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Full Length Research Paper

Design and Fabrication of a Portable Dry Groundnut Husk Peeling Machine

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Abstract

This research work focused on the design and fabrication of a portable dry groundnut husk peeling machine electrically powered by a 1 H.P electric motor in order to reduce the rigours encountered by the traditional (manual) method of peeling while optimizing the production of good quality groundnut seeds. Peeling is the process of removing the husk stuck to the seeds. The machine was designed, fabricated and tested. The materials for the fabrication were locally sourced which makes it cheap, easily affordable and maintainable. The performance test evaluation shows that the portable machine has a performance capacity of 36.12kg/h with a peeling efficiency of 92.14%. The digester is made up of simple components that can be easily assembled.

Keywords: Dry groundnut husk peeling, design and fabrication, locally sourced materials.

Introduction

Groundnut is the sixth most important oilseed crop in the world. It contains 48-50% oil and 26-28 protein, and is a rich source of dietary fibbers, minerals and vitamins. Groundnut is grown on 26.4 million ha worldwide with a total production of 37.1 million metric tons and an average productivity of 1.4 metric ton/ha (FAO,2003), over 100 countries worldwide grow groundnut, Shubham, 2015.

Groundnut in Latin called Arachis hypogaea contains a vegetable protein source that is essential to the diet. Primarily, this foodstuff is used for consumption and as industrial raw material in addition to being used as an additional animal food. In industry, the groundnut is used as a raw material for manufacturing cheese, butter, oil, candy and snacks, Kemala, 2016; Woodroof, 1983.

One of the processes determining the ready-consumed groundnut quality is the process of groundnut husk peeling. Groundnut husk Peeling is the last operation that is carried out in the processing of groundnut before extraction. Groundnut husk peeling aims to remove the husk stuck on the seed. Groundnut husk 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

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processing losses when large scale is involved. Recently, Manual husk peeling only results in the capacity of 4.2 kg/hour/person, causing fatigue and causing the grains to split at approximately 35%, Agus, 2012. Mechanization of the groundnut husk 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 husk to the groundnut seed; the physical and mechanical properties of the groundnut seed vary significantly with maturity time and season of harvesting (Beasley, 1963).

It is based on the aforementioned challenges that this work would extend the frontier of previous efforts with particular attention to a further development of a dry groundnut husk portable rotary peeler machine with; Increased peeling efficiency, reduced crushing of groundnut seeds, optimized production of good quality groundnut seeds and reduced rigors encountered by the traditional method of groundnut husk peeling. The significant effects accrued to the economy from the design and production of this machine are:

1). creation of local jobs both within the groundnut oil mills and the informal engineering sector.
2). farmers had a ready market provided for their seeds, often with cash prices guaranteed by the mill owners.
3). there is an increase in the quantity of peeled groundnut seeds available at affordable prices.
4). source of raw materials for pharmaceutical, soaps, cosmetics, emulsions for insect control, lubricants and fuel for diesel engines.
5). source of foreign exchange through exportation, due to its high yielding source of edible and technical oil.

This search work was carried out in the department of Production Engineering, faculty of Engineering, university of Benin with the aims to:

1). design and construct a portable groundnut husk peeling machine using a rotary peeler
2). identify and test the performance of this groundnut husk peeling machine using the rotary peeler principle.

Working Principle

The machine consists essentially of a rotary peeler enclosed in a vertical cylindrical shell lined with a soft rubber material. The groundnut is fed into the cylinder shell through the inlet into the cylinder where the roller rotates the groundnut seeds against the cylindrical shell wall which is perforated for effective peeling. The peeled groundnut kernels remain inside the cylindrical shell, while the husk goes through the perforations on the barrel wall. Husk discharged through the perforations is aided by gravity. The complete, half and broken pieces of peanut kernels left in the cylindrical shell is then collected. The machine is driven by a 1 H.P electric motor at a speed of 340 rpm. The speed of the motor is varied by the control unit when the machine is in operation. It has good effect of peeling off, long service life, reliable performance, very portable and able to add value for the people using it.

