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MODIFICATION AND DEVELOPMENT OF A MANUALLY OPERATED AND MOTORIZED MELON SEED SHELLING/SEPARATING MACHINE

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ABSTRACT

Melon shelling and separating/cleaning is usually done manually by hand in most part of the world. However, this method used to be time consuming and strenuous. To address such challenges, a machine for shelling the melon seeds and separating melon seeds from the chaff on a small scale was modified, developed and evaluated. The machine was constructed using locally available materials, and consists of shelling unit and separating/cleaning unit. The shelling unit was developed using impact method and consists of hopper, shelling drum, shelling vanes and shelling disc, outlet throat, chamber cover, collector, AC motor, bearing, manual operating handle, belt and pulleys. The separating/cleaning unit consists of blower fan, separator case, case cover, and base. A 1 Hp electric motor of 1400 rpm speed was selected to give 700 rpm speed on the drive shaft with a velocity of 5.87m/s and a torque of 10.18Nm. A blowing fan of 1950 rpm and 290mm blade diameter was selected to blow off the chaff for the seed to be discharged from outlet throat of the separating unit. Shelling efficiency at dry condition was 71.4% and at wet condition (moisture content of 21.4%) was 86.7%. The shelling and separating units performed satisfactorily and therefore recommended for domestic and commercial shelling of melon seeds. Adoption of this machine for shelling operations will go a long way in boosting the production of vegetable oil obtainable from melon seed for consumption.

KEYWORDS: Shelling, separating/cleaning, melon seed, moisture content, shelling efficiency

INTRODUCTION

Melon according to Aguayo and Artes, (2004), has 18 metric tons grown annually, and the fourth most important crop in the world in terms of production. It is also one of the highly cultivated and consumed oil seed crop in Nigeria and West Africa. The main cultivars found in Nigeria are *Bara, Serewe and Sofin. Bara* which is also known as papa has large brown seeds with thick black edges thickened towards the apex, about 16 x 9.5 mm and is common in the northern and western part of Nigeria. They are also found in eastern Nigeria and its shelled kernel could be grounded into thick paste or sprinkled into a soup or a stew and can be used as raw material in the production of margarine, salad local pomade, soap while its shell could be used as poultry litter (Bankole et al., 2010; Egbe et al., 2015; Shittu and Ndrika, 2012; Ogbe and George, 2012). Melon seeds are highly nutritious, providing the human diet with good quality proteins of about 26.2-37.4% and oil content of about 47.3-50 (Norton, 1993; Ogbonna and Obi, 2007; Ajibola, et al., 1990; Omidiji, 1997). It contains about 41.51% essential amino acids and other essential nutrients (Sabo et al, 2015; Achu et al., 2005).

Melon seed is also a good source of minerals, vitamins, oil and energy in form of carbohydrates (Olaniyi, 2008). Through fermentation, coring, washing, drying, shelling and oil extraction it can be processed to further diversify its use (James et al., 2011; Nwakire et al., 2011).

Shelling and cleaning is considered as one of and important postharvest processing of melon to its finished products. However, this operation is usually associated with some impediments such as high expenditure of human energy. The inability to effectively shell melon to meet the requisite capacity necessary for industrial utilization is also a great hindrance to its use for large scale production of various commodities (Adekunle et al., 2009). This conventional, traditional or manual method of shelling melon according to Pradhan et al, (2010), is considered to be inefficient, tedious and time consuming, such that the availability of their products in the market is limited. In addition, such unmechanized method also results in bruising and serious injury to the human fingers, coupled with low productivity (Nkakini, et al., 2007).

It is expedient that small and medium scale farmers in Nigeria have a satisfactory, cheap and effective means of mechanized melon shelling technique. However, their exist different forms and types of melon shellers according to the source of power which can be classified as, manually, electrically powered or fuel-driven melon shellers. Several researchers have reported the result of investigating the development and use of mechanical systems to address the problems associated with the traditional methods of shelling. Also, substantial research work has been carried out on mechanical melon devices to ease the shelling operation.

