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Designing and fabrication of Low-cost Melon Seed De-husking Machine using locally sourced Materials

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ABSTRACT: A Melon shelling machine was designed, constructed and tested in order to reduce the stress associated in manual shelling of melon process. The melon shelling machine was made from locally sourced machine parts which were assembled by machining and joining processes. The machine operates on the principle of friction as opposed to the use of an impact force in the shelling chamber for shelling melon seeds. This results in minimum seed breakage thus, reduces the amount of wastage involved in the mechanized processing of melon seed. This machine consist of a feed hopper, shelling chamber, gear unit and electrical motor unit. The melon shelling machine operates at a maximum shelling speed of 1400rpm, feed rate of 4g per minute and a shelling efficiency of 75.2%. The effect of moisture content of melon seeds regarding the shelling performance was considered and the result shown that 10ml of water in 36.6g of melon yields good shelling efficiency.

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Melon (Citrullus vulgaris) is widely cultivated food product in Nigeria among other seedlings during the planting season yearly. Several tons of melon seeds are gathered each harvesting period but only a very small percentage of the total harvest are dried by atmospheric draught and bagged for storage. A high percentage of waste is usually incurred in melon seeds processing due to lack of good processing and storage facilities (Adekunle 2009, Akoh *et al.,* 1992). Melon seeds when properly processed yield a lot of by-products, which could be used as food, feed or as raw materials for the small, medium and large-scale industrial manufacture outputs (Adekunle *et al.,* 2009). The major problems encountered in the processing of melon seeds are the removal of the yellow outside shell and the separation of the broken shells from the white seeds. Locally, in the current situation, manual method is being used for the commercial shelling and separation of melon seeds. Also, the little mechanized approach available presently is not efficient because the melon seeds are broken and no longer uniform upon removal from the de-husking machine. Therefore, an efficient and mechanized method of de-husking (shelling) and separation processes is capable of increasing productivity, reducing processing time and bringing down human labor input to the nearest minimum (Adekunle 2009, Akoh *et al.,* 1992). These problems arising from the manual de-husking and separation of the melon whitish seeds from the shells necessitated the idea of design, construction of an efficient melon de-husking and separation machine for our local communities and industries (Akpan 2004, Egbuta *et al.,* 2003). Post-harvest processing of melon is usually associated with some difficulties such as seed extraction and seed shelling. In Nigeria substantial research 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 principles of being by feeding seeds through set of rollers having ridges on their surfaces. Odigboh (1979) designed an impact Egusi shelling machine that works on the principles of impact force from spinning disc. Also, Fadamoro (1999) constructed a manually operated melon Sheller that works by frictional forces between rotating and

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stationary disc. Melon shelling by extrusion method was discovered by Obienwe (2002). Other researchers that has ever tried shelling melon mechanically are: Rotimi (20060, Kafi (1980), Adamu (1981), ringing (1982), Bable (1988), Mohammed (1989) and Adekunle *et al* (2009) most of those machines were found to have low shelling efficiency by high seed damage. Machine-crop parameters such as moisture content, crop variety and inclination or configuration of beater were identified as factors affecting machine shelling efficiency and percentage seed damage (Fashina, 1971: Odigboh, 1979: Adamu, 1981: Mohammed 2003 and Okon *et al.*, 2010).

Previous works revealed that post-harvest melon seed shelling is characterized by low shelling efficiency and high seed damage. Hence, the aim of this work is to design and fabricate a low-cost melon seed de-husking machine using locally sourced material capable of high shelling efficiency and low seed damage

MATERIALS AND METHODS

The melon shelling machine applies engineering principles in producing a desired output which is the shelled melon. As stated in previous chapter, melon is one of the most consumed soup ingredient in Nigeria which means a greater consideration must be taken to provide a controlled fabrication process as to prevent breakage of the melon or food poisoning due to corrosion of metal sheet. Therefore, for optimum performance and easy maintenance of the melon shelling machine, the following factors given by (Starkey, 1988) will be taken into consideration

1) Simplicity of design to meet the required standard and specifications
2) Mechanical strength of the materials used to ensure their durability and reliability
3) Cost of the materials used
4) Construction method used to ensure reliability and durability of the product

Design Consideration: The following are some parameters which were taken into consideration while designing the machine.

i. The type of material used for each component
ii. Soaking period
iii. Compaction of equipment
iv. Mobility of equipment
v. Speed of the shaft and shelling disk was put into consideration. Therefore a 1hp motor was used.