Research Method

The steps of the research are as follows:

1). Exploratory study of small scale industries/groundnut material based food product business related to groundnut husk peeling.
2). Data analysis of the result of the exploratory study, and the comparison of those results with the results of a literature search, so as to design a portable groundnut husk peeling machine that is suitable for the conditions of small scale industries/groundnut material based food product businesses, measuring the capacity needed to for groundnut husk peeling.
3). Design and fabricate a portable groundnut husk peeling machine according to the design
4). Test the performance of the portable groundnut husk peeling machine by combining the variables consisting of:

I. Motor power required (W);
II. Optimal shaft rotation (rpm),
III. Capacity of the peeling results
IV. Total volume required for effective peeling of the groundnut seeds without damaging the groundnut seeds.

Design Calculation And Analysis

The designs were on calculation of total volume occupied by the seeds and the maximum number of seeds in the cylindrical peeler barrel, power determination and shaft design.

Maximum Capacity of Barrel

According to American Society of Agricultural Engineers (ASAE), the mass of groundnut seed is between 0.22g – 1.17g. In addition, according to Davies, 2009, the average magnitudes of major, intermediate and minor diameter of groundnut at 7.6% dry basis using 100 samples are 14.42, 9.94 and 7.57 respectively. In this research work, the major diameter of 14.42mm was chosen for this analysis. Assuming the seed to be a sphere and using a diameter of 14.42mm which is equivalent to a radius of 0.72cm, the volume of seed can be determined using equation given by Archimedes:

$$V_S = \frac{4}{3}\pi r_g^3 \qquad (1)$$

Where,

V_S = Volume occupied by a seed (cm3),

r_g = Radius of seed (cm)

Where,

r_g = 0.72cm

By substitution, we have

$$V_S = 1.564cm^3$$

The total volume occupied by seeds is found using the equation for volume of a hollow cylinder

$$V_{TS} = \pi[\, r_c^2 h_c - r_p^2 h_p \,] \qquad (2)$$

Where,

V_{TS} = Total 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),

h_p = height of the cylindrical rotary peeler (cm)

Where,

r_c = 4.5cm

h_c=14cm

r_p=3.6cm

h_p =12cm

By substitution,

$$V_{TS} = 402.061cm^3$$

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

$$n_{ts} = {}^{V_{TS}}/_{V_S} \qquad (3)$$

Where,

n_{ts} =Total number of seeds in the barrel

By substituting values,

n_{ts} = 257.15

Therefore, maximum number of seeds in the barrel is 257.

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

$$m_{ts} = m_s \times n_{ts} \qquad (4)$$

Where,

m_{ts} = Total mass of seeds in the barrel (g)

m_s = Mass of a seed (g)

Where,

m_s = 1.17g per seed

m_{ts} = 300.69g

Total mass of seed in the barrel is approximately 301g

Power Determination Analysis

In accordance with the American society of Agricultural Engineers (ASAE), the peeling strength of dry groundnut seed is 0.0035N/mm^2. Assuming the groundnut seed to be a sphere, the area is found following the relationship given by McCabe *et al.,* 1986.

$$A_g = 4\pi r_g^2 \quad (6)$$

Where,

r_g = Radius of groundnut seed (mm) = 7.2mm

A_g = Area of groundnut seed (mm)

By substitution

$$A_g = 651.44mm^2$$

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

$$F_p = P_s \times A_g \quad (7)$$

Where,

P_s = Peeling strength of groundnut = $0.0035N/mm^2$

Therefore,

F_p = 0.0035 x 651.44

= 2.28N

Total peeling force for the groundnut seed is found using.

$$F_{pt} = P_s \times A_g \times n_{ts} \quad (8)$$

Where,

F_{pt} = Total peeling force (N)

Therefore, by substitution,

F_{pt} =585.96N

The total torque transmitted to the rotary peeler is found using equation given by

$$T_{pt} = F_{pt} \times L_p \quad (9)$$

Where,

T_{pt} = Total torque transmitted to rotary peeler (Nm)

L_p = Length of the rotary peeler (m) =$0.12m$

Thus, by substitution

$$T_{pt} = 70.315\ Nm$$

The angular speed of shaft is found using the equation given by

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

Where,

ω = angular speed of shaft (rad/sec)

g = acceleration due to gravity =$9.81m/s^2$

By substitution

ω=$9.04\ rad/sec$

The power required for peeling is found using the equation given by

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

Where,

P_p = Power required for peeling (Watt)

By substitution,

$P_p = 635.65Watt$

But power required for peeling in horse power (h.p) is

$$P_p = {}^{635.65}/_{746}$$

$$P_p = 0.85\ Hp$$

Since, there are friction losses and electrical losses due to heating; I therefore use 1hp electric motor to drive the machine.

