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Development of a Groundnut Decorticator with an Aspiration Cleaner

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Abstract

A groundnut decorticator with an aspiration cleaner was designed, tested, and developed. It was designed to address the issue of groundnut shelling efficiency, cleaning efficiency, and groundnut breakage that has been found in several groundnut decorticators. Hopper, shelling unit, aspiration unit, collection unit, and frame make up the machine. The machine was successfully designed, fabricated, and tested on three groundnut varieties: Samnut24, Samnut25, and Virginia, at three different working speeds: 200, 250, and 300 rpm. Machine capacity, shelling efficiency, cleaning efficiency, percent whole grain, and percent broken grain are all considered. The machine has the highest capacity of 134.034kg/h at 300 rpm, a shelling efficiency of 89.35 percent, a cleaning efficiency of 85.06 percent, and a percent of whole grains of 75 percent with 5-11 percent broken grains for the three types, according to the results. The machine capacity was 81 kg/h at 200 rpm, with a shelling efficiency of 84.75 percent, a cleaning efficiency of 81.42 percent, and a percent of whole grains of 60% at 200 rpm and a percent of broken grains of 5% at 300 rpm for the Virginia groundnut variety. With the findings obtained from the machine, it is expected that this machine will be able to solve the problem of farmers by reducing drudgery in manual groundnut shelling and therefore increasing agricultural production.

I. Introduction

The groundnut or peanut (Arachis hypogaea), is an annual herbaceous legume that grows in tropical and temperate climates. Peanuts are a composite food that contains a wide range of nutrients, including carbohydrates, proteins, fats, vitamins, minerals, and a high fiber content. Peanuts have also yielded bioactive substances such as flavonoids, phytosterols, amino acids, and stilbenes. Peanut consumption has been linked to a lower risk of cardiovascular disease, type 2 diabetes, and Alzheimer's disease, according to large-scale clinical research. It's a popular food source all throughout the world, whether in the form of peanut butter, groundnut oil, or confectionary snacks. This crop is a key source of income for individuals in Nigeria's major groundnut-producing states, as well as a major source of funding for rural and other capital development projects.Syed et al. (2021) reported that peanut flour, protein concentrates and isolates, confectionaries, oils, and beverages are all made with peanuts.Groundnut is grown on sandy soils in tropical and subtropical regions of the world. Depending on the cultivation system, groundnut yields range from 400 kg to several tonnes per hectare, but on average, the global output is 2500–2700 kg per hectare. According to the United States Department of Agriculture (USDA 2009), Nigeria ranked fourth in the world in groundnut output in 2012, with approximately 1.55 metric tons.The development of a low-cost groundnut decorticator to alleviate the labor associated with shelling and minimize operational costs and time would allow the crop's tremendous potential to be fully realized. The goal of this development is to design a light decorticator made of locally sourced materials that is inexpensive and accessible to the majority of groundnut growers and processors in order to promote the production of this vital food crop. A appropriate groundnut decorticator with an aspiration cleaner had to be made for this. The design, fabrication, and testing of a groundnut decorticator with an aspiration cleaner, capable of breaking pods and separating seeds from chaff, are presented in this work.

II. Design Considerations

Physical properties of groundnuts such as size, shape, sphericity, seed weight, density, volume, surface area, and porosity, compactness, human height, and machine affordability are some of the factors considered in the machine's design.

2.1 Material Selection

Essentially, in any given engineering design, the selection of materials for a certain task must be carefully evaluated. From an economic standpoint, such a material is intended to be inexpensive while also fulfilling the exact purpose for which it was developed. In order to achieve the required objectives, the following factors were considered in the fabrication of a machine for decorticating and cleaning groundnut seed from its pods: availability of materials, durability of materials, cost of materials, and ease of construction. For these conditions and material requirements, mild steel was selected, as it is readily available and easily machined.

