Design and Development of a Melon Shelling Machine

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Abstract

A melon shelling machine was designed and fabricated. The machine was designed to handle a capacity of 50 kg/hr of melons. This paper presents the design and fabrication of a melon shelling machine designed to mechanize the seed extraction process from melons. The machine was conceptualized to address the inefficiencies of manual shelling, including high labour costs and seed wastage. The power requirement was determined to be 0.6 kW and a 35 mm shaft was selected. Key features of the machine include an intake hopper, shelling unit, and a separation system, all powered by an electric motor. Fabrication used cost-effective, easily available materials, emphasizing robustness and maintenance ease.

Keywords: *Agricultural Machinery, melon shelling, machine design, power requirement, seed extraction.*

1.0 Introduction

Melons are a staple in Nigerian diets, valued for their refreshing taste and nutritional benefits, including essential vitamins, minerals, and hydration. Among the various types cultivated such as watermelon, cantaloupe, and honeydew being the most popular. However, a particularly significant variety in terms of local agriculture and food culture is the *Egusi* melon holds particular importance in local agriculture and cuisine. The seeds of the *Egusi* melon are highly valued for preparing popular dishes like *Egusi* soup, enjoyed across many regions of Nigeria [1]. Despite its economic and cultural significance, melon cultivation in Nigeria faces challenges such as pest infestations, unpredictable weather, and soil variability. Post-harvest processing remains one of the most labour-intensive stages, primarily due to the manual removal of the thick rind. Traditional methods using knives or basic tools not only pose safety risks but also result in inconsistent product quality and high physical strain [2]. The processing of Egusi melons is particularly demanding since the seeds are the primary product of value. After harvesting, the fruits are left to over-ripen and split open before the seeds are manually extracted, washed, and dried a process that is time-consuming, inefficient, and often leads to significant seed loss [1].

A machine designed to automate melon rind removal and seed extraction could ease processing for *Egusi* and other melon varieties. Such innovation would reduce labour requirements, enhance processing efficiency, and improve seed yield and quality. For local farmers and processors, it promises faster operations, reduced costs, and increased profitability. Furthermore, automation would help standardize production, enhance market competitiveness, and promote melon cultivation as a more sustainable and economically viable enterprise in Nigeria [1].

Developing melon decorticating technology suited to local agricultural conditions could therefore have a far-reaching impact. By minimizing manual labour and post-harvest losses while improving processing efficiency, this innovation would support farmers, strengthen value chains, and contribute to the overall growth of Nigeria's agricultural sector.

2.0 Materials and Methods
2.1 Materials

The materials were chosen on the basis of their availability, suitability, economy, viability in service among other considerations. Mild steel was used for the frame structure and other outer components. It is commonly chosen for machine frames due to its excellent combination of strength, toughness, and ductility, which are essential for supporting heavy loads and enduring operational stresses. It stands out for its ease of machinability, welding, and customization, facilitating the manufacturing process. Additionally, mild steel is cost-effective and widely available, making it a practical option for large structures. Though it has lower corrosion resistance compared to materials like stainless steel, this drawback can typically be mitigated with protective coatings, making mild steel a highly versatile and economical choice for constructing durable machine [3][4]. Figure 1 shows the designed machine.
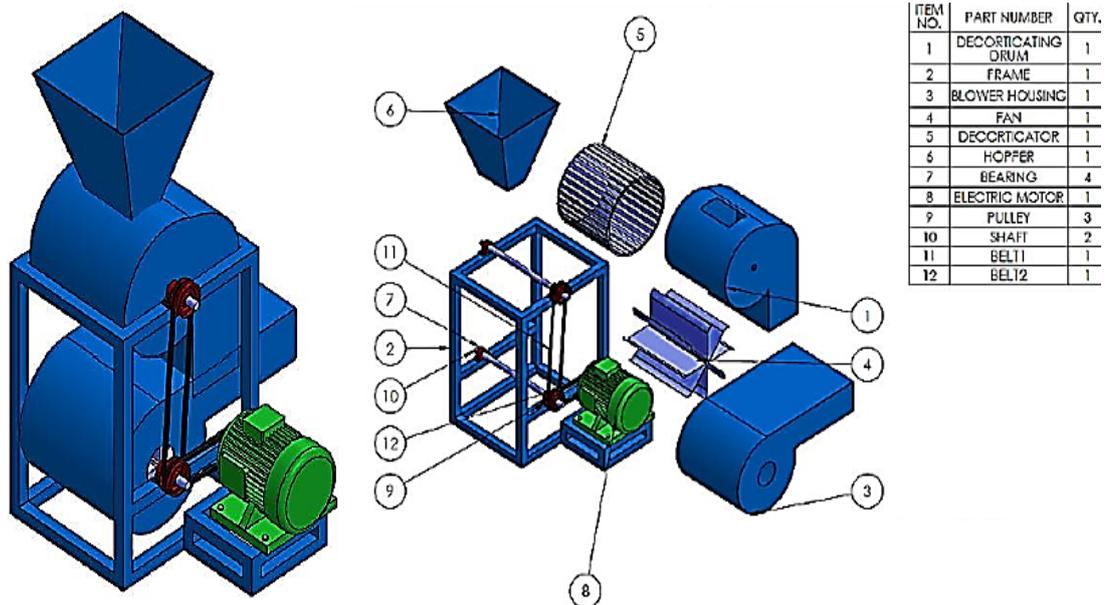
Figure 1: Isometric and exploded view of the machine

