

Design and Fabrication of a Maize Sheller Machine

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Abstract

For the attainment of processed maize of high-quality forms with insignificant labour-intensive tasks, this paper considered the design and development of the maize shelling machine with locally sourced materials. The developed machine was tested and its performance was evaluated against a hand maize shelling machine. The developed machine is found to be faster in shelling operation by more than 3 times than the hand maize shelling machine, the designed machine was documented with 100Kg/hr and 99.73% shelling effective capacity and shelling efficiency, respectively. An overall production cost of ₦95.970 was incurred.

Keywords: Maize**,** Sheller, Fabrication, Machine, Design

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1. Introduction

Due to its better versatility, maize (Zea mays L.), one of the principal cereal grains, is farmed around the world in many different environments (Adewale, et al, 2020). It is the third-most significant cereal grain in the world, behind wheat and rice, and it is used to produce starch, oil, and protein, as well as alcoholic drinks, culinary sweeteners, and, more recently, fuel. It also provides nutrients for humans as well as animals (Adewole and Babajide, 2015). In Africa, maize has developed into a staple food crop that even the poorest household is familiar with. It is utilized in many different ways to satisfy hunger, including pap or ogi, maize flour, and other things. Due to the significance of maize, an analysis of its processing and preservation under optimal conditions is required (Pavasiva, et al, 2018). According to Kabri et al, (2022), processing crops like maize into high-quality forms increases their usable shelf lives and guarantees year-round availability. Harvesting, drying, de-husking, shelling, storage, and milling has been identified by Liliane and Charles, (2020), as the main steps involved in the processing of maize. The technique is labour-intensive, time-consuming, and especially difficult for bigger small-scale maize farmers.

Modern corn-shelling machines have enhanced corn output while reducing labor-intensive tasks and ensuring workers' comfort and safety (Ashwin and Edukondalu, 2017). The improvement and durability of the maize sheller machine were the focus of Ashulata , et al. (2022) when the authors designed and fabricated pedal operated maize sheller machine. Reporting the operational simplicity of the developed machine, their work estimated 55.6 N as the machine pedalling force. At 13% maize moisture content, Aremu. et al, (2015), attained 87.08% of shelling efficiency, with their developed motorized maize shelling machine. Affirming the operational superiority of their developed maize shelling machine over the manually operated type, their work fixed 886rpm as the best shelling machine speed. Also, with 63.95Kg/hr operating capacity Igbinoba, et al., (2019), documented 79% efficiency of fabricated maize sheller. With a rotating blower shaft speed of 1400rpm, Babatunde and Techinse, (2020), achieved 17 times faster operation of a locally fabricated machine than hand shelling.

However, Senney, et al., (2022), linked the shelled production capacity of a designed maize shelling machine to corn diameter. Documented a 20% increase in productivity, their finding shows a direct relationship between corn diameter and maize sheller production capacity. In a bid to solve the problem of over/under size of certain components of maize sheller machines for effective performance, Abubakar, et al., (2022), adopted a numerical method to predict the optimum size of the shaft and spikes to be used on maize sheller. Under a specified value of maximum vonmises and factor of safety, their study established 12mm or 14mm and 20mm as the respective optimum size for spikes and shelling shafts.

Although several studies have been dedicated to different means of development of maize sheller machines with their established capacity to thresh maize from their cobs, however, the significance of damaged or unshelled losses of maize during shelling operation of the designed and fabricated maize sheller machine is less reported as shown in the available literature. This work seeks to design and fabricate an efficient maize sheller machine to reduce damaged or unshelled maize.

2.0 Methodology

Considering the economic and environmental factors as well as the availability of this machine to the end users, the materials used were sourced locally considering their availability and physical/mechanical properties. Figures 1 and 2 show the schematic and orthographic views of the developed maize sheller and its essential components shown in Figure 3.

2.1 Basic design calculations

i) Design of hopper.