Fashina, (1971) constructed a melon seed shelling machine which works on the principle of bending by feeding seeds through sets of rollers having ridges on their surfaces. Odigboh, (1979) designed an impact *egusi* shelling machine that works on the principle of centrifugal impact force from spinning disc. Also, Fadamoro, (1999) constructed a manually operated melon sheller that works by frictional forces between rotating and stationary discs. Melon shelling by extrusion method was discovered by Obienwe, (2002). Several other mechanically operated melon shelling machines have been developed by Rotimi, (2006); Babale, (1988); Adedoyin, (2015); Adekunle et al., (2009). Reports have shown that most of those machines were found to have low shelling efficiency and high seed damage.

However, factors affecting the shelling efficiency and percentage of seed damage include: seed moisture content, crop variety and inclination or design configuration of beater (Fashina, 1971; Odigboh, 1979; Okokon et al., 2010).

Studies by Oloko and Agbetoye, (2006) showed that these machines have average yield rates not more than 30%. These low efficiencies according to Ebe et al., (2015) could be due to the lack of process optimization (rotational speed of machine impeller, feed rate of melon seeds during shelling, moisture content of seeds, and impact force of machine impeller) during the operation. Therefore, the need to modify the existing melon shelling machine using impact method for operation to obtain higher efficiency and more productivity becomes necessary.

MATERIALS AND METHODS

The modified melon shelling machine consists of four sections, which include: the hopper, the shelling chamber, the prime mover and the separator. The hopper is made up of four welded galvanized plate slanting towards an opening to form a trapezoidal cross section. It has two openings. The larger upper opening is for discharging the unshelled melon seeds into the shelling unit while the smaller lower opening connects the hopper to the shelling chamber. The fabrication procedure consisted of marking of 155 mm x 600 mm dimension for the larger upper opening and 12000 mm x 17000 mm dimension for the smaller lower opening and a height of 150mm. The marked sheets were cut and the plates were then welded to form the trapezoidal shape.

The shelling chambers consist of shelling drum, shelling disc, chamber cover and outlet throat. The shelling drum is designed from mild steel sheet metal and lined internally with rod of 3 mm thickness at an interval of 10 mm distance through the diameter. It is designed such that the melon can hit the rods of the shelling drum in order to cause the breakage of the chaffs.t the shelling disc is designed with impeller blades (vanes) at an angle 45^o in order to make the melon seeds collide with the rough body of the shelling drum to allow for the breakage of the chaff. The outlet throat is designed from mild steel of 1900 mm x 1200 mm and 3200 mm in length and inclined at an angle so that the shelled melon seed can easily come out with gravitational support.

The prime mover is made up of a 0.75 KW electric motor of 1400 rpm to give a velocity of 5.87 m/s. The motor has a pulley diameter of 80 mm linked with a V- belt to a pulley of diameter 160 mm to give a speed reduction of 700 rpm.

The separating unit consists of a separator case made of 2 mm thick mild steel of 205 mm x 106 mm and 106 mm x 107 mm for the outer and inner section respectively with a height of 108 mm and a compartmentalized collector inserted in the separator case. An axial suction fan of 1950 rpm and 290 mm blade diameter was selected to blow off the chaff. The blower is encased in a box of 503 mm x 503 mm x 608 mm. The separating unit has a case cover to prevent littering of shelled melon and chaff to the environment.

When each of the components has been fabricated, the components were welded to the shelling chamber which consists of the shaft and the shelling disc with vanes. The hopper being at the top while the outlet throat is located at the front of the shelling chamber. The assembly was then fitted by bolt and nut to the support frame which in turn is fitted to the bench support made of the materials used in the fabrication are readily available, cost effective and possess the required physical and mechanical properties. Activities performed during fabrication of the machine include: marking out, folding, bending, welding, drilling, turning and fittings.

Design Considerations

A machine should be technically correct and operated as predicted and also be capable of performing the purpose of the proposed application. It is however important that a melon sheller should also satisfy process requirement throughout its service life and incorporate the design features of durability and hygiene. The following factors were also considered in the design of the melon seed sheller: (i) availability of raw materials for construction; (ii) physical and mechanical properties of the material; (iii) cost effectiveness (iv) power requirement; (iv) ease of fabrication, assembling and dismantling.