Shelling Chamber: The shelling chamber comprises of the shelling disc and the shelling drum. In manufacturing the shelling disk, a pair of metal sheet was marked 4mm in diameter and cut to form the head and tail of the shelling disc using the drilling machine, 24holes were drilled round the sphere of the flat cylinders. 24 pieces of threaded rod of 7.5 inches was market and cut and then welded through each hole in the flat cylinder to form the length of the shelling disc.

Fig 1. Shelling Disc

Hopper: The dimensions of the hopper were marked out with the aid of a scriber. The top dimension is 12x12 inches and the bottom dimension was 2.4x2.4 inches were cut out. After these processes, the cut out parts were joined together by welding. The hopper was then fastened to the shelling chamber. In other to control corrosion, galvanized sheet was riveted around the exposed part of the hopper.

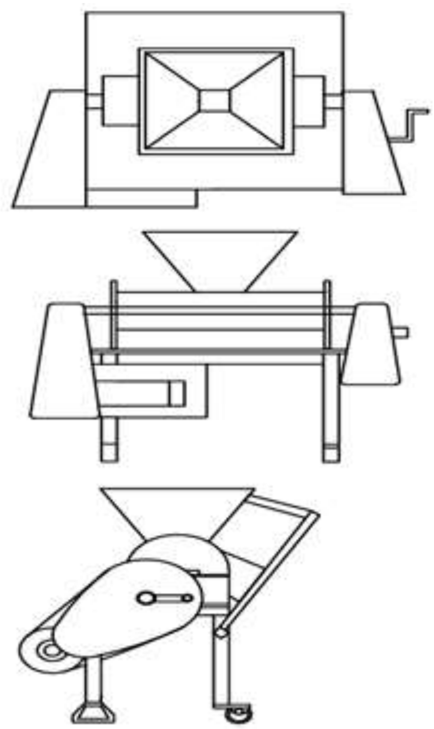


Fig 2. Orthographic projection of the design

*Assembling***:** The arrangements of the components to form the machine structure are outlined as follow:

- Weld shelling drum around the sphere of the shelling disc
- Weld the Hooper on the shelling chamber
- Rest the shaft extrusions on the pillow bearing attached to the support plat form
- Fit in the driven pulley to one end of the pulley
- Attach the electric motor to the frame and attach its driving pulley
- Fit in the V belt into the two pulleys
- Fit the gear box to the other end of the shaft extrusion
-

Fig 6. Machine Assembly

Mathematical Calculations and Equations/Design Assumptions: The assumption made during this design of the machine were of the America society of Mechanical Engineer (ASME)

Coefficient of friction of pulley, $\mu = 0.3$

Density of rubber belt,$\rho = 1140 kg/m^3$

Pie,$\pi = 3.1242$

Acceleration due to gravity g = $10 m/s^2$

1hp = 746w

Hopper Capacity: The cross sectional area of the hopper is more like the frustum of a pyramid According to Moise (1967)

Volume of the frustum of the pyramid

$v = \frac{1}{3}h(B + BS + \sqrt{BxBS})$………….. (1)

Where: B = Area of large base = mm^2: BS = Area of small base = mm^2: H = Altitude of the frustum = 210mm

$$\therefore v = 7.6 \ x \ 10^6 \ mm^3$$

Velocity of Pulley

$N_1D_1 = N_2D_2$………………….…….. (2)

Known that N_1= 1400 rpm, D_1 = 0.1397m, D_2 = 0.1651m. N_2 =?, 1400 x 0.1397 = N_2 0.1651

Therefore, N_2 = 1184.615 rpm

Number of revolution of the driven pulley is 1184.615rpm

Torque Transmitted By Electric Motor (T_s): The machine is design with 1hp electric motor

1hp = 0.7kw

Number of revolution = 1400 rpm

$T_s = \frac{P}{\omega}$ ……………………. (3)

Where: P = power of electric motor; = Angular speed of electric motor
Known that

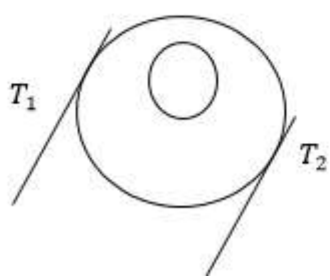
$\boldsymbol{\omega} = \frac{2\pi N}{60}$ ………………….. (4)