The hopper of this machine was designed to accommodate the allowable volume of maize being fed into the machine. With mild steel of 2mm thickness, the volume of the hopper is calculated based on Equation 1 as explained by Khurmi and Gupta, (2000)

$$V_h = B_h H_h (L_h + {}^{C}/_{2}) \qquad 1$$

Where, L_h − Lenght of hopper B_h − Breath of hopper
H_h − Height of hopper V_h − Volume of hopper

Meanwhile, the allowable weight of the maize in the hopper is determined with Equation 2

$$W_m = \rho_h \times V_h \times g) \qquad 2$$

Where, W_m − Weight of maize ρ_h − Hopper density

ii) Design of Feed Tray

Located at the upper part of the machine to hold cobs before moving into the hopper, feed tray. calculated with Equation 3 is fabricated with mild steel.

$$V_t = L_t \times B_t \times H_t \qquad 3$$

Where,
V_t − Volume of the feed tray L_t − Length of the feed tray
B_t − Breath of the feed tray H_t − Height of the feed tray

iii) Design of spikes

Designed to beat grains out of maize cobs with little or no damage to the grains, a number of spikes formed around a cylindrical is fabricated using a rod of 10mm diameter, the length of the spike is equivalent to the shelling drum diameter. Adopting the formula used by Senny, et al, (2022) the number of spikes on a cylinder is calculated based on Equation 4 as stated below

$$N_p = \frac{L_s \times \pi d_s \times Z}{S_{pr} \times S_{pc}} \qquad 4$$

Where, N_p − No of spikes on shelling cylinder L_s − Length of shelling cylinder
d_s − Diameter of shelling cylinder S_{pr} − Spikes spacing on the row
S_{pc} − Spikes spacing on the circle. Z − No of shelling cylinder.

2.2 Shearing force and bending moment

With the imposed loads (W) of 0.505/mm, 1.014N/mm and 0.505N/mm at different sections on the shaft during shelling of the cobs through the hopper, is as shown in Figure 1. Thus the total force is 283N.

R_A = Reaction at suppor A R_E = Reaction at suppor E

$$\therefore \quad R_A = R_E = \frac{283}{2} = 141.5N$$

a) Shear Force

Shearing force (V) at distance 0mm < x < 50mm, V = R_A = 141.5N
Shear force (V_B) at distance 50mm < x < 190.5mm

$$V_B = R_A - W_B \times X_B = 70.5N$$

Shear force (V_C) at distance 190.5mm < x < 329.5mm

$$V_C = R_B - W_C \times X_C = -70.5N \qquad 4$$

Shear force (V_D) at 329.5mm < x <520mm

$$V_D = R_C - W_D \times X_D = -141.5N \qquad 5$$

b) bending moment

Bending moment M at distance 0mm < x < 50mm

$M = R_A X = 7{,}075$ Nmm = 7.08Nm

Bending moment at distance 190.5mm < x < 329.5mm is $R_A X - \frac{W}{2}(X - 190.5)^2$

Bending moment is maximum when shearing force equal to zero i.e. when X = 260 from the end BM_{260} = 34.34Nm

Bending moment for 470 < x < 520 = 7.08Nm

2.3 Design for Shelling Cylinder

The weight and volume of shelling cylinder is determined as:

$$W_{cy} = \rho V_{cy} \times g \qquad 7$$

and $V_{cy} = \frac{\pi D^2{}_{cy}}{4} \times L_s$ 8

Where, $W_{cy} -$ Weight of shelling cylinder $V_{cy} -$ Volume of shelling cylinder.