2.2 Machine Components

The groundnut decorticating machine is comprised of the factors discussed below:

i. Frame: It's made of mild steel, which was chosen for its ability to withstand external force without breaking (strength) and resistance to deformation under stress (stiffness). It was made of mild steel angle iron measuring 50 mm by 50 mm. It has a. 890 mm height and a horizontal base of 1320 mm. It is shown in Figure 1 and Plate I.

ii. Hopper: Before and during the shelling process, groundnuts are held in the hopper. It's for supplying groundnuts to the crushing unit on a constant basis. The groundnut hopper was chosen to allow for easy flow into the shelling chamber. The hopper was built out of 16-gauge mild steel and had a trapezoidal shape. It is shown in Figure 1 and Plate I.

iii. **Shelling Chamber:**The beater and a semi-circular sieve with a clearance of 10 mm make up the shelling chamber. A 16 mm iron rod was used to make the beater, and a 12 mm iron rod was used to make the sieve. The groundnut is crushed by the rotating beater and falls through the sieve into the aspirator, or winnowing machine, in the shelling unit. It is shown in Figure 1 and Plate I.

iv. **Aspiration Mechanism:**This unit consists of a fan with four blades, each with a diameter of 20 mm, each connected to a 20 mm shaft and suspended from the frame. The function of the aspirator assembly is to separate the shell from the seed as the seeds fall into the collecting unit due to the specific gravity difference. It is shown in Figure 1 and Plate I.

v. Collector: Is an inclined rectangular hollow trough made with 1.5 mm sheet. It is inclined in other to allow the material to flow to the collecting tray. It is shown in Figure 1 and Plate I.

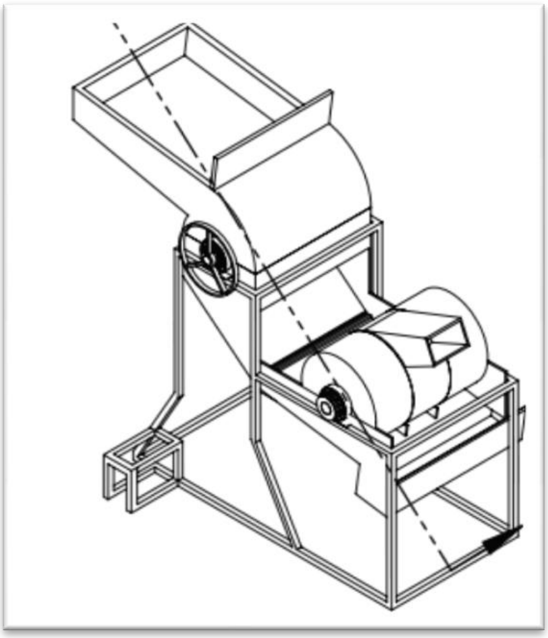

Figure 1: AutoCAD Drawing of Machine

`Plate I: The Developed Machine

III. Design Calculations

To determine appropriate sizes for the various sections of the machine, necessary design analysis and calculations were performed.

i. Determination of the Decorticator Drum Diameter

The diameter of the decorticating drum was calculated in order for the machine to work at its maximum capacity. As a result, the cylinder's diameter was calculated using the method below, which is the formula for computing a cylinder's volume.

$$V = \frac{\pi d^2}{4} \times L \quad (1)$$

$$d = \sqrt{\frac{4 \times V}{\pi L}} \quad (2)$$

Where; v is the volume (m^3), D is the diameter of the drum/cylinder (m), L is length of the drum (m)

ii. Determination of the Power Requirement of the Machine

The groundnut decorticator's power requirement is the sum of the fan's power and the power necessary for decorticating groundnuts from the pod, as shown below.

$$P_T = P_d + P_f \quad (3)$$

Where, $P_T$is the total power required by the machine (watts), P_d is the power required for decorticating the groundnut from the pod (watts), P_f is the power required by the fan (watts),,

iii. Power Required to Decorticate Groundnut from Pod.

The power required to decorticate groundnut pod was determined as reported by Khurmi and Gupta, (2008), and is given as

$$P_d = T\omega \quad (4)$$

$$\omega = \frac{2\pi N}{60} \quad (5)$$

$$T = n_a \times n_s \times F \times r \quad (6)$$

Where;P is the power required (W), T is the torque of the beater (N/ms), w is the angular velocity (rad/s), F is the force per spike required to break the groundnut pod (N), R is the distance from the axis of rotation to the point of action of the force (N), n_s is the number of spikes per anchor, $n_a$is the number of active anchors at a time

iv. Power Required by the Fan

This wasdetermined as reported by Khurmi and Gupta, (2008), and is given as

$$P_f = \frac{\mathbf{2\pi N T_f}}{\mathbf{60}} \quad (7)$$

$$T_f = (T_1 - T_2)R \quad (8)$$

Where P_f is the power required by the fan, N is the speed of the fan, $T_1$is the slack side tension (N), T_2 is the tight tension (N), R is the radius of the fan pulley (mm)