= 146.627rad/sec

Therefore

$T_s = \frac{746}{146.627} = 9.548 Nm$

Torque supplied



$T_s = (T_1 - T_2)r_1$………………….. (5)

Where r = radius of small driving pulley

Therefore,

9.548 = $(T_1 – T_2)0.06985$

T1 – T2 = 136.6929N………… (6)

Belt Speed

$V = \boldsymbol{\omega} r_1$ ………………. (7)

Where, V= peripheral velocity of the belt, $\boldsymbol{\omega}$= Angular velocity=146.627 rad/sec

V= 10.2419 m/s

Length of belt

$L= \frac{\pi}{2}(r_1+r_2) + 2x + \frac{(d1-d2)}{4x}$ …….. (8)

The center distance between the driving and driven pulley is given as

$X = (\frac{r1+r2}{2})r_1$ ……………….. (9)

X = 0.02129m

Therefore, L= 0.528997m = 528.997mm

Wrap Angle (α): To find the angle of contact of both pulleys,

$\sin\alpha = (\frac{r2-r1}{x})$ ……………… (10)

$\alpha = 36.62^0$

Angle of contact of motor pulley

$\theta 1 = 180^0 - 2\alpha = 180 - 2(36.62) = 106.76^0$

$= 106.76 \times \frac{\pi}{180} = 1.864$ rad

Angle of contact of shaft pulley

$\theta 2 = 180^0 + 2\alpha = 253.24^0$

= 4.42 rad

Area of Belt (A)

$A = \left(\frac{a+b}{2}\right)h$ ………………… (11)

Where: a=3.3mm, b=16.23mm and h= 8.7mm

$A = 85.086mm^2 = 85.086 \times 10^{-6}m$

Mass Of Belt **(M):** Mass of belt per meter length

$M = A \times L \times \rho$ …………. (12)

Mass = area of belt x length of belt x density of belt

Known that density of rubber belt is $1140kg/m^3$

$M = 85.086 \times 10^{-6} \times 0.528991 \times 1140$

M = 0.0513kg

Tension on Belt: From the dimension of a standard V-grooved pulley

$T_1 = T - T_c$ ……………… (13)

Where, T_1 = Tension on tight side, Tc = Centrifugal tension

$Tc = Mv^2$ ……………… (14)

$= 0.0513 \times 10.2419^2$

= 5.38N

$\frac{T1-Tc}{T2-Tc} = e^{(\frac{r1\alpha1}{\sin\frac{\theta}{2}})}$ ……………… (15)

$T_1 = 1.17612T_2 - 0.9229$

Known that

T1 – T2 = 136.6929N

Then T1 =73.45N, T2= 63.24N

Power transmitted by the belt

$P = (T_1 - T_2)V$ ……………...(16)

= (136.6929) x 10.2419

= 1399.995W = 1.9Hp

Torque, $T = \frac{60P}{2\pi N2}$ ………………… (17)

Where power = 746w

T=6.0128Nm

Bending moment $M = (T_1 + T_2 + 2T_c)$ …………. (18)

= 147.45Nm

T_e(Equivalent twisting moment) = $\sqrt{T^2 + M^2}$ = 147.573Nm

RESULT AND DISCUSSION

The performance evaluation was carried out using the fabricated melon shelling machine to shell melon in both wet and dry conditions electrically and mechanically (manually).

Machine Performance Evaluation: A number of analysis were done using the machine to test for its shelling efficiency, likelihood of damaged seeds and effect of moisture content on the shelling efficiency if the machine.

Shelling Efficiency: This is a factor of the number of shelled seeds obtained after shelling operation. Same quantity of melon is fed into the shelling drum at a varying feed rate. This is done by adjusting the shelling drum inlet.

