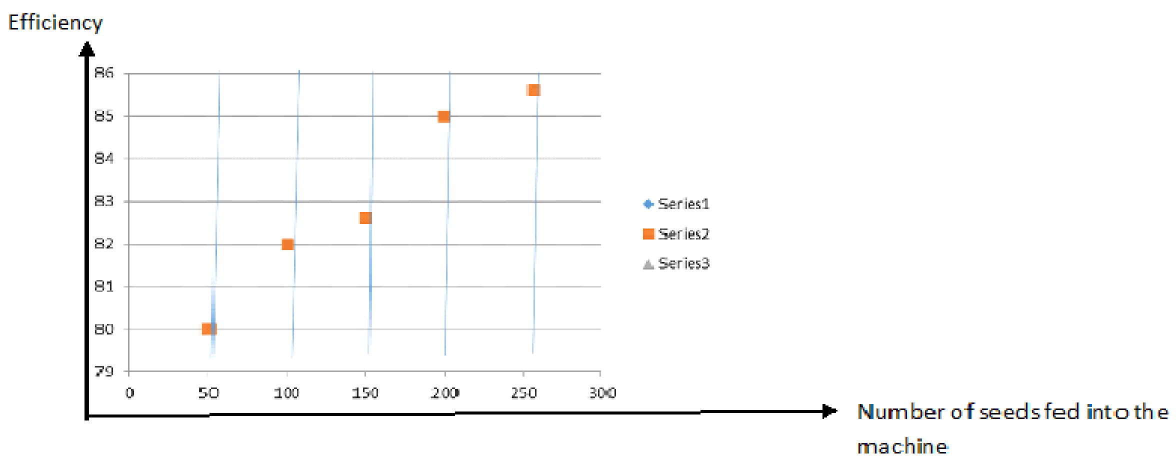

Figure 4: The graph of peeling efficiency against number of seeds fed into the machine.

From the Table 1, the average peeling efficiency is 83.04%.

3.1 Performance Test

The performance of any system depends to a large extent on the design and conditions under which the system is operating. The design was done to achieve maximum output. In order to obtain the desired result, the groundnuts have to be properly roasted before charging them into the peeling chamber. The design consideration was based on dry roasted groundnut and any deviation would not produce the desired result.
The performance evaluation of the machine was carried out manually and with 1hp low speed (320rpm). 0.301kg of roasted groundnut was charged into the peeling chamber. The speed of rotation was used to evaluate the performance of the machine through the use on the identified and selected speed of the motor which are N_1 = 340rpm and N_2 = 320rpm respectively, at different operations. The result shows the effect of varying speeds on peeling of dry groundnut seeds. It was observed that there was an increase in the percentage of seeds peeled as the speed increased from 340rpm to 320rpm and decrease in percentage of unpeeled and broken seeds. It can be deduced that increase in speed resulted in more breakage and lesser percentage of unpeeled seeds. This was further illustrated in Table 1 and 2.

Table 2: Performance Test Result

Quantity in peeling chamber (kg)	Peeled Nut (kg)	Mass of Broken Groundnuts (kg)	Mass of Partially or Not Peeled Groundnut (kg)	Mass of Peels (kg)	Speed (rpm)		Time Taken (s)
					N_1	N_2	
0.301	0.248	0.018	0.015	0.010	320	-	832
0.301	0.253	0.020	0.021	0.012	-	340	780

The result is in agreement with the findings of references [13, 14], which reported an increase in the damage of seeds with a consequent increase in speed. This can be attributed to the relative increase of impact force that resulted from increased speed. The machine is shown in Figure 5.


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Figure 5: Groundnut shelling machine

4. Conclusion

A modest attempt has been made to design, construct and test the portable groundnut peeling machine. Test results show that the machine performed effectively and had a peeling average peeling efficiency of 83.04% as compared with designs of references [11, 12] with lower peeling efficiencies. The machine is made up of simple components that can be easily assembled and operated, and can also handle all varieties of groundnut seeds. The machine when developed further will have the prospect to meet the need of small scale and medium firms in the groundnut oil industry. It will create employment opportunity for the designers and fabricators as well as many unemployed youths in the country, thus, leading to an improvement in their standard of living.

Nomenclature

V_s = volume occupied by a seed (cm^3)
r_s = radius of seed (cm)
V_{TS} = Volume occupied by seeds (cm^3)
r_c = radius of the cylindrical barrel (cm)
h_c = height of the cylindrical barrel (cm)
r_p = radius of the cylindrical rotary peeler (cm)
n_{ts} = Total number of seeds in the barrel.
M_{ts}= Mass of a seed (g)
A_g = Area of groundnut seed (mm^2)
ω = angular speed of shaft (rad/sec)
P = Power required for peeling (Watt)
P_p = Peeling power (watt)
P_h = Power to overcome heating loses (watt)
A_g = Area of groundnut seed (mm^2)
F_{pt} = Total peeling force (N)
T_{pt} = Total torque transmitted to rotary peeler N-m
r_g = radius of groundnut seed (mm)
L_p = Length of the rotary peeler (m)
h_p = height of the cylindrical rotary peeler (cm)
M_{ts} = Total mass of seed in the barrel (g)
P_s= Peeling strength of groundnut seed (N/mm^2)
F_p = Peeling force of groundnut seed (N)
g = acceleration due to gravity (m/s^2)
P_r = Power rating (watt)
P_f = Power to overcome friction losses (watt)

5. Conflict of Interest

There is no conflict of interest associated with this work.

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