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COMBINED SHELLING-SEPARATING MACHINE: A PANACEA FOR IMPROVEMENT IN THE TURNOVER OF SMALL-SCALE STAKEHOLDERS IN POST-HARVEST PROCESSING OF GROUNDNUT

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ABSTRACT

Human being, the prime mover that drives the wheels of survival of any nation, survives only in the presence of food. This food exists in various forms and consumes in different ways; one of this is Groundnut (Arachis hypogea). Groundnut, apart from being considered for food, creates jobs and sources of income for the teeming populace and contributes to GDP of the countries where grown. The contributions to the growths of the nation increase when processing (e.g. during post harvesting stage) is mechanized. However, in spite of the use of mechanized method of farming, the contributions are still low in developing countries, compared to the developed. Some of factors responsible for this center on the fact that the available machinery are for turkey projects, expensive and as such they are viewed irrelevant among the small scale stakeholders in the developing, based on the quantity of their produce. More so, the available ones are mono-purpose (e.g. shelling, separating, crushing, grinding, pressing, roasting/drying). In order to find solution to some of these challenges, the present study utilizes the characteristics of both pods and shells of groundnuts to develop and evaluate the performance of a groundnut shelling-separating machine. The developed machine with a theoretically throughput capacity of 20 kg/h, required 80.2 minutes to shell the designed capacity, has shelling efficiency of 76.38% and separating efficiency of 56.31% with loss of 3.125% due to crushing. Findings show that the separating performance of the separating unit increases as the shelling performance increases. It was developed at a cost of one hundred and seventy-five thousand Naira only.

KEYWORDS: Groundnut, Shelling-separating Machine, Contributions, Performance

Groundnut, also known as peanut, goober, or monkey nut, (Wiersema, 2016) and taxonomically classified as Arachis hypogaea, is a crop grown mainly for its edible seeds. Groundnut, as a legume, belongs to the botanical family Fabaceae; and as such it is called Leguminosae, but commonly called 'bean, or pea'. It is classed as: an 'oil crop' due to its high oil content as it contains 46 % mono-unsaturated fats (primarily oleic acid), 32 % polyunsaturated fats (primarily linoleic acid), and 17% saturated fats - primarily Palmitic acid (Food allergen, 2011; Oil crops for production of advanced biofuels, 2015); nut" as its fruit's ovary wall becomes hard at maturity; and sustained the name 'ground' as it exhibits habit of ripening its pods underground Groundnut is native of Brazil, South America, but reached India through Africa and China through India. It is a creeping annual crop that thrives well when planted during the raining season on sandy soil or friable soil with moderate water content to avoid decay and washing away of its seeds. It is widely grown in areas ranging from latitude 40°N to 40°S, it is normally grown by both small and large commercial producers, as a result of its oil content, food and market values. In Nigeria, it is mainly grown in the northern part of the country and accounts for this region major crop. The country ranks the leader in Africa and third producer after China and India globally (Nikita,; Pattee and Young, 1982; Freeman *et al.*, 1999; Finelib. com, 2017).

Groundnuts are mainly processed into oil for human consumption or industrial uses, the residual cake, because of its good protein source, is often used to enrich animal feed (e.g. cattle and poultry mash) or processed for human consumption. Notable products produced from the cake include kulikuli, donkua. Besides, the nuts when roasted or boiled are often consumed as desserts or with cassava flakes (Garri) in developing countries (e.g. Nigeria, Ghana) to quenching hunger, used as a substitute for melon to produce soup (called groundnut soup), and used in processed food and snacks. Also, of any quantity of groundnut grown shells or hulls account for about 25%. The shells are used for the production of alpha-cellulose, groundnut shell charcoal, activated charcoal,

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and composites of briquette and concrete bricks because of its energy- and fibre-contents (Nautiyal and Mejia, 2002). Peanuts are similar in taste and nutritional profile to tree nuts, such as walnuts and almonds, as a culinary nut and are often served in similar ways in Western cuisines.