The shelling efficiency was calculated mathematically using the expression

$$\eta = \frac{N_{su} + N_{sb}\ x100}{N_t}$$

Where, η= shelling efficiency; N_{su}= Number of unbroken seeds shelled; N_{sb} = Number of broken seeds shelled; N_t = Total number of seeds

Fig 7. Fraction of the perfectly Shelled melon

Fig 8. Fraction of the unshelled Melon

Table 4 Manually driven shelling efficiency with variation in condition

S/N	CONDITION	N_{su}	N_{sb}	N_t	η
1	DRY	480	200	1000	68
2	SEMI-WET	619	110	1000	73
3	WET	600	150	1000	75.2

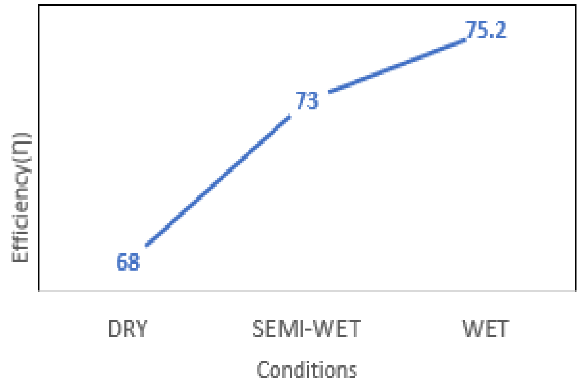


Fig 9. Manually-driven Shelling efficiency against seed condition

From table (4) and fig. (9), it shows that for the manually operated unit of the machine when the seeds are highly moisturized a higher machine efficiency is achieved, this is as a result of the variation in speed of the gear during operation.

Table 5 Electrically driven shelling efficiency with variation in condition

S/N	N_{su}	N_{sb}	N_t	η
1	100	200	1000	30
2	700	50	1000	75
3	500	180	1000	68

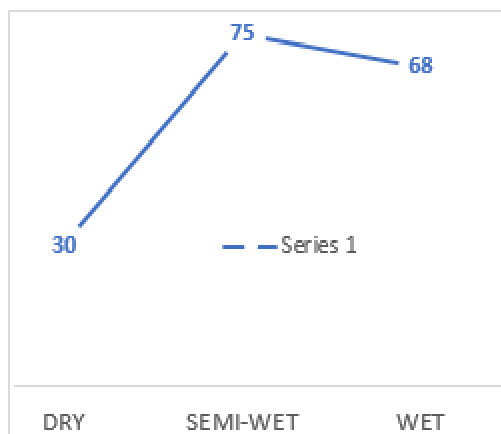


Fig 10. Electrically-driven Shelling efficiency against seed condition

From table (5) and fig. (10), it shows that for the electrically operated unit of the machine its efficiency is increased when the seeds are moisturized in an average scale. For a highly moisturized seed its shell becomes extremely soft and easy to peel but due to the high speed of the motor it damages the soaked seeds.

Probability of Seed Damage: This is evaluated to ascertain the amount of damaged melon seed during shelling process for both the electrically driven mechanism and manual driven mechanism. The Probability of seed damaged was obtained using the formula below

$$P_b = \frac{N_{ub} + N_{sb}}{N_t} X100$$

Where: P_b = percentage of broken seed; N_{ub} = Number of unshelled broken seeds; N_{sb} = Number of broken seeds that were shelled; N_t = Total number of seeds

Fig 11. Shelled Aggregate

Table 6 Percentage of broken seed with variation in condition for manual mech.

S/N	CONDITION	N_{ub}	N_{sb}	N_t	η_b
1	DRY	50	75	1000	12.5
2	SEMI-WET	35	63	1000	9.8
3	WET	22	82	1000	10.2

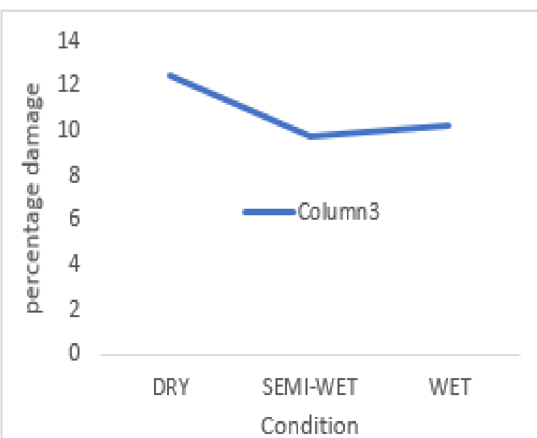


Fig 12. percentage damage against seed condition

Machine Capacity: It describes the capacity of the machine in terms of the quantity of melon seed shelled by the machine per unit time. This can be expressed in the formula below

$$C_m = \frac{M_s}{T}$$

Where C_m=Machine capacity (g/hr); M_s= Mass of seeds shelled (g); T = Time taken to complete the operation (hr)