Design Analysis

Design and selection of materials for this machine is significantly influenced by the properties of melon seed (Davies, 2010; Sobowale et al., 2015). Proper and adequate considerations were given to the design for the capacity and size of the machine, power requirement, speed of the pulley, length of the belt, pulley and belt size, diameter of the shaft and electric motor specifications.

Hopper capacity

The cross-section of the hopper looks like frustrum of a pyramid,

According to Moise, (1967),

Volume of frustrum of a pyramid (V) = $\frac{1}{3}$ h $\left(B + B^1 + \sqrt{BB^1}\right)$ (1)

Where,

B= the area of large base = 84,000 mm^2, B^1 = the area of small base = 20,000 mm^2, h = altitude of the frustrum = 210 mm, therefore, V= 7.6 x 10^{6}mm^3.

Pulley size

According to Ringin, (1982)

$N_1D_1 = N_2D_2$ (2)

where, N_1 = speed of driving pulley = 1400 rpm, N_2 = speed of driven pulley = 700 rpm, D_1 = diameter of driving pulley = 80mm (0.08 m), D_2 = diameter of driven pulley, calculated as 160mm (0.16 m)

Belt speed

$V = \frac{\pi N_1 D_1}{60}$ (3)

$V = \frac{3.142 \; x \; 1400 \; x \; 0.08}{60}$ = 5.87 m/s

Belt length

According to Khurmi and Gupta, (2005), the belt length is determined by equation 4a

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{D_2 - D_1}{4C} \quad (4a)$$

And the centre to centre distance between driving pulley and driven pulley is given by equation 4b

$$C = \left(\frac{D_1 + D_2}{2}\right) + D_1 \quad (4b)$$

L = Length of Belt, D_2 = Diameter of Pulley on Shaft, D_1 = Diameter of Pulley on Electric Motor C = Centre Distance Between Pulleys.

Thus,

$C = \left(\frac{80 + 160}{2}\right) + 80$ = 200 mm

Therefore, L = 2(200) + $\frac{3.142}{2}(80 + 160) + \frac{160 - 80}{4(200)}$ = 777.1 mm,

From table 1, the nearest standard belt length of 823 mm is chosen since the power rating is 1 hp (746 Watts).

That is, A 823 – IS: 2494 belt

Wrapping angle (α)

Using equation 5 the angle of wrap (α) was calculated as follows:

$$\text{Sin } \alpha = \frac{R - r}{C} \quad (5)$$

Where:

R = 80 mm, r = 40 mm and C = 200 mm,

Thus,

Sin α = $\frac{80 - 40}{200}$ = 0.2

α = 11.54^{o}

Belt tension

The cross-sectional area of the belt is obtainable from table 2. Check for belt A 823 – IS: 2494.

The top width (b) is 13 mm while the thickness is 8 mm.

The groove angle 2β is 32^o from table 2. From trigonometry, other two angles are 74^o each.

The belt cross-sectional area is obtained from the area of trapezium,

$$A = \left(\frac{a+b}{2}\right) h \qquad (6)$$

Where, a = 8.42mm from trigonometric ratio with $\alpha = 11.54^o$, b = 13mm and h = 8mm

Belt cross-sectional area is then calculated as 85.68 mm^2

Also, from table 1, Weight per unit length = 1.06 N/m, therefore, F = 0.88 N for 823 mm belt length (i.e., 1.06N/m x 0.823m)

Where m = 0.09 kg if g = 10 m/s^2, from F= mg

$$T_1 = T - T_c \qquad (7)$$

Where T_1 = tension in the tight side and T_c = Centrifugal tension

$$T_c = mv^2 = 3.07N \qquad (8)$$

Where, T = maximum tension in belt

T = 309.5 N

Therefore, T_1 = 306.4N

To calculate T_2 (tension in the slack side of belt)

$$2.31\log\left(\frac{T_1}{T_2}\right) = \mu\theta\operatorname{cosec}\beta \qquad (9)$$

Where, $\mu = 0.02$ from $F = \mu R$, $\theta = 180 - 2\alpha = 180 - 2(11.54) = 156.92^o = 2.74$rad.

