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# Development of Groundnut Chaff Removing Machine

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***ABSTRACT :*** *In this paper, groundnut chaff removing machine was designed and developed. The traditional method of removing chaff from groundnut kernels is by rubbing the kernels in between the palms and blowing the chaff away from the kernel with the mouth. This process is time consuming. A prototype machine is designed and developed to remove chaff from roasted groundnut kernels. The machine consist of a hopper that receives the groundnut kernels, the de-chaffing chamber with two rotating brushes where the chaff is removed from the kernel and the separation chamber, where the chaff is blown away from the kernel. The kernel falls freely under gravity in the separation chamber in the presence of a blower. The clean kernels are collected on one side of the chamber while the chaff is blown out into waste collection bag.*

***KEYWORDS:*** *De-huller, De-hulling Machine, Design, Groundnut, Legumes*

## I. INTRODUCTION

Groundnut (*Arachis hypogaea)* is a member of legumes (*Fabaceae*) family and it is very popular in West Africa especially Nigeria. It is an important food and cash crop in Nigeria. It is rich in edible oil and protein. It is widely believed that groundnut was first domesticated and cultivated in the valleys of Paraguay [1]. It is presently cultivated in about 108 countries of the world. De-hulling (removal of seed coat from a grain) after the kernel has been roasted is vital in the final processing of such seed for human consumption. For roasted groundnut, de-hulling also means de-chaffing. This is traditionally done manually by the women and children by rubbing the groundnut kernels in between their palms. The cleaning is achieved by using mouth to blow away the chaff from the kernels while the kernels are still in their palms, while the de-hulling process for other legumes such as sorghum and millet is accomplished either traditionally by hand pounding of tempered grain using pestle and mortar or mechanically using abrasive de-hullers [2]. Although, the manual de-chaffing of groundnut kernels give the maximum whole kernel counts, but the process is slow and time consuming. The machine or the automation concept is borne out of the desire to make the process faster and product more ready available in finished form in the market. There have been several attempts to make machines that de-hull legumes and other seeds such as sorghum, cowpeas, maize etc. Between 1972 and 1976, the then Nigeria's Federal Ministry of Agriculture and Natural Resources and the North-Eastern State Ministry of Agriculture and Natural Resources established a complete processing plant consisting of de-huller, hammer mill and a diesel engine to drive the equipment in Maiduguri [3]. In 1976, Ghana began research at their Food Institute using Prairie Regional Laboratory (PRL) machine to de-hull cowpeas [3]. Fetzer [4] compared the head-end and tail-end de-hulling systems including yield, investment costs, and energy consumption and providing the European and US methods of using head-end and tail-end de-hulling. He also showed the combination of front-end and tail-end de-hulling systems. In 1985, Campbell and Chubey [5] designed and developed a buckwheat de-huller capable of removing the hulls from small samples with minimum damage to the inner grout. The De-hulling process took place by passing the seed between a rotating lower emery stone and a stationary top emery stone. It was observed of also capable of de-hulling basswood seed. The project was a success. In 1979, the National Agronomic Research Centre (CRNA) in Bembey Senegal began to use PRL de-huller to de-hull sorghum and millet [6]. Schmidt [7] characterized two interrelated problems facing the South African Development Community countries and their inhabitants and proposed two developmental objectives. He noted that home de-hulling of sorghum and pearl millet had been a problem. He discussed and described the relevance of mechanical de-hullers for these grains. Oje [8] studied the physical properties of locust beans pods and seeds relevant to de-hulling. Omobuwajo et al. [9] designed a machine in order to remove the drudgery involved in de-hulling African breadfruit seeds. The machine comprised of a roller which cracks the hull with an oscillating cam follower which removes the cracked hull through repeated shearing against a stationary wall, and an aspiration unit which sifts the hull from the endosperm. Huang et al. [10] designed and manufactured a de-hulling machine for camellia oleosa seed with a de-hulling principle of extrusion and mill and a separating principle of sifting with wind. In order to reach high efficiency and low loss of mechanized de-hulling for lotus seeds, Zhang et al. [11] designed a de-huller for lotus seeds based on the cutting principle and corresponding to the physical and structure characteristics of lotus seeds. In the design of the de-huller, the lotus seeds were fed into the de-hulling channel in queue of the seeds with a certain heading orientation by using a screw expeller, and the de-hulling channel composed of two rotating supporting roller and a con-rotating cutting roller was established to realize the de-hulling of seeds. Wang et al. [12] designed a lotus seed de-huller. Lotus seed was arranged by groove on the screw rollers. And it was de-hulled by the de-hulling channel which was composed of two rotating supporting roller and a con-rotating cutting roller. While the previous works focused on the de-hulling of grains such as sorghum, attempt has not been made to de-chaff roasted groundnut kernels. Therefore, the objective of this paper is to design and develop groundnut kernel chaff removing machine.