v. Determination of Belt Length

The length of decorticator drum belt was determined reported by Gana et al. (2017), and is given as;

$$L_b = \frac{\pi}{\frac{d2}{2}} + d1 + 2C + \frac{[d2 - d1]^2}{4c} \quad (9)$$

Where L_b is the length of belt, m, $D_2$is the diameter of bigger pulley (mm), $D_1$is the diameter of motor pulley, (mm), C is the center distance (mm)

vi. Determination of Angle of Contact

The angle of contact of belt between the pulley and the fan was determined in order to know the tensions which exist between the pulley and the belt. Therefore, the angle of lap of the belt between the two pulleys was calculated reported by Khurmi and Gupta, (2008), and is given as

$$\theta = (180 - 2\alpha) \times \frac{\pi}{180} rads \quad (10)$$

$$\alpha = sin^{-1}(\frac{r_2 - r_1}{C}) \quad (11)$$

Where;W is the angle of contact of the belt between the two pulley (^{0}), $r_2$is the radius of the shaft pulley (mm), $r_1$is the radius of the motor pulley (mm), C is the centre distance between two pulleys (mm)

vii. Determination of the Belt Tensions

The tension was determined so as to ascertain the power transmitted to the fan belt, therefore the tension on the two sides of an open belt was calculated reported by Khurmi and Gupta, (2008), and is given as

$$\frac{T_1}{T_2} e^{k\theta} \quad (12)$$

Where; $T_1$is theright-side tension ofthe belt (N), $T_2$is theslack side tensionof the belt (N)

φ is theangle of contact or lap of belt between the two pulleys (rad)

viii. Determination of Decorticator Shaft Diameter

This was determined to know the size of the shaft diameter that will withstand the applied loads. For a solid shaft with little or no axial load, the diameter of the shaft is determined reported by Khurmi and Gupta, (2008), and is given as:

$$d^3 = \frac{16}{\pi \varsigma_s} \times \sqrt{(K_b M_b)^2 + ((K_t M_t)^2} \quad (13)$$

Where; d is the diameter of shaft (m), $\varsigma_s$is the maximum permissible shear stress for shaft with allowance for keyways allowable stress, Kb is the combine shock and fatigue factor for bending moment, Mb is the maximum bending moment, Kt is the combined shock and fatigue factor applied to twisting moment, Mt is the twisting moment

ix. Determination of Critical Speed of the Shaft

It is obvious that the weight of the semi- circular sieve and beater will definitely have effect on the critical speed. Therefore, the need to design the shaft in order to overcome these.
The critical speed of the shaft was determined as reported by Khurmi and Gupta (2008)

$$W_S = \sqrt{\frac{48EI}{mL}} \quad (14)$$

Where, Eis the modulus of elasticity of mid steel= 0.2Nm2, Iis the moment of inertia (M^4), m is the mass of the shaft (kg), L is the length of the shaft (m)

x. Determination of Angle of Twist

The angle of twist is important as it helps to know if the diameter of the shaft is safe to carry the applied load. The amount of twist permissible depends on particular application and varies about 0.3 degree per meter for machine tool shaft and about 6degree per meter for line shafting as reported by Khurmi and Gupta (2008)

$$\theta = \frac{584 M_t L}{G d^4} \quad (15)$$

Where, L is the length of shaft (m), Mt is the twisting moment (Nm), G is the torsional modulus, (Nm^2), d is the diameter of the shaft (m)

3.1 Mode of Operation of the Machine

The machine was tested without any load at initially. This was done to ensure that the machine was in good operating order. Shearing, blowing, and separating movements are used to operate it. The shelled nuts become shelled due to shearing action as the groundnuts are fed into the shelling mechanism through the hopper (crushing). The clearance between the sieve and the beater is determined by the size of the groundnuts to be decorticated. The peanut and shells of the groundnut are dropped through the semi-circular sieve in a downward direction after they have been shelled, and the fan then provides centrifugal force to the peanut and shell of the groundnut. The seeds slid downward and collected in the collector, which is tilted to allow the material to flow to the collecting tray due to the increased weight. The shells, however, are swept up by the air from the fan and thrown outside the machine through an outlet due to their lighter weight. A 15-hp petrol engine drove the machine, which had a capacity of 400–500 kg/h. It was turned at 200, 250, and 300 revolutions per minute, respectively.