Motor of Specification

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

Motor rating = 1hp = 746kw
Speed = 340rpm

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.
m_{ts} = 301g

Total weight of seed can be found from the equation

$$W_{ts} = m_{ts} \times g / 1000 \quad (12)$$

By substitution,
W_{ts} = 2.95N

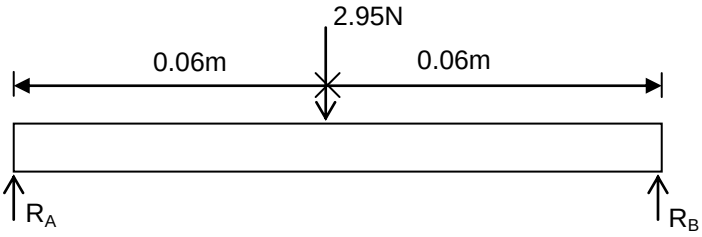

Fig. 1: The free body diagram (FBD) for the shaft loading

Considering the above figure,

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

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

$$R_B = 1.475N$$

Substituting into equation (12) the value of R_B

$$R_A = 1.475N$$

The reactions at the supports are $R_A = R_B =$ 1.475N

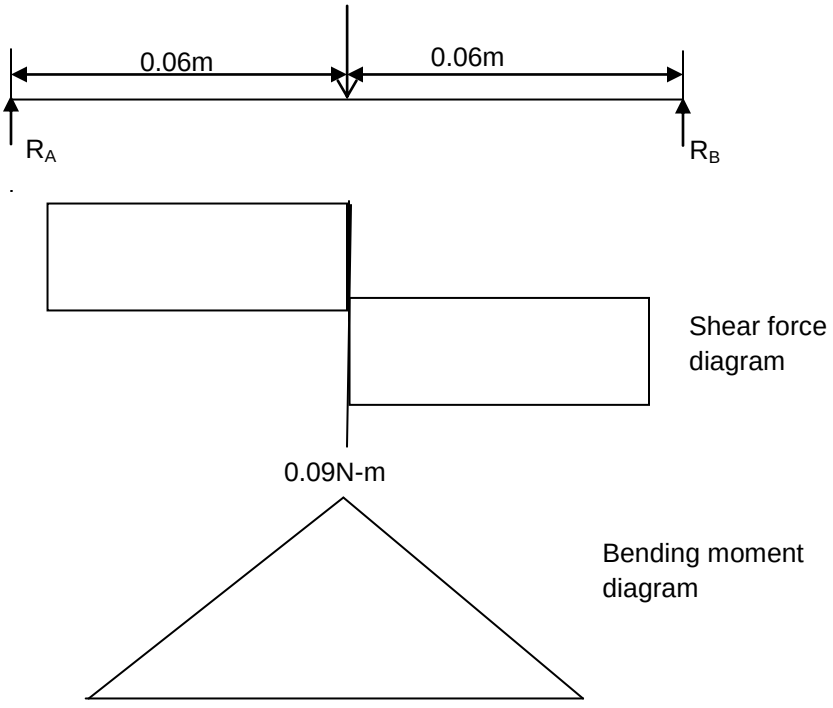

Fig. 2. Shear force and bending moment Diagram for the shaft

From the bending moment diagram above the maximum bending moment is given as

M_b = 0.09Nm

From the American society of mechanical engineering (ASME) code for shafting, the diameter is found from the equation.

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

K_b = combined shock and fatigue factor applied to bending moment for shaft with keyway
S_s = Maximum allowable stress
Ss = 40MN/mm^2 for shaft with Keyway
Kt = combined shock and fatigue applied to torsion

For gradual shaft loading for a rotating shaft,

K_b = 1.5 and Kt = 1
M_b = Maximum bending moment
M_t = Maximum torsional moment

For the shaft considered,

$M_t = 0$

Therefore,

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2}$$

By substitution,

$$d = 2.412 \times 10^{-3} m$$
$$d = 2.412 mm$$

Therefore, a shaft of diameter of 2.5mm was selected for the design.