After harvesting, the post-harvesting stage which is a semi-continuous process involves 7 stages (threshing, roasting/boiling or digesting, shelling, sifting/shell separation crushing pressing, clarification and packaging) which required various type of machines. However, over the years, most of these stages are often manually carried out, using the age-long crude implement (hoe, cutlass) and methods (e.g. mouth-shelling, hand-shelling hand-picking/sorting), by majority of the small scale holders (precisely local farmers) More so, in as much as groundnut production, alongside with its allied products, has been a target for these investors who, and also due to the fact that most of these concerned stakeholders are still finding it hard to meet their production targets as a result of the poor equipment they worked with which made it difficult for them to match operation/labour time with the production output , it becomes imperative to develop machines that could integrate/ combine some of these stages so that two (shelling and dehusking/shell-separation) or three (Drying, Shelling and Dehusking) processing stages could be simultaneously performed with single machine so as to ameliorate the yearnings of these local producers and create enabling environment to boost the production capacity. Hence, this research aimed at developing a combined groundnut shelling-separating machine using locally sourced materials that would be affordable for low and medium scale investors in rural areas.

DESIGN ANALYSIS OF COMBINED GROUNDNUT SHELLING-SEPARATING MACHINE

Research Design

This research was directed towards alleviating some of the post-harvesting challenges confronting the small-scale stakeholders that derive their livelihood from groundnut processing and at the same time boosting its output. In order to cater for these two factors, the machine was made dual – shelling and separating. Thus, the machine comprises the following three major parts: (i) shelling unit; (ii) separating unit, and (iii) the combined-power transmission unit.

(i) Shelling Unit

This is the part of the machine where shelling of the feedstock, unshelled groundnut, is done; it comprises the: hopper, neck, shelling chamber/drum, and shaft. The hopper serves as the loading bay for the feedstock; it is made trapezoidal in shape and connected to the shelling chamber by means of rectangular-shaped neck. The neck was incorporated and made lengthened to ensure smooth and steady loading/conveyance of the feedstock into the shelling chamber, and also, to prevent crushing (of nuts including unshelled feedstock), instead of shelling that might arise when the shelling chamber is suddenly clogged with feedstock due to improper loading. The shelling chamber serves two purposes; it houses the feedstock as the rotating shaft swirls them round in the clearance between the inner wall of the shelling chamber and the shaft while shelling, and it conveys the feedstock to the separating unit. The shelling chamber is cylindrical shaped.

(ii) Separating Unit

The separating unit, otherwise called dehausking unit, preforms the process of separating the shells from the nuts, it comprises: a tray, blower and sets of tension springs (vibrating system).

The design analysis was done using data expunged from findings of earlier scholars, oral interviews with local practitioners in the trade, and engineering design standards relevant to the development of the machine

Design Criteria

In carrying out the analysis in harmony with its construction, the following design criteria were considered;

- Rated shelling capacity of the shelling machine is 2.5 kg/ batch,
- design speed is 200 rpm,
- allowable shear stress in bolt is 30 MPa (ASME, Khurmi et al, 2005, pg 511)
- factor of safety of 4 (for steady load)
- ultimate stress is 54 MPa (for shaft with keyway)

The combined groundnuts shelling-separating machine was developed based on the following design considerations;

Characteristics of groundnut

- Average density of groundnut with shell is 406.2 kg/m3,
- Average length of groundnut with shell is 30.40 mm,
- Average diameter of unshelled is 13 mm,
- Average length of seed is 15.56 mm,
- Average diameter of seed is 9.74 mm, and
- Optimum moisture content is 9 %;

These data were obtained through participant observation.

Design Characteristics of the machine

- Throughput capacity of the machine is 20 kg/hr
- Density of steel is 7851 kg/m3 (Khurmi and Gupta, 2009)
- Trough loading factor of the machine is 60 %
- Number of loading (n_l) per hour is 8
- Speed of the motor is 1440 rpm,
- Acceleration due to gravity (g) is 9.8 m/s2
- Optimum speed of machine for shelling groundnuts is 200 rpm (Bobobee, 2002),
- Electric motor efficiency is 80 %
- Frequency ratio (r_f) is 0.8 (assumed), since for vibration amplification $r_f < \sqrt{2}$ (Bhatia, 2008; Sinha, 2010; Kelly, 22012)
- Density of the spring material is 7850,