Table 7. Shelling efficiency with variation in feed rate

S/N	EFFICIENCY	FEED RATE(g/min)
1	69	2
2	72	3
3	75	4
4	50	5
5	46	6

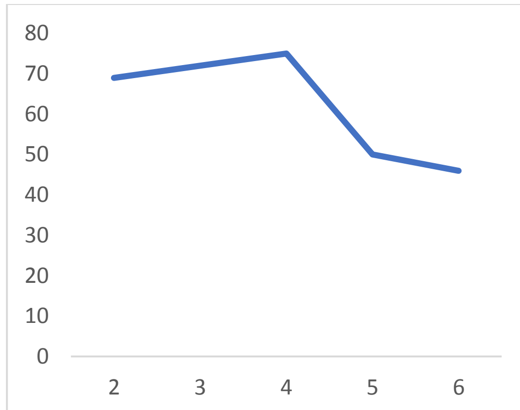


Fig. 13. Shelling efficiency against feed rate

From the analysis as seen in figure 14 and table 7, it can be deduced that there's a significant increment in shelling efficiency for the first quarter of the shelling rate and on getting to half of the shelling rate, shelling efficiency reduces drastically.

Moisturizing Rate: It explains the effect of moisture quantity in the melon on the shelling efficiency of the machine.

Table 8 Manual Efficiency and Electrically driven efficiency with variation in moisture content of seed

S/N	Number Of Seed	Water Added (ml)	Soaking Time (SEC)	Manually driven efficiency	Electrically driven efficiency
1	1000	5	5	66	60
2	1000	10	5	70	76
3	1000	15	5	72	74
4	1000	20	5	71	65

From table (8), fig. (13), fig. (14), it is observed that the amount of water sprinkled on the melon seeds for moisturizing affects the efficiency at which the machine operate. Results from the analysis shows that when 15ml of water is used an efficiency of 72% was obtained from the manually operated unit of the machine. 10ml of water produces an efficiency of 76% for the electrically operated unit of the machine.

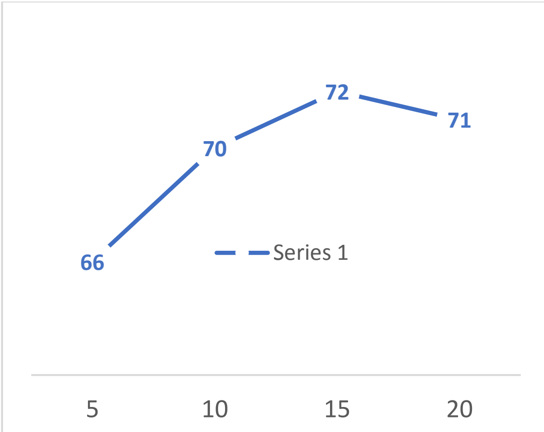


Fig 14. Manually-Driven Efficiency against Moisture content

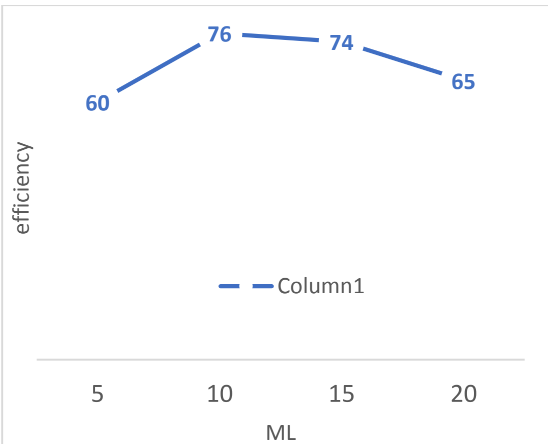


Fig 15. Electrically-Driven Efficiency against Moisture content

Conclusion: The project "Design and fabrication of melon shelling machine" using locally sourced materials is an attempt by the students of the department of Mechanical Engineering Delta State University Abraka, Oleh campus to help in the development of Nigeria's indigenous technology. Individuals can acquire it for domestic use and melon farmers for medium scale production.

The result achieved further suggest that seed soaking time, spreading time and speed of shelling disc influences the shelling efficiency of the machine.

For mechanically driven mechanism the highest efficiency of 72% for 15ml of water being added to 1000 seeds of melon (36.98g) while for the electrically driven mechanism a maximum efficiency of 76% was attained when 10ml of water was added to same amount of seeds (1000).

These findings are innovative and still subject to improvement in the case of future researches and development for agricultural and food scientists as well as engineering experts or students.

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