Peeler Assembly

The various parts of the peeler model were so constructed that they fit into the spaces provided for them. The electric motor is mounted on the main base. The plastic electric motor casing which has a centre hole of diameter 3mm is 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 is then brought out through a small opening at the side of the base for onward connection to the power source while the control unit is mounted on the side of the electric motor casing.

A pulley of two slots is then fitted on the electric motor shaft. The rotary peeler is fitted into the peeling chamber having perforations at it sides to allow the peeled red skin to pass through. The unit is then fitted into a dust receiver chamber so that both the peeling and receiver chambers do not rotate as the rotary peeler is rotating. A discharge chute is at the bottom end 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.

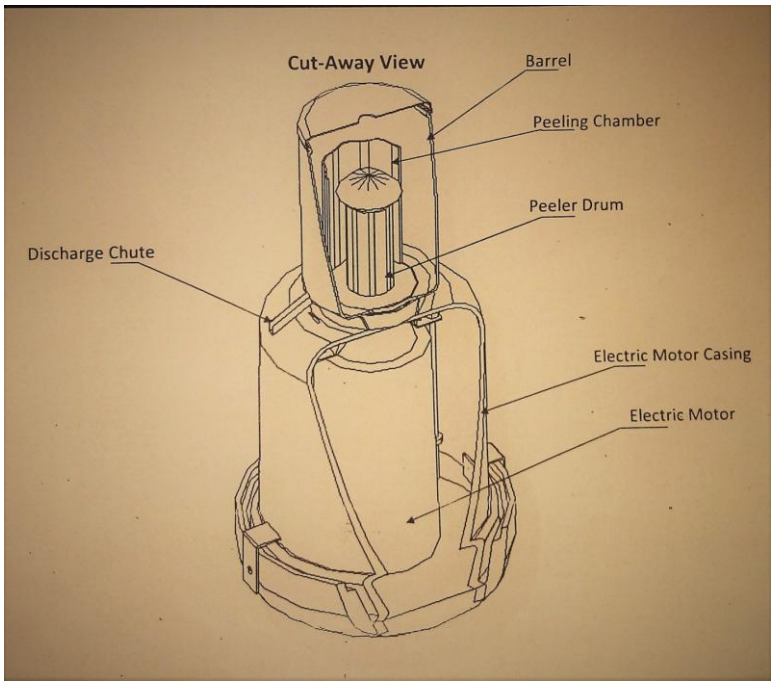

Fig 3. Cut away view of the portable peeling machine

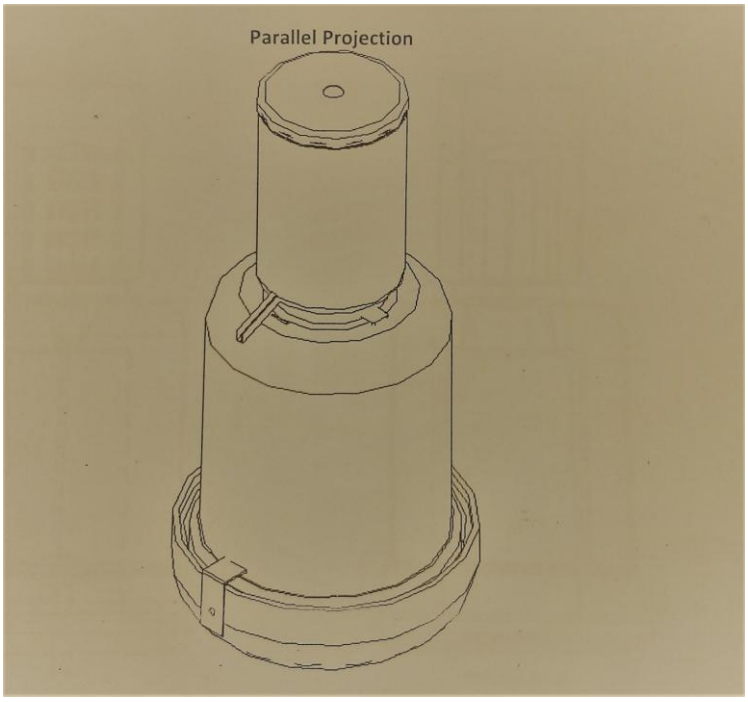

Fig 4. Parallel projection of the portable peeling machine

Performance Test of the Machine

In realizing the aim of this research work, the performance was carried out after machine parts have been assembled. The machine was started and allowed to run in order to observe the behaviour of the machine without dry groundnut seeds poured through the inlet into the machine. Test was carried out to evaluate the performance of the machine based on its peeling efficiency, time taken to peel a known weight of dry groundnut seeds and the capacity of the machine. Five samples of 257 dry groundnut seeds of equal weighted mass were fed through the inlet, each time. A stop watch was used to monitor the time taken for proper peeling per batch. A 1 – horse power electric motor was used as prime mover. After each sample was passed through the machine, the output was analyzed by physically counting the peeled, unpeeled, partially peeled, broken or shattered groundnut seeds. The peeling efficiency of the machine is made up of the sum of the peeled and shattered dry groundnut seeds. Table 1 below shows the test result for the peeling efficiency.

Table 1. Test Results on Groundnut Peeling

S/N	NO OF PEELED SEEDS (A_2)	NO OF UNPEELED SEEDS (A_3)	BROKEN OR SHATTERED SEEDS (A_4)	PARTIALLY PEELED SEEDS	NO. OF PEELED GROUNDNUT SEEDS $A_5 = (A_2 + A_4)$	PEELING EFFICIENCY (%) $= (A_5/A_1 \times 100)$
1	230	16	15	6	235	91.43
2	228	12	12	5	240	93.39
3	220	12	18	7	238	92.61
4	221	14	14	8	235	91.43
5	223	17	13	4	236	91.83

Where

A_1 = total number of seeds fed into the machine = 257seeds