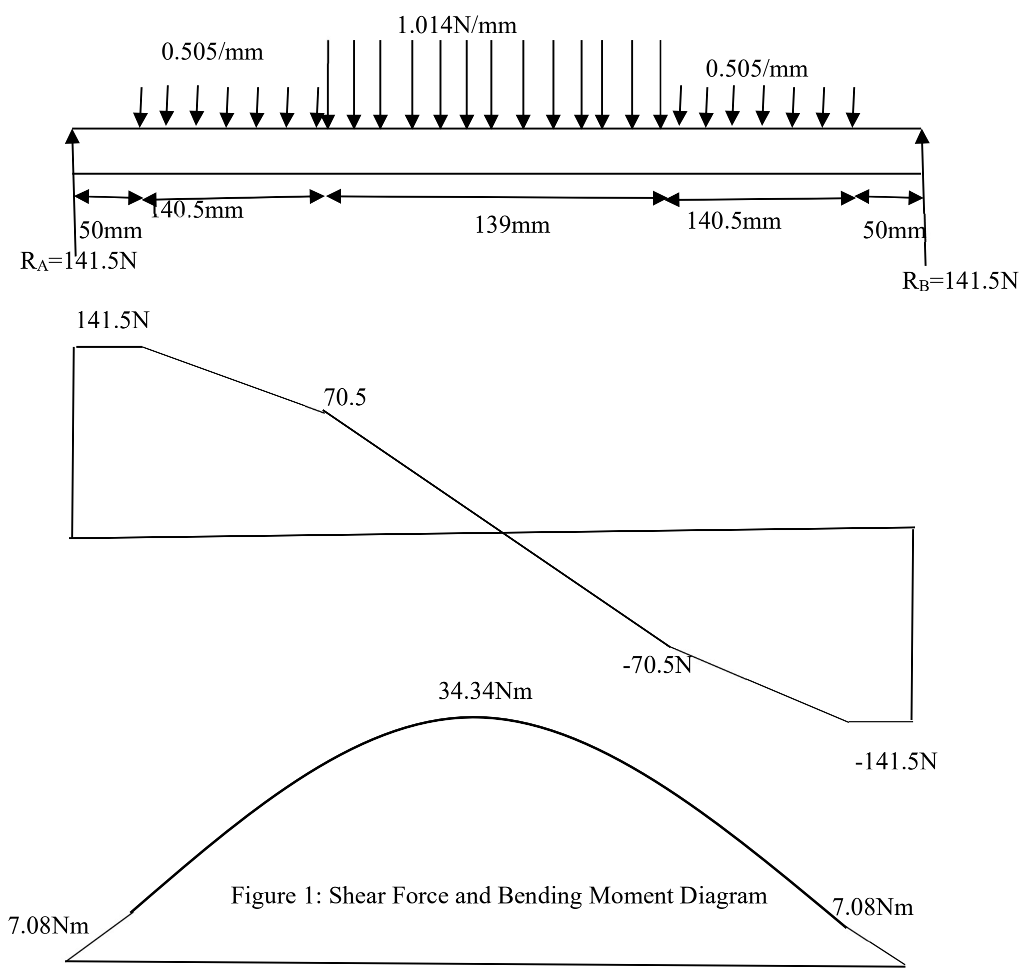

Figure 1: Shear Force and Bending Moment Diagram

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Where, $W_{cy} -$ Weight of shelling cylinder $V_{cy} -$ Volume of shelling cylinder.

2.4 Design for shaft

(a) Weight on shaft

Taking the total permissible weight of maize on shaft as 8132.04 N and weight of shelling drum as 71.12N. The total weight on shaft of the machine is calculated as follow

$$\mathrm{W_{os}} = \mathrm{W_{td}} + \mathrm{W_m} \quad 9$$

Where, $\mathrm{W_{os}} -$ Total weight on shaft $\mathrm{W_{td}} -$ Weight of shelling drum