## II. MATERIALS AND METHODS

The groundnut chaff removing machine (de-huller) consists of a simple arrangement of two shafts carrying de-hulling drums and passing through the de-hulling chamber. The hopper is a square pyramid. The de-hulling chamber is rectangular and housing two de-hulling drums. Soft materials were wrapped round the drums to perform the de-hulling jobs. Below the de-hulling chamber is the separating chamber which houses the fan that blow the chaff away from the kernel. The whole system is powered by an electric motor.

***Machine Operation*****:** The roasted groundnut kernels are fed into the de-hulling machine through the hopper. The machine is designed so that the groundnut will be falling gradually into the de-hulling drum. The rotating shaft with soft brushes will then be rubbing the kernels between the two brushes thus removing the chaff from the nuts in a process akin to rubbing those kernels in between human palms. The chaff gets peeled off due to the friction generated as the drums rub against each other. The kernel and the chaff travel towards the outlet of the de-chaffing chamber into the separator chamber where the kernels and the chaff are allowed to fall freely under gravity in the presence of a blower to separate the chaff from the seed. The chaff is blown off while the seed is collected in a container where it is packed for final storage.

***The Hopper Design:*** The hopper, Figure 1, is the part of the machine serving as inlet for the roasted groundnut into the de-hulling chamber. Stainless steel of a standard gauge (2.5mm thick) is utilized for the hopper to avoid corrosion which can eventually contaminate the product. The hopper is of the shape of a truncated pyramid. The volume is determined as follows:

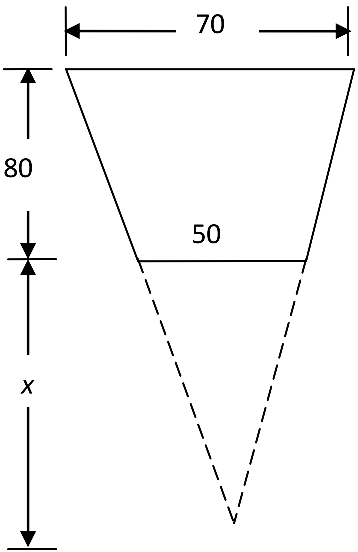


Figure 1: The hopper

From Figure 1 above, and by similar triangles,

$$\frac{x+80}{70} = \frac{x}{50} \qquad (1)$$

*x = 200 mm*

Volume of a pyramid = *1/3 AH* (2)

Where $A$ = base area

$H$ = height

Volume of the hopper = Volume of the big pyramid – volume of the small pyramid (3)

$= (1/3)[(70)^2(280) - (50)^2(200)]$

$= 290{,}666 \text{ mm}^3$

Each kernel is assumed to be a prolate ellipsoid.
From measurement taken, (Appendix A),

Average major axis, 2c = 13.75 mm
Average minor axis, $2a=2b$ = 7.35 mm
Average mass, $m$ = 0.4318 $g$ = 4.318 x $10^{-4}$ kg

Where $a$ = semi minor axis in the $x$ direction
$b$ = semi minor axis in the $y$ direction
$c$ = semi major axis in the z direction

Cross-sectional area of a kernel, $a_k = \pi ac$ (4)

$= 3.142 \times 3.675 \times 6.875$

$= 79.384\ mm^2$

Volume of a kernel = $\dfrac{4\pi abc}{3}$ (5)

$$= \frac{4 \times 3.142 \times 3.675 \times 3.675 \times 6.875}{3}$$

= 388.94 $mm^3$

The density of a material = $m/v$ (6)

Therefore, the density of the groundnut kernel = $\dfrac{4.318 \times 10^{-4}\,kg}{3.88 \times 10^{-7}\,m^3}$