$2\beta = 32^o$ from table 2, therefore, $\beta = 16^o$

$$2.31\log\left(\frac{306.6}{T_2}\right) = 0.02 \; x \; 2.74 \; x \; cosec \; 16^o$$

T_2 = 254.4N

Torque, T = $\frac{60\,P}{2\,\pi\,N_2}$

Where, P = 1hp = 746 Watts

Torque, T = 10.175 Nm

Bending moment, M = $(T_1 + T_2 + 2T_c) = \left(306.6 + 254.4 + 2(0.883)\right) = 562.67Nm$

Te (equivalent twisting moment) = $\sqrt{T^2 + M^2}$ (10)

Te = 565.26Nm

Shaft Diameter

d = $\sqrt[3]{\frac{16T}{\pi\,S_s}}$ where, S_s = shear stress (11)

Taking allowable shear stress of steel (S_s) = 100MPa (Khurmi and Gupta, 2005)

Therefore, d = 8 mm = 0.008 m

Since the diameter used is based on allowable shear stress, it can therefore withstand twist. By selecting a shaft of 16mm for the fabrication,

The torque is calculated to be 8Nm

Transmitted Power, P

P = $\frac{2\,\pi\,N\,T}{60}$, (12)

P = 586.4 Watts which is less than the 1hp used

This justifies for the 16 mm shaft used.

Table 1: Dimensions of standard V-belts according to IS: 2494-1974.

Type of belt	Power ranges in KW	Minimum pitch diameter of pulley (D) mm	Top width (b) mm	Thickness (t) mm	Weight per metre length in Newton
A	0.7 – 3.5	75	13	8	1.06
B	2 – 15	125	17	11	1.89
C	7.5 – 75	200	22	14	3.43
D	20 – 150	355	32	19	5.96
E	30 – 350	500	38	23	-

Table 2: Dimensions of standard V-grooved pulleys according to IS: 2494-1974.

Type of belt	w	d	a	c	f	e	No of grooves (n)	Groove angle (2β) in degrees
A	11	12	3.3	8.7	10	15	6	32, 34, 38
B	14	15	4.2	10.8	12.5	19	9	32, 34, 38
C	19	20	5.7	14.3	17	25.5	14	34, 36, 38
D	27	28	8.1	19.9	24	37	14	34, 36, 38
E	32	33	9.6	23.4	29	44.5	20	-

Note: Face width (B) = (n – 1) e + 2f

Source: (Purohit and Sharma, 2003)

Terminal Velocity

Pneumatic separation of melon involves the separation of coating seed from the melon seed with the aid of air stream. The design of fan for effective separation takes advantage of the variation in the aerodynamic properties of the coating and the melon seed. The fan speed is regulated greater than the terminal velocity of the coating and less than that of the seed. The air is made to pass through the falling shelled seed to blow off the coating while the seed falls by gravity into the collector. A blowing fan of 1950 rpm and 290 mm blade diameter was selected. The terminal velocity of the shelled seeds and chaff was determined using equation 13 as follows:

$$Mg = \frac{1}{2} P V_t^2 C_d A \tag{13}$$

Where:

M = mass of the object (kg)

g =gravitational acceleration (m/s^2)

C_d = drag coefficient

p = air density (kg/m^3)

A = projected area (m^2)

V_t = terminal velocity (m/s)

(Mohsenin, 1970)

Principle of operation

Unshelled melon seeds are fed into the machine through the hopper which open directly into the impeller blade of the shelling unit. The machine works based on the impact energy absorbed by the seed and a rough surface stationary wall of the shelling unit. The shelling disc has a pulley-belt arrangement from which it is driven by a motor and can also be hand driven. It is thus manually operated by a handle or an electric motor. The collision causes the cracking and removal of the seed coat. The cracked and chaffs pass through the outlet throat into the separating unit where the chaffs are blown off while shelled melon seed come out with gravitational support.

Figures 1, 2 and 3 show the orthographic projection, exploded view and isomeric view of the machine respectively while figure 4 shows the photograph of the fabricated machine.