(b) Shaft diameter

Considering the effect of centrifugal force, the 30mm shaft diameter was used in the fabrication of this machine is determined with the combination of Equations 10-16

$$\frac{T}{J} = \frac{\tau}{r} \quad 10$$

$$N = \frac{120 \times F}{P} \quad 11$$

$$T = \frac{P \times 60}{2\pi N} \quad 12$$

$$T_e = \sqrt{M^2 + \sqrt{T^2}} \quad 13$$

$$T_e = \frac{\pi}{16} r d^3 \quad 14$$

$$M_e = \frac{1}{2}(M + T_e) \quad 15$$

$$M_e = \frac{\pi}{32} \sigma d^3 \quad 16$$

Where, $T -$ *Torque* $J -$ *Polar moment* $\tau -$ *Torsional shear stress*
$N -$ *Speed* $F -$ *Frequency* $P -$ *No of pulley*
$M -$ *Bending moment* $M_e -$ *Maximum torsional moment*
$T_e -$ *Torsional stress* $d -$ *shaft diameter*

2.5 Design for pulley

For effective transmission of power between the shafts of the machine, the volume, weight and driving system of pulley were carefully considered in our designed calculation.

$$V_{py} = \pi r^2 w^2 \quad 17$$

$$W_{py} = \rho V_{py} g \quad 18$$

The contact angle between the belt and pulley is determined by

$$\theta = (180 - 2\alpha) \times \frac{\pi}{180} \quad 19$$

$$Sin\ 2\alpha = \frac{D_2 - D_1}{2C} \quad 20$$

Where,
V_{py} *—Volume of pulley*
$r^2 -$ *Radius of pulley*
$w^2 -$ *width of pulley*
$W_{py} -$ *Weight of pulley*
$\theta -$ *Angle of lap of pulley*
$C -$ *Centre distance between two pulleys*
$D_1 -$ *Diameter of a smaller pulley*
$D_2 -$ *Diameter of a bigger pulley*

3.0 Results and Discussion

The schematic diagram of the developed maize sheller, its orthographic views and its components are shown in Figures 2, 3 and 4 respectively. To ascertain the performance of the developed machine, performance evaluation test was carried out in relation to the maize hand shelling machine. The results of the performance are as stated in Table 1. From the table, it was seen that 15kg of shelled maize required 12 minutes to be shelled by the developed sheller given a shelling effective capacity of 100kg/hr compared with the manual shelling which required 1hr 15 minutes to shell 13.6kg of maize at shelling effective capacity of 16kg/hr. Thus, the shelling efficiency were 99.73 and 90.31%, for the developed maize sheller and the manual sheller, respectively. The unshelled losses was

calculated to be 0.27% (which is very small). Thus, the shelling efficiency of this machine higher compared with the work of Hassan et. al. (2019).
Thus, capacity of the designed maize shelling machine works 3.6 faster than the manual maize shelling which is the very common practice
A lower value of maize unshelled losses exhibited by developed maize sheller machine suggests its ability to adequately prevent maize losses during shelling operation better than maize hand shelling. The estimated cost known as Bill of Engineering Measurement and Evaluation (BEME) for the locally fabricated maize shelling machine is as presented in Table 2. The unshelled maize, maize cobs, chaff, and the shelled maize are shown in Figure 5

4.0 Conclusion

A maize sheller machine was developed and tested. The machine was so easy to use and given a clean shelled maize with higher shelling efficiency of 99.73 % and shelling capacity of 100kg/hr.
The cost of production of this locally fabricated maize sheller machine is estimated to ₦95,970 as stated in Table 2. The cost is likely to reduce when the design components of this machine are produced with a standard approach.