= 925 $kg/m^3$

Capacity of the hopper = volume of the hopper/volume of a groundnut kernel (7)

$$= \frac{290666}{388.94}$$

= 747 kernels
= 0.322 kg/batch

***The Pulley*:**
To determine the size of the pulley, the relationship

$$nd = ND \tag{8}$$

Where $d$ = diameter of the small pulley = 125 mm
$n$ = speed of the small pulley = 1440 rpm
$N$ = desired speed of the big pulley = 300 rpm
$D$ = desired diameter of the big pulley

$$D = \frac{nd}{N} = \frac{1440 \times 125}{300} = 600\ mm$$

***The Shaft*:**
The shaft is made from mild steel with the following parameters:
Yield strength of the material, $Y = 770\ N/mm^2$
Ultimate tensile strength, $S_{ut} = 580\ N/mm^2$
Since the loading of groundnut kernel is not strong, we assume load is applied gradually,
The combined shock and fatigue factor applied to bending moment, $K_b = 1.0$
The combined shock and fatigue factor applied to torsional moment, $K_t = 1.5$
The ratio of belt tension on tight and loose sides is *3:1*
The motor rating is *750 W* at *1440 rpm*.
The permissible shear stress, τ, for the shaft without keyways is taken as 30% of the yield strength or 18% of the ultimate tensile strength of the material, whichever is minimal.
If keyways are present, the value will be reduced by 25%.

τ = 138.6 N/mm2

$$M_t = \frac{60 \times P}{2 \times \pi \times n} \quad [13] \tag{9}$$

Where $M_t$ = Torsional moment
*P* = Power rating of the motor
*n* = motor speed

$$M_t = \frac{60 \times 750 \times 1000}{2 \times \pi \times 300}$$

$M_t = 23,870$ *Nmm*

The ratio of belt tensions on loose sides is 3:1

$$P_1 = 3P_2$$

Where $P_1$ = belt tension on the tight side, $P_1$
$P_2$ = belt tension on the loose side, $P_2$

Calculating the belt tension

$$M_t = \frac{(P_1 - P_2) \times 600}{2} \quad (10)$$

$P_1 - P_2 = Mt/300$

$$= \frac{23870}{300} = 79.56\ N$$

But $P_1 = 3P_2$
$P_1 = 119.34\ N$
$P_2 = 39.78\ N$

The total tension of the belt on the pulley $= P_1 + P_2 = 119.34 + 39.78$
$= 159.12\ N$

The shaft bending moment, $M_b = 31,824$ *Nmm*

The diameter, *d*, of the shaft is obtained from the relationship according to [14]

$$\tau = \frac{16\sqrt{\left[(K_b M_b)^2 + (K_t M_t)^2\right]}}{\pi\ d^3} \quad (11)$$

$$d^3 = \frac{16\sqrt{\left[(K_b M_b)^2 + (K_t M_t)^2\right]}}{\tau\ \pi} \quad (12)$$

$$d^3 = \frac{16 \times \sqrt{(1.5 \times 31824)^2 + (1.0 \times 23870)^2}}{138.6 \times 3.142}$$

*d = 12.48 mm*
use *d = 13 mm*

***The Separator Chamber*:**
The separator is the chamber where the kernel is separated from the chaff. The unit consists of a blower mounted on a shaft and it blows on the groundnut kernels as they fall under gravity in the chamber. In the blower region, the chamber is separated into two channels so the chaff and the kernels can be properly separated.

The electric motor used for the blower in the separation chamber is 1/8 hp, 220v, blade diameter is 0.3m.
Weight of a kernel, $W = mg$ (13)
$= 4.318 \times 10^{-4}\ kg \times 9.81\ m/s$
$= 4.24 \times 10^{-3}\ N$

Mass density of air = 1.225 kg/m$^3$ (at standard temperature and pressure)

The area of the blower blade, $A = \frac{\pi\ d^2}{4}$ (14)

$$= \frac{3.142 \times 0.3^2}{4}$$

$= 0.07m^2$

Power of the electric motor = 1/8 hp = 93.25 W. But if we assume 75% efficiency, from equation B6, the velocity of the blade,

$$v = \sqrt[3]{P/\rho A} \tag{15}$$

$$v = \sqrt[3]{\frac{0.75 \times 93.25}{1.225 \times 0.07}}$$

$v = 9.29$ m/s

The force exerted by the blower on a groundnut kernel of cross-sectional area *79.384 mm²* is given by equation B7