ITEM NO.	PART NUMBER	QTY.
1	DECORTICATING DRUM	1
2	FRAME	1
3	BLOWER HOUSING	1
4	FAN	1
5	DECORTICATOR	1
6	HOPPER	1
7	BEARING	4
8	ELECTRIC MOTOR	1
9	PULLEY	3
10	SHAFT	2
11	BELT1	1
12	BELT2	1

2.2 Design Calculations

A. Hopper design

The hopper was designed to accommodate a feed rate of 50 kg/hr of Egusi melons. Using a bulk density of 456.34 kg/m³[5], the required hopper volume (V) was calculated from Equation (1):

$$V = \frac{Q}{\rho}$$

(1)

Where Q is the feed rate in kg/hr and ρ is the density in kg/m^3. Assuming the hopper should hold around 5 min of seeds then:

$$V_{total} = 0.001095 \times 5 = 0.00548 \text{ m}^3$$

The hopper was designed with a truncated pyramid shape as seen in Figure 2, with an upper width (W_1) of 0.6 m, a lower width (W_2) of 0.3 m, and a height (H) of 0.6 m. The volume of the truncated pyramid is given by Equation 2.
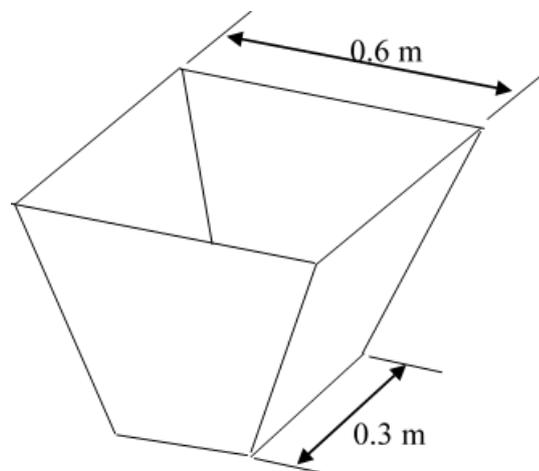

Figure 2: Truncated pyramid shaped hopper

$$V = \frac{H}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$

(2)

Where: V is Volume of the hopper (m³), H is Vertical height of the hopper (m), A_1 is Area of the top (larger) rectangular base (m²), A_2 is Area of the bottom (smaller) rectangular base (m²), and $\sqrt{(A_1 A_2)}$ = Geometric mean of the two base areas (tapering effect between the two base surfaces)

$$V = \frac{0.6}{3}\left(0.36 + 0.03 + \sqrt{0.36 \times 0.09}\right) = 0.126 \text{ m}^3$$

B. Power Requirement and Motor Selection

The power required to drive the shelling machine was determined using Equation 3.