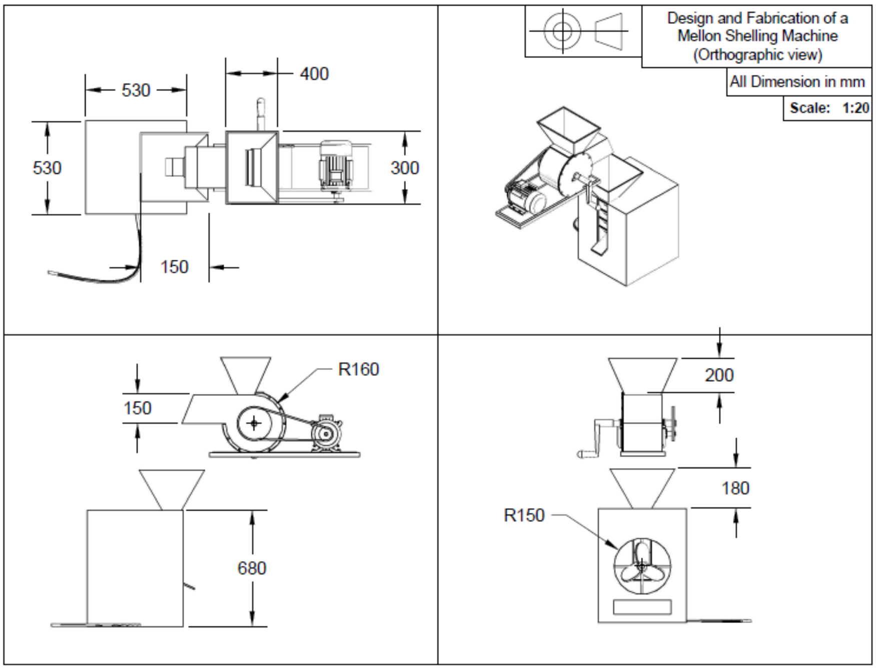

Figure 1: Orthographic projection.

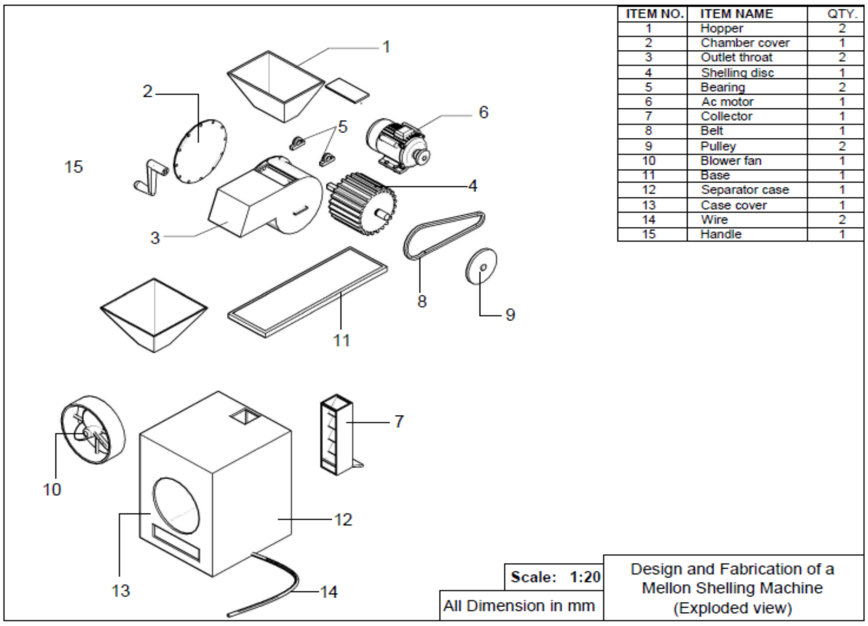

Figure 2: Exploded View.