The average peeling efficiency of the machine =

$$\frac{91.43 + 93.39 + 92.61 + 91.43 + 91.83}{5}$$

Therefore, the peeling efficiency of the machine = 92.14%

Capacity of the Machine

During the test performance evaluation, it was observed that it took 30seconds to peel 0.301kg of dry groundnut seeds. This means that in one minute a total of 0.602kg of dry groundnut seeds were peeled and in 1 hour, a total of 36.12kg of dry groundnut seeds can be peeled. Therefore, the capacity of the machine is 36.12kg/hr. It was also observed that some of the seeds came out unpeeled, partially peeled and shattered.

Result/Discussion

Data from the experimental result showed that for a total number of 257 seeds fed into the machine at various times, the efficiency of the machine at optimal speed varied slightly. In addition, according to [10] the average magnitudes of major, intermediate and minor diameter of groundnut at 7.6% dry basis using 100 samples are 14.42, 9.94 and 7.57 respectively. In this research work, the major diameter of 14.42mm which is equivalent to a radius of 0.72cm was chosen for this analysis and a mass of 1.17g was also used. These values are extreme values chosen to take care of the other values.

The performance result presented in table 1 shows that the peeling efficiency and capacity of the machine are 92.14% and 36.12kg/hr respectively. This performance result when compared to the research results obtained by Sutejo and Adithya on the performance test of the groundnut husk peeling that resulted in a peeling capacity around 35kg/hr with a percentage of split husks at 35% and when compared with the manual method that only produces 4.2kg/hr/person, the portable groundnut husk peeling machine using a rotary peeler could save energy and time (increasing work efficiency) and enhances productivity.

Conclusion

A portable dry groundnut husk peeling machine was designed, fabricated and performance evaluation carried out. The test result revealed that the machine has an efficiency of 92.14% and a performance capacity of 36.12kg/h. The machine is made from locally sourced materials and is made up of simple components that can be easily assembled. Local experts can maintain and operate the machine with ease. It is anticipated that the machine when commercialized will meet the need of small scale and medium scale farmers. In addition, the national economy will receive a boost since adoption of such machines will help in the production of high quality groundnut seeds and groundnut oil which when sold results in foreign exchange earnings.

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