P = Fr.V   (3)

Where Fr is the weight of rotating parts in N and V is the tangential velocity of the rotating parts in m/s. The mass of rotating components (shaft, hopper materials and shelling drum) was measured as 5.4 kg. Hence, Fr is 52.98 N by multiplying with acceleration due to gravity, 9.81 m/s². The suggested tangential velocity is adopted from [6] as 11.4 m/s. Therefore, Equation 3 yields 0.6 kW. It is ncessary to design for losses to be encountered during operation, like friction and air resistance. A design factor of 0.95 was used as suggested by [4] which was used in Equation (4).

$$\text{Nominal power} = \frac{\text{Estimated power}}{\text{Design factor}}$$ (4)

$$\text{Nominal power} = \frac{603.9}{0.95} = 0.64 \text{ kW or 0.9 hp}$$

A 1 hp electric motor was selected to power the machine.

C. Selection of Belt Type

A V-belt drive was adopted because it offers high efficiency, compactness, and low maintenance. Based on [7], Belt Type A was chosen to transmit 0.9 kW power, suitable for small capacity mechanical systems. The selected driver pulley had a diameter of 100 mm, while the driven pulley was 150 mm, determined using Equation (5).

D. Selection of appropriate pulley

The recommended minimum pulley diameter is 75 mm; therefore, a 100 mm diameter pulley was obtained as suggested by [3] However, the shaft pulley is also to be selected. [8] obtained 800 rpm as a suitable speed for delivering high shelling efficiency. [3] provided Equation 12 to determine the pulley speed.

$$N_1 D_1 = N_2 D_2$$ (5)

Where N_1 is the rpm of driver pulley, D_1 is the diameter of the driver pulley in m, N_2 is the rpm of driven pulley and D_2 is the diameter of the driven pulley in m.

$$1440 \times 0.10 = 800 \times D_2$$
$$D_2 = \frac{1440 \times 0.10}{800} = 0.15 \text{ m}$$

E. Belt drive analysis

The maximum tension T in the belt was determined using Equation 6 as given by [3].

$$T = \sigma.b.t$$ (6)

The allowable safe stress σ is adopted as 2.1 MN/m², b and t are the thickness and width of the belt which are 13 mm and 8 mm respectively [3].Thus, T is 208 N. T_1 and T_2 (Tension on the tight and slack side) were determined as 201.3 N and 26.5 N using Equation 7 and 8 respectively.

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

Where: T_c is centrifugal tension in N.

$$\frac{T_1}{T_2} = e^{\mu\theta_1 \text{cosec}\beta}$$ (8)

F. Determination of shaft diameter

The total weight acting on the shaft was determined to be 35.46 N and the tensions were 201.3 and 26.5 N. They are represented in Figure 3. Next the maximum bending moment was obtained.
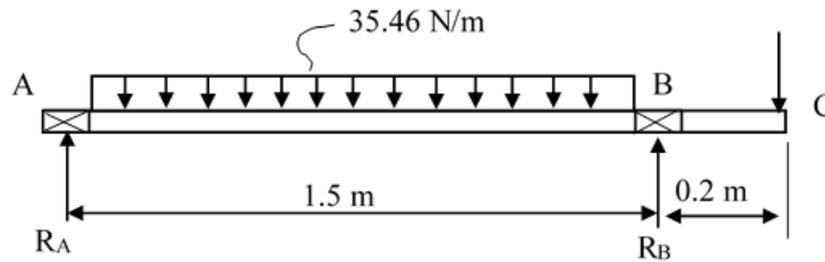
Figure 3: Forces acting on the shaft

The equilibrium equations are used to determine the reactions at A and B.

$R_A + R_B = 35.46 \times 1.5 + 227.8$

$R_A + R_B = 281 \, \text{N}$

Sum of Moments about A = 0 (to solve for R_B)

$R_B \times 1.5 - 53.19 \times 0.75 - 227.8 \times 1.7 = 0$

$R_B = 281 \, \text{N}$

Solve for R_A

$R_A = 281 - 284.77 = -3.77 \, \text{N}$

The shear forces, V at A, B and C are also determined.

$0 \, \text{m} \leq x < 1.48 \, \text{m}$

$V_y = R_A = -3.77 \, \text{N}$

$1.48 \, \text{m} \leq x < 1.5 \, \text{m}$

$V_y = -35.46 \times 1.5 - 3.77 = -56.96 \, \text{N}$

$1.5 \, \text{m} \leq x < 1.7 \, \text{m}$

$V_y = -35.46 \times 1.5 + 281 = 227.8 \, \text{N}$

x = 1.7 m

$V_y = 0 \, \text{N}$

The bending moment, M. at A, B and C are also determined.