$$F = \rho A v^2 \tag{16}$$

$= 1.225 \times 79.384 \times 10^{-6} \times (9.29)^2$

$= 8.39 \times 10^{-3}$ N

The forces acting on a kernel is shown in Figure 2,

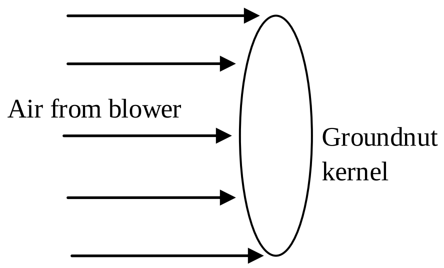


Figure 2a: a kernel being blown by air

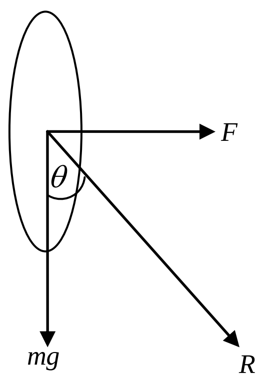


Figure 2b: Free body diagram of a kernel

$$R = \sqrt{F^2 + (mg)^2} \tag{17}$$

$= 9.40 \times 10^{-3}$ N

The angle between the resultant force and the vertical axis is given as

$$\tan\theta = \frac{F}{mg} \tag{18}$$

$$\theta = \tan^{-1}\frac{F}{mg} \tag{19}$$

$= 63^0$

## III. RESULT AND DISCUSSION

The yield of clean groundnut kernels obtained from the machine is obtained as follows

$$\text{Material rate} = \frac{Area\ of\ hopper\ outlet}{Cross-sectional\ area\ of\ kernel} \times machine\ speed\ in\ rpm \tag{20}$$

$= \frac{2500}{79.384} \times 300$

= 9,448 kernels/minute

= 4 kg/minute = 245 kg/hr

Where

Cross-sectional area of a kernel = *79.384 mm²*

Volume of a kernel = 388.94 mm³

Average mass of kernel, $m$ = 0.4318 $g$ = 4.318 x $10^{-4}$ kg
Mass density of a kernel = 925 $kg/m^3$
The machine is expected to work continuously for eight (8) hours and deliver 2 tons of clean groundnut kernels during this period..

## IV. CONCLUSION

The groundnut chaff removing machine was design and developed. Since groundnut is cash as well as food crop, many families and food industries depend on it as food and raw material. Development of chaff removing machine is a welcome idea. This will increase the productivity of such industries and bring down the cost of their final products.

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**APPENDIX A**

| SAMPLE | Mass (g) | Major Axis (mm) | Minor Axis (mm) |
|---|---|---|---|
| 1 | 0.486 | 14.0 | 7.5 |
| 2 | 0.481 | 14.0 | 7.0 |
| 3 | 0.629 | 15.0 | 9.0 |
| 4 | 0.470 | 14.0 | 7.5 |
| 5 | 0.492 | 14.0 | 7.5 |
| 6 | 0.300 | 14.0 | 6.0 |
| 7 | 0.505 | 15.0 | 7.5 |
| 8 | 0.234 | 14.0 | 6.0 |
| 9 | 0.414 | 12.5 | 7.5 |
| 10 | 0.307 | 11.0 | 8.0 |
| Total | 4.318 | 137.5 | 73.5 |
| Average | 0.4318 | 13.75 | 7.35 |

**APPENDIX B**

*Useful Derivation*
From the first principle, force, F is given in equation B1 as

$$F = ma = m\frac{v}{t} = \frac{m}{t}v = \dot{m}v \qquad \text{(B1)}$$

And work is given in equation B2 as

$$W = F \times s = \frac{m}{t} \times v \times s = m \times v \times \frac{s}{t} = mv^2 \qquad \text{(B2)}$$

The expression for power is given in equation B3

$$P = \frac{W}{t} = \frac{F \times s}{t} = \frac{m \times a \times s}{t} = m \times \frac{v}{t} \times \frac{s}{t} = \dot{m}v^2 \qquad \text{(B3)}$$

and density is

$$\rho = \frac{m}{V},$$

$$\therefore\ m = \rho V = \rho A s$$

The mass flow rate is given equation B4

$$\dot{m} = \rho \dot{V} = \rho \times A \times \frac{s}{t} = \rho A v \qquad \text{(B4)}$$

Equation B4 is substituted into equation B3 to give equation B5

$$P = \rho A v (v^2) = \rho A v^3 \qquad \text{(B5)}$$

$$v = \sqrt[3]{P / \rho A} \qquad \text{(B6)}$$

Substituting equation B4 into equation B1 gives

$$F = \rho A v^2 \qquad \text{(B7)}$$

Where
*a* = acceleration
*A* = area
*F* = force
*m* = mass
$\dot{m}$ = mass flow rate
*v* = velocity
*V* = volume
*s* = distance
*t* = time
*ρ* = density
*W* = work done
*P* = power