3.3 Testing of the Machine with Groundnut Varieties

Under no load conditions, the machine was first run with a prime mover (petrol engine) at a speed of 200 rpm. This was done to ensure that the machine's rotating elements operated smoothly. On the basis of the speed of rotation of the shelling drum, the machine was tested to determine its shelling efficiency (percent), cleaning efficiency (percent), machine capacity (percent), percentage of broken grains (percent), and percentage of whole grains (percent). The test used 60 kilograms of groundnut pods, with three different types weighing 20 kilograms each. The performance test was carried out with the shelling drum spinning at 200, 250, and 300 rpm. As the machine was being set up, 20kg of each kind were fed into the hopper. To determine the total groundnut recovered, the decorticated groundnut was collected and weighed. The amount of time it took to finish the shelling was noted. The weighing balance was used to weigh the healthy groundnut seeds that had been harvested. The shattered seeds were gathered and weighed as well. For each kind, the test was repeated three times at three different speeds. The decorticated groundnut was then manually cleaned and graded into whole grains and broken grains to remove some chaff. In addition, the decorticated groundnut's winnowed pods and chaff were collected and weighed separately. Following that, the following machine parameters were calculated and tabulated.

3.4 Performance Evaluation

The performance evaluation of the machine was carried out based on the machine capacity, shelling efficiency, cleaning efficiency percent whole grain percent broken grain as reported Mohammed and Hassan (2012)

Machine Capacity (kg/h)

Machine capacity is the mass of shelled groundnut in a given time and expressed as:

$$M_t = \frac{Q_s}{T_m} \quad (16)$$

Where; Q_S is the Quantity of shelled groundnut (kg), T_m is the Time (hr)

Shelling Efficiency:

Shelling efficiency is the ratio of quantity of shell groundnut to the total quantity of groundnut expressed in percentage.

$$S_{eff} = \frac{W_t - W_U}{W_t} \times 100 \quad (17)$$

Where; S_{eff} is the shelling efficiency (%), W_t is the weight of total grains (kg), W_U is the weight of the unshelled (kg)

Cleaning Efficiency: This is the degree of cleanliness of the grain expressed as η_C

$$C_{eff} = \frac{W_p}{W_p + W_c} \quad (18)$$

Where; W_p is the weight of winnowed pod, W_c is the weight of chaff that accompany the decorticated groundnut

Percent broken grain

This is the proportion of broken grains collected relative to the total quantity of grain expressed in percentage.

$$PW_b = \frac{W_b}{W_t} \times 100 \quad (19)$$

Where; PW_b is the percentage of the broken grain (%), W_t is the weight of total grains (kg), W_b is the weight of broken grains

Percent whole grain: This is the proportion of whole grain collected relative to the total quantity of grain expressed in percentage.

$$W_g = \frac{W_w}{W_t} \times 100 \quad (20)$$

Where; W_w is the weight of whole grains (kg), W_t is the weight of total grains (kg)

IV. Results and Discussion

Results

The machine was successful designed, fabricated and tested for some machine parameters which include shelling efficiency, machine capacity, cleaning efficiency, whole grains and broken grains are presented in Table 1 to 3. The machine capacity range from 104.76 kg/h to 134.03 kg/h for Samnut24 Variety, 84.75% to 130 kg/h for Samnut25 Variety, and 81.00 kg/h to 130 kg/h for Virginia Variety. The shelling efficiency range from 87.30% to 90% for Samnut24 Variety, 84.75% to 85.80% for Samnut25 Variety, and 87.50% to 90.20% for Virginia Variety. The percentage of broken grains range from 8.00% to 11.5% for Samnut24 Variety, 8.00% to 10.5% for Samnut25 Variety, and 6.25% to 5% for Virginia Variety. The shelling efficiency range from 87.30% to 90% for Samnut24 Variety, 84.75% to 85.80% for Samnut25 Variety, and 87.50% to 90.20% for Virginia Variety.