$0 \, \text{m} \leq x < 1.48 \, \text{m}$

$M = -17.73 \times 1.48^2 - 3.77 \times 1.48 = -44.4 \, \text{Nm}$

$1.48 \, \text{m} \leq x < 1.5 \, \text{m}$

$M = -17.73 \times 1.5^2 + 281 \times 1.5 - 427.16 = -45.6 \, \text{Nm}$

x = 1.7 m

$M = 0 \, \text{Nm}$

The shear force and bending moment diagram is presented in Figure 4.

The diameter of a shaft can be determined from the American Society of Mechanical Engineers ASME design code as used by [9];

$$d^3 = \frac{16}{\pi S_s} \sqrt{(Mk_b)^2 + (Tk_t)^2} \tag{9}$$

Where M is the bending moment in Nm, T is the torque in Nm (Torque is 7.09 Nm with a radius of 0.2 m), S_s is the shear stress, and it is taken as 42 MN/m². According to the American Society of Mechanical Engineers (ASME) design code: combined shock and fatigue bending (K_b) and torsion (K_t) factors for suddenly applied load, minor shock are 1.5-2 and 1-1.5 respectively. The allowable shear stress for steel with keyway is 40 MN/m² [3].
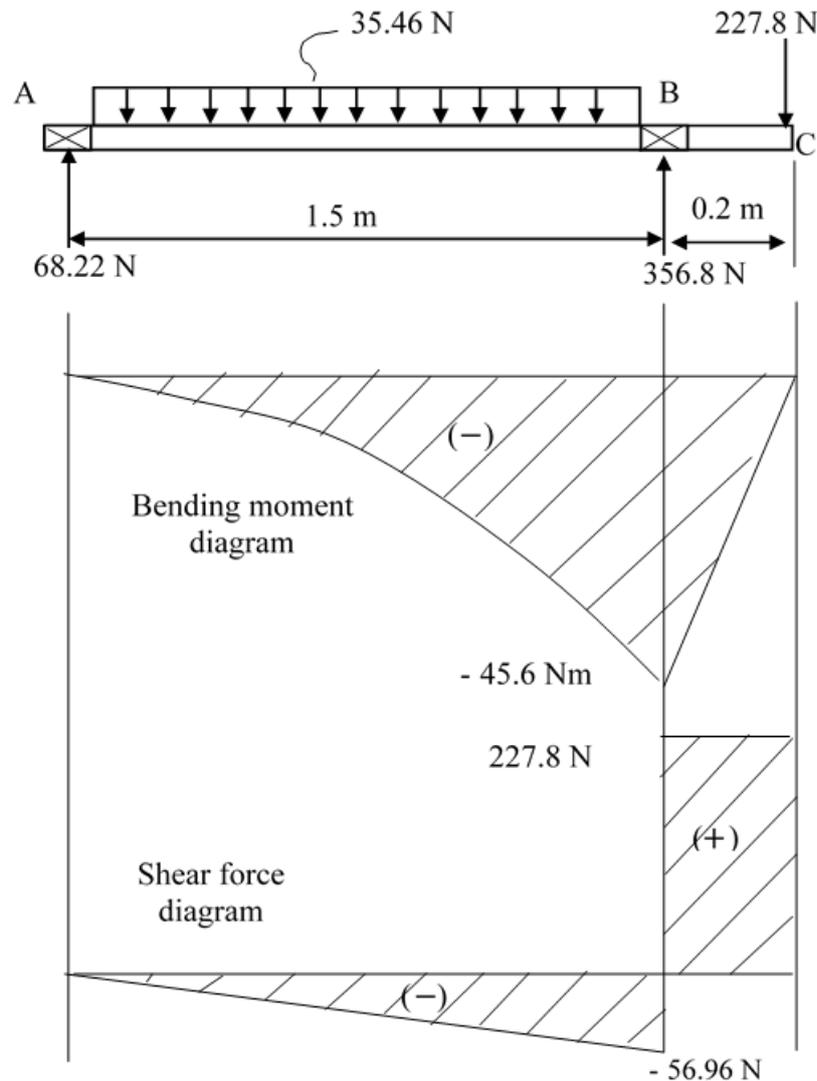
Figure 4: Shear Force and Bending Moment diagrams

The diameter was obtained as 27 mm. The shaft diameter available for the machine is 35 mm, this was more than the calculated value obtained, and thus design was safe.