Design Procedure

- The idea of designing groundnut shelling machine was conceived and the functional requirements of the machine were established.
- The different design sketches for the groundnut shelling machine representing different design assemblies were made and the best of the sketches was chosen, through ranking. The chosen sketch of the machine was detailed using AutoCAD software.
- Determining the sizes of different parts of the groundnut shelling machine: using appropriate engineering design equations and standards whilst considering the ergonomics of design.
- Standard parts, having specifications/dimensions in tandem/closest with the calculated results/data, selected and procured in order to allow for principle of interchangeability of parts,
- Manufacturing/construction of the individual components using a detailed engineering drawing as a guide.
- Assembly of the machine components as detailed in the exploded drawings
- Test running of machine and documentation of measured data for evaluating performance characteristics and degree of conformity

C Determination of the size of the Hopper

The volume is determined by evaluating the density and the capacity of the machine per hour.

The volume of the hopper can be obtained using equation (1)

Machine capacity ($\dot{m}_c$) is

Capacity per batch $\dot{m_{c/b}}$`= $\frac{\dot{m}_c}{n_l}$

20 * 5/60 = 5 kg per batch

The calculated volume of groundnut required to fill the hopper per batch Volume of the hopper,

$$V_h = \frac{m_{c/b}}{\rho_f} \quad \text{or} \quad \left[\frac{\dot{m}_c}{n_l} \cdot \frac{1}{\rho_f}\right] \tag{1}$$

= 0.006155 m^3

and the dimensions of the hopper were determined using equation (2)

$$V_h = \frac{h}{3}[L_t^2 + L_t l_b + l_b^2] \tag{2}$$

where:

Top Length of hopper = 252 mm = 0.252 m

Bottom length of hopper = 126 mm = 0.126 m

Height of hopper = 253mm = 0.253m

and the designed volume of hopper is 0.009 m^3

D Determination of the volume and selections of appropriate sizes of the shelling chamber

The shelling chamber, fabricated from Mild Steel material, is cylindrical shape. This geometrical shape was selected to ensue free flow and proper decortication of the shells as the feedstock is conveyed from the inlet to the discharge chute whilst the shaft is being rotated with the aid of the power transmission system.

The volumes (theoretical and actual) of the dryer can be determined using equations (3) to (5) respectively.

$$V^t{}_{sc} = \frac{m_{c/b}}{\rho_f} \tag{3}$$

$$V^a{}_{sc} = \varphi_f V^t{}_{sc} \quad \text{s} \tag{4}$$

and

$$V^a{}_{sc} = \frac{1}{4}\pi d_1^2 l_c \tag{5}$$

While keeping the volume fixed, a program was written in python programming language to vary the length so as to obtain an optimum diameter for the cylinder. From this, the selected dimension is 89 mmØ by 250 mm. The dimensions were considered to take advantage of principle of interchangeability of part and appropriate strategy for maintenance in case of machine breakdown

Determination of properties of the vibrating system (springs)

Mechanical spring refers to an elastic body which has the primary function to deflect or distort under load and to return to its original shape when the load is removed (Society of Automotive Engineers, SAE,)Figure 1 shows the free body diagram of the arrangement of the vibrating system. The force (F_o) required to cause oscillation of the receiving tray for proper separation of the shells from the nuts can be expressed with Newton law of motion as

$$\sum F_o = m_t.\ddot{x} + k_A.x_1 + k_b.(x_1 - x_2) = 0$$

where: k_A and k_b are the equivalent spring stiffnesses on the left and right sides of the receiving tray, and for a system subjected to dynamic excitation, the total mass (m_t) can be obtained with equation

$$m_t = m_f + (1 + \emptyset_m)\rho_t.V_t.$$

The natural frequency (ω_n) of the system is given by equation (x)

$$\omega_n = \sqrt{\frac{(k_A + k_b)}{m_t}} = \frac{\omega}{r_f} = \sqrt{\frac{\sum k_n}{m_t}}$$