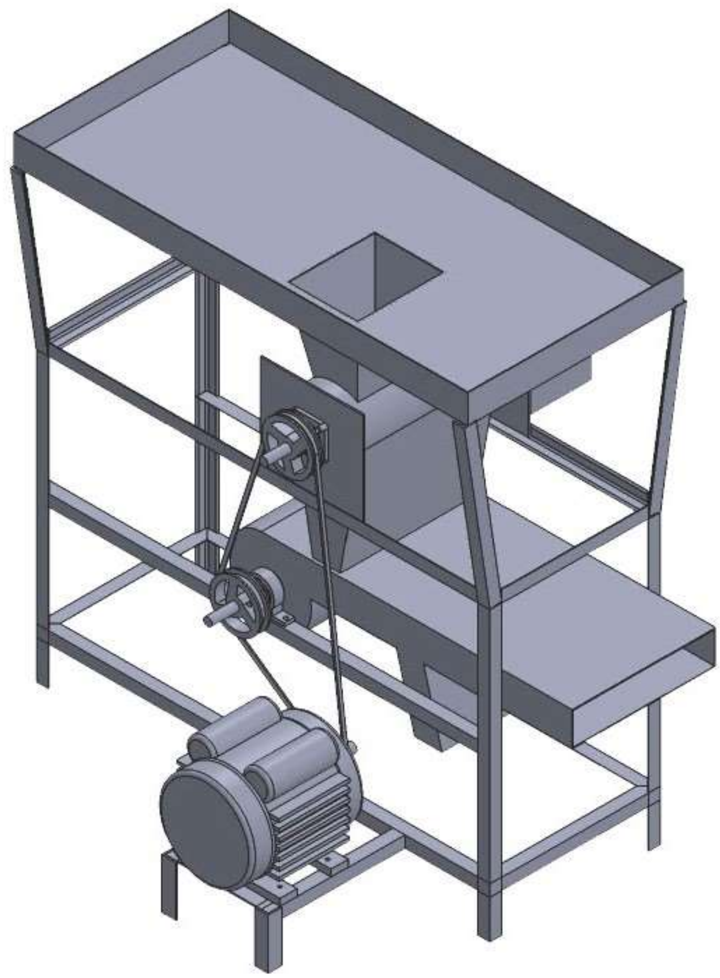

Figure 2: Schematic diagram of developed maize sheller machine

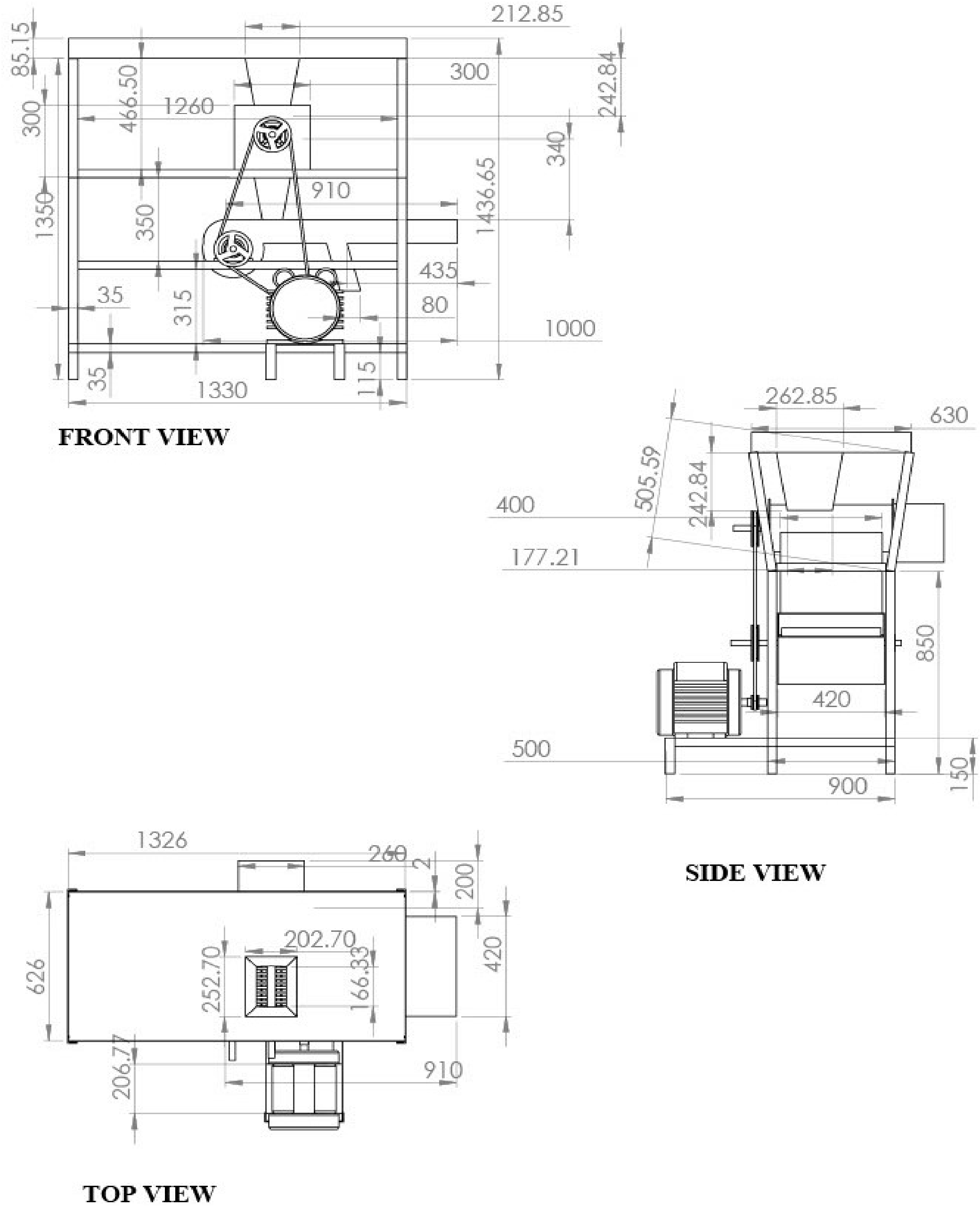

Figure. 3: Orthographic views of developed maize sheller machine

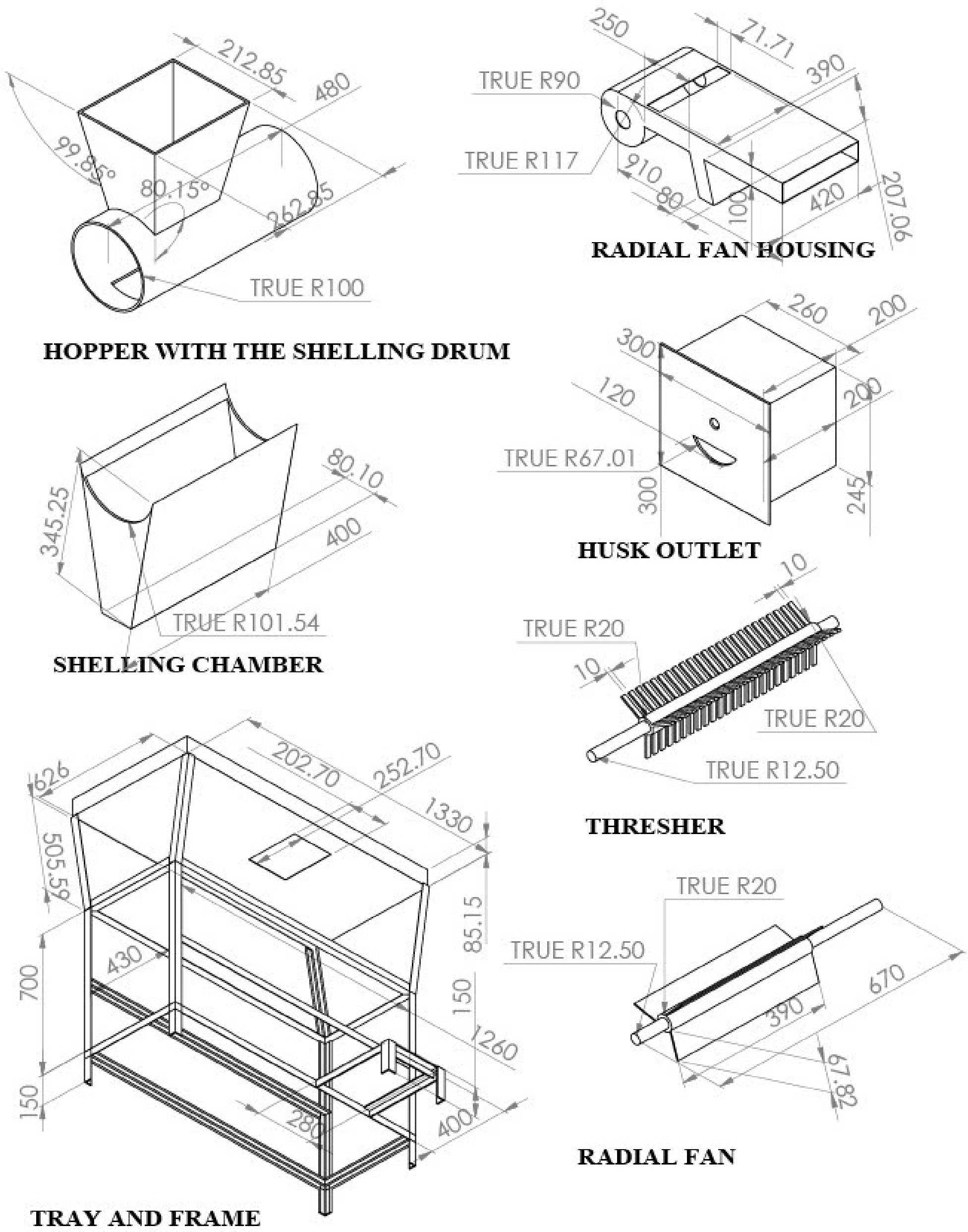

Figure. 4: Developed maize sheller components

Table 1: Obtained performance evaluation results

	Shelling machine	Hand shelling
Mass of unshelled maize (maize + cob)	20kg	20kg
Shelling Time	12mins	1hrs. 15min
Mass of shelled maize	15kg	13.6kg
Shelling effective capacity C= mass/time	$C = 20/0.2$ $= 100kg/hr$	$C = 20/1.25$ $= 16kg/hr$