Table 1: Result of effect of varying speeds on machine performance using Samnut24 Variety

Parameters	Shelling speed (rpm)			
	200rpm	250rpm	300rpm	350rpm
Machine capacity (kg/h)	104.76	116.87	134.03	134.03
Percent whole grain (%)	66.00	66.00	65.00	65
Percent broken grain (%)	8.00	9.00	11.00	11.5
Cleaning efficiency (%)	84.77	85.57	85.06	84
Shelling efficiency (%)	87.30	87.65	89.35	90

Table 2: Result of effect of varying speeds on machine performance using Samnut25 Variety

Parameters	Shelling speed (rpm)			
	200rpm	250rpm	300rpm	350rpm
Machine capacity (kg/h)	84.75	102.16	128.57	130
Percent whole grain (%)	61.00	60.00	61.00	61
Percent broken grain (%)	8.00	10.00	10.00	10.5
Cleaning efficiency (%)	81.42	82.21	83.04	83.5
Shelling efficiency (%)	84.75	85.15	85.50	85.80

Table 3: Result of effect of varying speeds on machine performance using Virginia Variety

Parameters	Shelling speed (rpm)			
	200rpm	250rpm	300rpm	350rpm
Machine capacity (kg/h)	81.00	89.00	128.57	130
Percent whole grain (%)	68.75	72.50	75.00	76.00
Percent broken grain (%)	6.25	5.50	5.00	5.00
Cleaning efficiency (%)	85.70	87.60	88.90	88.95
Shelling efficiency (%)	87.50	89.00	90.00	90.20

Machine Capacity (kg/h)

The throughput capacity of the groundnut decorticator at 200 rpm, 250 rpm and 300 rpm respectively for Smnut24 variety was found to be 104.76, 116.87, and 134.03kg/h. 84.75, 102.16 and 128.57kg/h, for Samnut25 Variety 84.75, 102.16 and 128.57kg/h and for Virginia Varieties of groundnut it was found to be 81,89, and 108kg/h respectively as shown in Table 1-3. Samnut24 (IGS) was found to have highest throughput capacity of 134.03kg/h at 300rpm as reported by Ojo et.al., (2021). However, the throughput capacity range of 81 to 134kg/h for the three varieties is higher than those of Dandekar Sheller (50-60kg/h),Baby decorticator (40kg/h), Foot operated decorticator (25kg/h), Rubber type Sheller (40-60kg/h), engine powered groundnut shelling machine (64.9kg/h), modified of groundnut decorticator (25-30kg/h) as reported by Mohsenin 1980, power operated groundnut decorticator (50-75kg/h) as reported by Maduako and Hamman, (2004).

6.1.3 Shelling Efficiency

The shelling efficiency of the groundnut decorticator at 200rpm, 250rpm and 300rpm respectively for Smnut24 variety as shown in Table 1-3 was found to be 87.30%, 87.65%, and 89.35%. for Samnut25 Variety 84.75%, 85.15% and 85.50%, and for Virginia Variety 87.50%, 89% and 90% respectively as shown in table 1,2 and 3 respectively. Samnut24 (IGS) was found to be easier to shell than Samnut25 and Virginia Varieties, as evidence by the machine highest shelling efficiency of 89.35% at 300rpm as reported by Maduako and Hamman, (2004).

6.1.4 Cleaning Efficiency

The machine cleaning efficiency (85.06%) for Samnut24 was found to be highest at 300rpm, 83.04% for Samnut25 and 88.9% for Virginia groundnut variety in Table 1-3. The decorticating machine can be seen to be consistent in the quality of shelled groundnut seeds, judging from the fact that the cleaning efficiency of the three varieties of groundnuts compares favorably. The quality of it material handling and the final product (groundnut seeds) was found to be constant steady, no matter the varieties of groundnuts involved as reported by Ikechukwu et. al., (2014)

6.1.5 Percent Broken Grain

The percent broken grain of 11, 10 and 5% was found to be highest at 300rpm for Samnut24, Samnut25 and Virginia Varieties of groundnuts respectively, (table 4.1, 4.2and 4.3). With the percent broken grain of 5.0% obtained at 300rpm with this machine for the three varieties of the groundnuts is far better when compared with that of Cayor rotary groundnut Sheller which was reported to be 14.0% [13]and engine powered groundnut Sheller which had 14.5% as reported by Maduako and Saidu, (2006).

Conclusions

The machine was designed, fabricated, and tested satisfactorily. The machine's ability to handle all of the groundnut kinds evaluated makes it very appealing to the market. Furthermore, because the sheller is powered by an 8.0 hp petrol engine, it may be used in rural regions without electricity, but in urban areas with electricity, it can be changed with a 10 hp electric motor. This machine's advancement will boost production and utilization.

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