The oscillatory motion of the tray caused by the periodic motion of the springs consists of transient and steady-state response, since the transient response dies with time, the dynamic force transmitted ($F_t(t)$) to each of the supporting springs during the excitation due to the working load (F)

$$F_t(t) = \frac{F}{n_{sp}}.\frac{1}{(1-r_f{}^2)}.sin(\omega t)$$

The deflections (minimum and maximum), over the stroke length (h_s) of the separating unit, due to variation in the load can be determined with equation, according to Sadhu (2004)

$$\frac{F_{min}}{\delta_{min}} = \frac{F_{max} - F_{min}}{h_s}$$

The static deflection of the spring due to the applied load can be determined with equation as:

$$\delta_{stn} = \frac{F_t}{k}$$

The number of active coil (N_a) is given by equation

$$N_a = \frac{(\delta_{st2} - \delta_{st1})}{2\pi R_m^2\,\tau_{max}} d_w G$$

The total force to be transmitted to the tray for creating the periodic oscillation required for shell-nut separation is given by equation

$$F_s = F_t(t) + N_s W_s$$

where: $W_s = \rho_s.(N_a + N_p).(\pi D_{mean,s})\pi\, d_w^2/4$ (Hinkle and Morse () p23)

acting on the system along axis of excitation the dehausking process Assuming m_t and m_f are masses of the empty tray and federate of the feedstock (in kg),

E Determination of the shelling force, Torque and Power required

The force required for performing the shelling operation comprises three forces, Gravitational force ($\boldsymbol{F_g}$), Centripetal force ($\boldsymbol{F_c}$) and Frictional force ($\boldsymbol{F_f}$). Hence, the total force ($\boldsymbol{F_t}$) required for effective decortication is given by equation (9)

$$F_t = F_g + F_c + F_f + F_s \tag{9}$$

where:

$F_g = m_f$g; $F_c = \frac{m_f v_p^2}{r_p}$; $F_f = \mu F_c$; $v_p = \frac{\pi d_p N_p}{60}$;

The coefficient of friction (μ), according to Barth (Khurmi and Gupta, 2009), can be obtained using equation (10)

$$\mu = 0.54 - \frac{42.6}{152.6 - v_p} \tag{10}$$

The torque required (T_{sm}) is given by equation (11)

$$T_{sm} = F_t r_p \tag{11}$$

The power required ($\boldsymbol{P_{sm}}$) for effective shelling is expressed in equation (12)

$$P_{sm}\ (\text{kW}) = T_t \frac{v_p}{1000\eta_m r_p} \tag{12}$$

F Determination of the speed ratios and appropriate diameters of pulleys

According to Bobobee (2002), desired speed to achieve optimum shelling operation should be 200 rpm, the speed ratio (N_r) was obtained using equation (13)

$$N_r = \frac{N_m}{N_p} = \frac{d_p}{d_m} \tag{14}$$

In order to achieve the required speed ratio, a compound pulley system. This was calculated using equation (15)

$$N_r = N_{r1}.N_{r2} \tag{15}$$

where the d_{p1} and d_{p2} are the diameters of the two sets of pulley to justify the first speed ratio N_{r1} are 50 mm and 180 mm, but due to the fact that pulley of diameter (d_{p2})was not available 190 mmØ was adopted. Also, to achieve the second speed ratio, N_{r2}, diameters of the sets of pulleys are d_{p3} and d_{p4}

G Determination of the sizes of the Shafts

The shafts are of two types, shelling and power transmission shafts. The shelling shaft is a hollow shaft utilized during for shelling the feedstock (unshelled groundnuts); it houses the power transmission shaft.

Since the machines shells by impact; its diameter is equal to the inside diameter of the shelling chamber less twice the thickness (diameter) of the unshelled groundnut. Hollow pipe was selected to reduce additional power due to twisting moment if solid pipe were used. Mathematically, the diameter of the shelling shaft (d_{ss}) is estimated using equation (16)

$$d_{ss} = d_o - 2(d_f) \quad (16)$$

The mechanical power required for effective shelling process was transmitted to the shelling shaft by means of the power transmission shaft from the electric motor. The diameter (d_t) of the transmission shaft was obtained using equation (17)

$$T_{sm} = \frac{\pi\tau}{16F} d_t^3 \quad (17)$$

with, $\tau = 0.3\sigma_{ul}$

H Determination of the lengths and selection of belts

Since the machine was developed for processing an agro-allied product; a v- type belt was adopted to prevent slipping. The lengths, $\boldsymbol{L_1}$ and $\boldsymbol{L_2}$, of the belts between the two sets of pulleys were determined from the modified equation given by Khurmi and Gupta (2005):