Shelling efficiency $E = \frac{mass\,shelled}{total\,mass} x100$	$E = \frac{15}{15.04} x100$ $= 99.73\%$	$E = \frac{13.6}{15.04} x100$ $E = 90.31\%$

Table 2: Bill of Engineering Measurement and Evaluation

S/N	**Description**	**Quantity**	**Unit**	**Rate**	**Amount (₦)**
1.	2mm mild steel plate	3	Sheet Metal	7000	21,000
2.	50 x 50mm angle iron	3	Length	4000	12000
3.	Bearing 1604	2	Nr	500	1000
4.	Welding electrode 12 & 10 gauge	1	Packet	5,000	5,000
5.	Electric motor 2.0 hp	1	Nr	15,000	15,000
6.	V. belt	1	-	750	750
7.	Pulley	2	Nr	1,500	3,000
8.	Bolt and nuts	24	-	30	720
9.	Labour	-	-	25,000	25,000
10.	Painting	Lot	Nr	2,500	2,500
11.	Transportation	-	-	-	10,000
	Total				**95,970**

The Unshelled Losses (UL), which is the mass of grains that are unshelled to the total of grains shelled.

$$UL = \frac{unshelled\ mass}{total\ mass\ of\ grains} x100$$

$$= \frac{0.041}{15.04} x100$$

$$= 0.27\%$$

a) The Unshelled Maize b) Maize cobs after shelling

c) Maize chaff d) Shelled Maize

Figure 5: Unshelled Maize cobs and its Products after Shelling

Figure 6: The developed Maize sheller

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