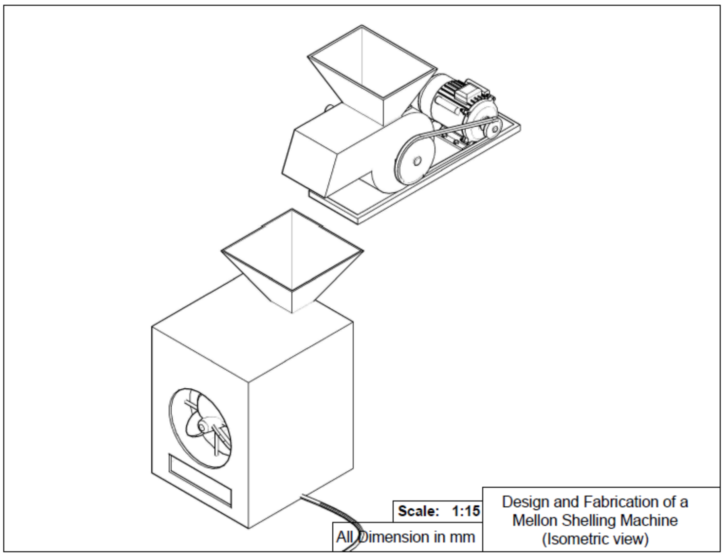

Figure 3: Isometric View.

Figure 4: Photograph of the Shelling/Separating Machine.

Evaluation method

The performance evaluation was carried out using the fabricated machine to shell the *Serewe* type of melon in both dry and wet conditions. For the dry condition, the melon was weighed using a digital weighing balance and then shelled and reweighed after shelling to know the weight of the shelled and unshelled, broken shelled and broken unshelled. The same procedure was repeated for the wet condition after the melon was moisturized for about twenty minutes and the optimum moisture content was determined. The shelled melon and the chaff was dried and fed to the separating unit and the optimum number of times needed to be fed was determined.

RESULT AND DISCUSSION

Dry condition

Mass of dry melon = 125g

Mass of completely shelled melon = 5g

Mass of broken shelled = 45g

Mass of unshelled = 20g

Mass of broken unshelled = 0

Mass of chaff = 55g

Total mass after chaff separation = 70g

Efficiency in terms of complete shelling = $\frac{mass\ of\ completely\ shelled\ melon}{total\ mass\ after\ separation}\ x\ 100$

$$= \frac{5}{70}\ x\ 100 = 7.1\%$$

Shelling efficiency = $\frac{mass\ of\ shelled\ melon}{totalmass\ after\ separation}\ x\ 100$

Shelling efficiency = $\frac{50}{70}\ x\ 100 = 71.4\%$

Wet condition

Mass of melon = 140g

Mass of melon when moisturised = 170g

Moisture content = 30g = 17.6%

Total mass after shelling and separation of chaff = 75g

Mass of completely shelled melon = 45g

Mass of broken shelled = 20g

Mass of unshelled = 10g

Mass of broken unshelled = 0

Mass of chaff = 65g

Efficiency in terms of complete shelling = $\frac{mass\ of\ completely\ shelled\ melon}{total\ mass\ after\ separation}\ x\ 100$

$$= \frac{45}{75}\ x\ 100 = 60\%$$

Shelling efficiency = $\frac{mass\ of\ shelled\ melon}{totalmass\ after\ separation}\ x\ 100$

Shelling efficiency = $\frac{65}{75}\ x\ 100 = 86.7\%$

DISCUSSION

The evaluation above shows that the melon should be shelled in the wet condition with optimum moisture content of 17.6%. shelling efficiency without breakage for dry condition is 7.1% while that of wet condition gives 60%. Shelling efficiency including broken shelled at the dry condition dives 71.4% while that of the wet condition gives 86.7%. Therefore, the best result could only be obtained in the wet condition.

However, during the experimentation, it was discovered that the chaff separation is to be carried out three times for optimum result.

CONCLUSION

A melon shelling machine which operates manually and by using an electric motor as its prime mover has been designed. In addition, it has a separating unit which uses electrically operated fan. It is safe, easy to operate and consume less operation time. Ergonomics has also been put into consideration during the design and fabrication procedure. The materials used are cheap and sourced locally. The machine can be used for domestic and commercial purposes to enhance the production and processing rate of melon.

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