$$L_1 = 2c_i + \frac{\pi(d_{pi} + d_{p(i+1)})}{2} + \frac{({d_{p(i+1)}}^2 - {d_{pi}}^2)}{4c_i} \quad \{\text{with i} =1, 2\} \quad (18)$$

where c_1 and c_2 are center-to-center distances between each set of pulleys

The number of belts (n_{bt}) can be obtained using equation (19)

$$n_{bt} = \frac{P_{sm}K_a}{kW_{bt}K_cK_d} \quad (19)$$

where: K_a, is the correction factor for industrial service with value of 1.1 for light duty with operation hour over 10 to 16 hr per day (IS: 2494 - 1974)

kW_{bt} is the power rating of V-belt (A type) obtained with equation (20), in consonance with IS:2494 – 1974

$$kW_{bt} = 0.7355\left\{0.61v_b^{-0.09} - \frac{26.68}{d_e} - 1.04x10^{-4}v_b^2\right\}v_b \quad (20)$$

d_e is the equivalent pulley pitch diameter expressed with equation (21)

$$d_e = d_pK_b \quad (21)$$

K_c, K_d, K_b and d_p are the correction factor for belt length (with value of 0.80), arc of contact factor (with value of 0.88), small diameter factor (with value of 1.14) and pitch diameter of the small pulley (with value of 125 mm):

The belt speed V_b is estimated with modified equation (22) by Khurmi and Gupta (2005) (2015);

$$V_b = \pi\frac{DxN}{60} \quad (22)$$

where, N is the angular speed of motor (1440 rpm), and D is diameter of motor pulley (50 mm)

The angle of contact (ø), for the belt around auger and motor, according to (Hall et al., (1983):, can be determined using equation (23)

$$ø = (180^0 - 2sin^{-1}\left(\frac{r_2 - r_1}{c}\right))x\frac{\pi}{180} \quad (23)$$

where, r_2 is radius of motor pulley, r_1 is radius of auger pulley, and c is centre-to-centre distance between pulleys,

I Determination of Tensions in the Belts

The centrifugal Tension acting on the belt to keep it in equilibrium ($\boldsymbol{T_c}$) can be estimated with equation (24)

$$\boldsymbol{T_c = \rho_b t_b[w_b - t_b tan\beta]v_b^2} \quad (24)$$

The maximum tension (T_{max}) due to the belt tensile strength (σ_b) at factor of safety (f_s) to safe strength proper is given by equation (25)

$$T_{max} = \frac{\sigma_b}{f_s} \quad (25)$$

The relationship between the tensions in the belts, designated as T_1 and T_2, according to Khurmi and Gupta, (2009) is as expressed in equation (26):

$$2.3log\frac{T_1}{T_2} = \mu\emptyset_1 cosec\beta \quad (26)$$

where

$T_1 = T_{max} - T_c$

$$\mu = 0.54 - \frac{42.6}{152.6+v} \quad (27)$$

$\emptyset_1$ is the angle of contact on smaller pulley,

The number of belts (n_b) can also be estimated with equation (28)

$$n_b = \frac{P_{sm}}{v_b[T_1 - T_2]} \quad (28)$$

J Design for key

From Table of Proportion of Standard Parallel, Tapered and Gib head key; according to IS : 2292 and 2293 – 1974 (Reaffirmed 1992, Khurmi, 2005), it was found that for a $\emptyset 25\ mm$ shaft:, Width of key, (w_k) is 8 mm; thickness of key, (t_k) is 7 mm, and length of key, (l_k) is11 mm

MATERIALS AND METHODS

Materials

The material utilized for the development and evaluation of the machine comprises MS sheet, MS shaft, sets of pillow bearing, blower, chain and sprockets, pieces of MS bolts and nuts, 20 kg mass of unshelled dried groundnuts, yards of stainless-steel wire mesh, lengths of 40 x 40 x 3 MS angle iron, The equipment utilized for its evaluation include weight measuring scale and time counter/recorder

Details of components and materials selected, alongside with factors considered for using them for developing the groundnuts shelling machine are as detailed in Table 1. These materials also include the feedstock (groundnuts) used for evaluating the developed machine; they were all procured within Akure metropolis, Nigeria

Feedstock collection and preparation for machine evaluation

The dried feedstock procured was sieved, with mesh, to remove debris. The sieved feedstock was further sun-dried in open air-space successively over period of 1, 2, 3, 4, and 5 hours respectively. Two (2) sets of 2.5 kg of the newly dried feedstock were measured at each of the time intervals into 2 separate containers, labelled as A and B.