2.3 Fabrication Details

Mild steel, angle iron, pulleys, shafts, belts, and motors are examples of locally accessible, high-quality materials that were employed to achieve the intended result at the lowest possible cost. The shelling unit, which consists of a revolving disc and a static disc, the hopper, the frame, the cleaning unit, and the chutes make up the machine. Mild steel was used to construct a truncated pyramid-shaped hopper with a height of 0.6 m and top and bottom widths of 0.6 and 0.3 m, respectively, in order to enhance the free flow of seeds into the shelling unit. The shelling unit is made up of the shelling drum, vanes, and rotating and static discs. The ¾-inch flat metal blades, spaced 9 mm apart, were welded at a 75 ° angle and placed side by side along the disc's diameter to create vane slots at the revolving disc's edges. These blades line the outer portion of the rotating disc. The flat metal rods of 250 mm in length are placed side by side and fused at a distance of 10 mm from one another at an angle along the walls of the stationary drum to generate spikes that make up the static disc. The frame which is the support on which the whole unit rests was made from angle iron into a rectangular of size 1340 mm × 400 mm × 750 mm high. The fabricated machine is presented in Figure 4.

Figure 5: The fabricated machine

3.0 Results and Discussion

The developed melon shelling machine, designed for a throughput of 50 kg/h, preliminary tests demonstrated satisfactory operational performance under test conditions. Experimental evaluation showed that the machine achieved an average shelling efficiency of 94.4%, with a throughput capacity of 47.6 kg/h, which closely aligns with the theoretical design target. The seed recovery efficiency was measured at 92.1%, indicating minimal seed loss during operation. This validates the adequacy of the feed mechanism and the design choice of the hopper, whose 0.00548 m³ volume ensured a uniform and continuous flow of melon pods into the shelling chamber, preventing clogging and ensuring consistent performance.

The machine was powered by a 1 hp (0.7457 kW) electric motor, operating below its rated capacity since the actual power requirement was computed as 0.6 kW. This design margin improved energy efficiency, reduced overheating, and minimized mechanical stress on the drive system. The 35 mm diameter shaft withstood the operational torque and bending stresses during shelling, with no observed deflection or failure, confirming the accuracy of the design calculations. These features collectively contributed to the overall robustness and operational reliability of the system. When compared with existing melon shelling systems reported in the literature, such as the machine developed by [10] [13] [15] [16] with a throughput of 53.4 kg/h and a shelling efficiency of 95%, the developed machine demonstrates similar performance in both capacity and efficiency. Moreover, compared to traditional manual shelling, which averages 8–10 kg/h, the mechanized process significantly reduces labour intensity and processing time while improving seed quality consistency [10] [14].

However, some operational limitations were observed. The machine's performance was slightly affected by variations in melon size and moisture content, leading to minor seed damage (approximately 4.3%) in larger or over-dried samples. Additionally, the system would benefit from further refinement of the shelling clearance adjustment to accommodate different melon varieties. Future improvements could include integrating a moisture conditioning unit and an adjustable shelling gap to enhance versatility and reduce seed breakage. Overall, the results confirm that the designed melon shelling machine effectively meets the target operational capacity and efficiency, offering a durable, energy-efficient, and higher-output alternative to existing models

4.0 Conclusion

The design and fabrication of the melon shelling machine successfully addressed several inefficiencies associated with the traditional manual shelling process. With a capacity of 50 kg/hr and significant improvements in seed yield and processing time, the machine stands out as a valuable addition to the melon processing industry. The selection of a suitable electric motor and careful consideration of mechanical components like the shaft and hopper have ensured that the machine is both reliable and efficient. The potential for future enhancements and scalability further enhances its utility in various processing environments. Beyond technical performance, the adoption of this machine could have notable socioeconomic impacts. By reducing manual labour intensity and processing time, it enables small- and medium-scale processors to increase production efficiency and profitability. On a broader scale, widespread implementation could enhance local value addition, reduce post-harvest losses, and support rural employment in melon-producing regions. Overall, the machine presents a practical and scalable innovation that advances mechanized seed processing and strengthens the sustainability of agricultural value chains.

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