The purpose of re-drying the feedstock at varied time intervals is to evaluate influence of varied moisture contents on the performance of the machine. More so, the reason for effecting the drying with sunlight insolation energy centered on the fact that the investors are small scalers who might not afford the costs of electrically powered grains dryer or oven

In the course of achieving this task (sun-drying the feedstock), the evaluation was made to commence at 10.00hr (10.00 am) and end at 15. 00 hr (3.00 pm) of 25th and 26th days of November, March, 2021 (Table 2)

Experimental Procedure

Selection of Bearing

Bearing is a machine element which supports another moving machine element (called a journal). The bearing used for this project, pillow bearing. Thus, for a shaft of diameter 25 mm the corresponding bearing size is 25 mm, according to Ondrive (2012), the Specification Number is P205. The factors considered in selecting it are as follows:

- Direction of load in relation to the bearing, which is axial
- Intensity of load which depends on speed of rotation and thermal stability. It conveys live and partially moistened material, cake, at rated speed of 200 rpm
- Shaft Stiffness; grease, as a lubricant, is recommended for it which is supplied to the surfaces of contact with aid of nipples to ensure presence of adequate oil film at all time; apart from presence of film of oil in the cake which assists in offering lubricating effect to surfaces of both rotating and fixed parts of the machine every time it is in operation.

Table 1: Details of materials used for developing a groundnuts shelling machine

S/N	Machine Components	Criteria for Material Selection	Suitable Engineering Materials	Material selected	Reasons for selection
1	Frame	It should be able to withstand the periodic motion of the machine during operation	Mild steel, High Carbon steel	Mild steel	Rigid and strong, easily withstand vibration and maintain firm stability
2	Shaft	It should be able to withstand the stress and the weight of the other components attached to it	Medium carbon steel, mild steel, stainless, aluminum	Mild steel	Ability to withstand twisting due to torque moment and compressive force due to loads attached to it and affordability.
3	Power Unit	It should be able to power the whole machine components	Manually operated, electric motor, diesel engine, petrol engine	Electric motor	It is available and affordable
4	Pulley	It should be able to overcome torque from the machine and motor	Cast iron, wood, mild steel, galvanized steel, stainless steel	Mild steel	Reliability, strength, ability
5	Belt drive	It should be able to overcome torque from the machine and the motor	Rubber, leather	Rubber	Availability, flexible, self-lubricant and affordability
6	Hopper	It should be rigid and	Galvanized steel, stainless	Mild	

		support the load fed to it	steel	steel	
7	Shelling shaft	It should be able to shell the groundnut with the impact	Wood, steel, rubber	Galvanized Steel	Availability, higher efficiency
8	Delivery Chute	It should aid the movement of the nut and the shell to the outlets	Stainless steel, mild steel	Mild steel	Availability, reliability and affordability
9	Bolts and nuts	It should be to withstand the twisting moment and external loads	Mild steel, galvanized steel, high speed steel, cast iron	Mild steel	Resistance to corrosion, strength, rigidity

Table 2: Summary of the design analysis and Plate 1 shows pictorial view of the developed Groundnut shelling machine

Summary of the Design Analysis				
Parts of Machine	**Equation Number**	**Parameter**	**Calculated Results**	**Adopted Results**
Hopper (m3)	2	L, b	0.0123	0.0205
Shelling chamber Volume (m3) $*10^{-4}$	3	L, h	1.3	1.3
Shelling shaft Volume (m3) $*10^{-4}$	4	L, h	8.21	8.21
Gravitational force (N)	5	M, g	13.02	13.02
Centripetal force (N)	6	M, v, r	20.74	20.74
Frictional force (N)	7	R	5.5	5.5
shelling Power required (W)	9	T, w	171.74	171.74
Shelling shaft diameter (mm)	16		64	
Power transmission diameter(mm)	17		22.2	25. 0
Pulley sizes (mm)	10	N, D	360	50 and 180, 50 and 100
Power transmitted (W)	11	T, w	165	206
Length of belts (mm)	12	C, D_1, D_2	610 and 710	610 and 711
Number of belts	19, 27		0.2752 and 0.44	1 and 1

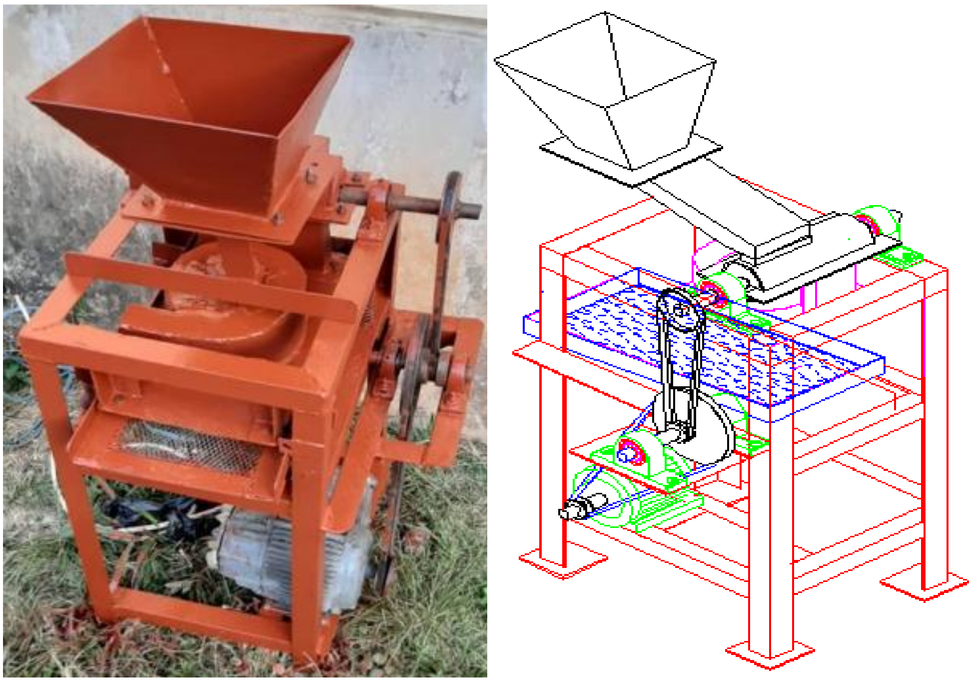

Figure 1: 3-D view of the developed Combined Groundnuts shelling-separating Machine

C Machine Description

The fabricated shelling machine has the following parts such as the Electric motor, the Hopper, the Delivery Chute for Groundnut seeds, the Delivery chute for pods, the Shelling unit, the Blower, the Frame and the Shaft (Figure 1).

D Evaluation Procedure

Two bags, labelled A and B, were filled each with 20 kg mass of the feedstock (unshelled groundnuts) measured successively on a spring balance; this was done after sun-drying them in open space to reduce the moisture content The measured mass of feedstock from each of the bag was then divided into eight sections by filling them into bags, labelled 1, 2, 3, 4, 5, 6, 7 and 8 each of mass 2.5 kg.. The machine, after switched on, was charged with feedstock from bag labelled-1 and time recorder was switched on to record the shelling time (t_{st}). The procedure was repeated successively for the entire 16 bags and the average shelling time between two bags .with similar number was used to determine the machine shelling efficiency. Table 3 shows summary of the results.

E Bill of Engineering Materials and Evaluation (BEME)

In the course of producing Groundnut shelling machine, not all the parts were fabricated within the Mechanical Engineering Workshop, FUTA; some were procured from the market. These associated costs include: bought-out items, fabrication, and Contingency. The contingency encompasses the profit and overhead; it was computed at 10 % of the production cost; whilst the Value Added Tax (VAT) was done at 5 % of the production Cost. (Table 4)

Thus, the Cost of developing 20 kg/hr rated Groundnuts shelling machine is thirty one thousand three hundred and thirty-five naira, fifty kobo (N31, 335.15).. More so, a sum of seventy five naira (N75. 00) was incurred in procuring the unshelled groundnut utilized for evaluating the machine. Table 4 shows the BEME for the development and performance evaluation of a 20 kg/h rated groundnuts shelling machine.

RESULTS AND DISCUSSION

Groundnuts shelling machine is a device used for decorticating shells of unshelled groundnuts, it comprises, basically, a trapezoidal shaped hopper, cylindrical shaped shelling chamber, power transmission shaft jacketed with hollow shaft, termed as the shelling shaft, electrical motor, sets of pillow bearings, 2 pieces v-belt and the frame structure.

The design, fabrication and procurement of parts of the machine were done in line with some design criteria and standards in accordance with the principle of interchangeability of parts in case of failure whose effects could be cushioned, if not fully prevented, when proper maintenance practice as stated above could be put into practice.

The machine, being produced at a cost of thirty one thousand, three hundred and thirty-five naira, fifty kobo (N31, 335. 15), cost of procuring feedstock (unshelled groundnuts) for performance evaluation non inclusive, was developed for rated capacity of 20 kg/hr. at speed of 200 rpm when driven by a 0.206 kW (but 0.55 kW adopted). Electric Motor at full load, considered to be 60 % of the trough loading.

Table 3: Summary of the Experimental Results

S/N	Mass of groundnut fed into the hopper (kg)	Mass of groundnut shelled (kg)	Mass of unshelled groundnut seed (kg)	Time required (min)	Shelling efficiency (%)	Mass separated	Separating efficiency
1	2.50	1.750	0.500	7.54	70.00	0.823	47.02
2	2.50	1.875	0.375	6.14	75.00	0.915	48.80
3	2.50	1.750	0.500	5.16	70.00	1.011	57.77
4	2.50	1.500	0.500	7.10	60.00	1.102	73.46
5	2.50	1.750	0.500	7.50	70.00	1.342	76.69
6	2.50	2.250	0.750	7.15	90.00	1.875	83.33
7	2.50	2.275	0.500	7.18	91.00	1.675	72.63
8	2.50	2.125	0.150	7.23	85.00	1.563	73.55
Total	20.0	15.275	3.775	55.00	76.38	8.601	56.31

Table 4: Bill of Engineering and material Evaluation (BEME)

S/ N	Items	Specification	Material	Quantity	Mass (kg)	Amount N : K
1	Shaft	Ø 25 x 500	M.S	1	463.605	2, 500.00
2	Pillow Bearing	P205		4	500	2, 000.00
3	V-Belt	A type	leather	2	150.00	300.00
4	Angle rion	40 x 40 x 5	M. S	3 length	300.00	900.00
5	Pulley	Ø 190 mm/50 mm, Ø50 mm, Ø50 mm	MS	3		200.00
	Bolts and Nuts	M10 x 20	M. S	18	10.99	180.00
8	Electric Motor	0.55 kW		1	5,000	5, 000.00
9	Paint	Ferrous oxide		3 Cans	50.00	150.00
10	Electrode	Gauge 10		1pk	1500	1500.00
11	Sheet	1220x2440 x 3 mm	MS	1	6500.00	6, 500.00
	Total (Materials)					19, 230.00
	Fabrication	Operation	Duration (Hr)	MHR (₦)	Operational cost (₦)	
		Turning Shearing Rolling Drilling Welding Painting	1/5 4 1/3 1/2 24 3	500.00 1,000.00 600.00 300.00 250.00 150.00	100.00 1,000.00 200.00 150.00 6,000.00 450.00	7, 900.00
	Contingency (10 %)					2, 7130.60
	VAT					1, 492.15
	Overall cost					31, 335.15

CONCLUSION

The study focused on the development and performance evaluation of a 20 kg/hr electrically powered groundnut shelling machine with an attached separating unit developed with locally sourced materials. The machine when tested, it has shelling efficiency of 76.38 % and separating efficiency of 56.31 % at 9.0 % moisture content. A sum of thirty-one thousand, four hundred and ten naira, fifteen kobo (N31, 415.15) one hundred and ninety thousand was expended in the cost of this research (VAT inclusive)

I hereby recommend that special steel should be used for fabricating this device in future as no effect due to inhalation of toxic substance into human blood stream is minimal.

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