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Development of a maize shelling machine using Hem-Fir wood

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ABSTRACT

This report presents the development of a maize shelling machine using Hem-Fir wood as the primary material. Maize shelling is a labor-intensive and challenging task, particularly in Nigeria, where it is a crucial cereal crop. The use of unhygienic and metal grinding machines in the market poses health risks to consumers. To address these issues, the study focuses on constructing simple maize shelling machine using Hem-Fir wood, which is durable and versatile. The machine consists of four major units: Framework, shelling unit, grain outlet, and cob outlet. The design criteria include simplicity, ease of fabrication and operation, control, and efficiency. The machine's performance was evaluated in terms of workability, throughput capacity, efficiency, and cost. The results showed that the Hem-Fir wood machine had an average throughput capacity of 111kg/hr and an efficiency rate of 86%. The estimated cost of fabricating the machine was ₦ 42,000, making it economical and affordable for small-scale farmers. Compared to existing metal shelling machines, the Hem-Fir wood machine offers a cheaper and safer alternative. The study demonstrates the successful development of a maize shelling machine using Hem-Fir wood, providing a cost-effective solution for maize processing in Nigeria.

Keywords: Maize, Machine, Shelling, Hem-Fir, Performance, Efficiency

1. INTRODUCTION

Maize (*Zea mays*) is one of the most important cereal crops grown in Nigeria (Akpan & Edem, 2022); it is the most important cereal crop after sorghum and millet (Ojo, 2000). The major steps involved in the processing of maize are harvesting, drying, de-husking. The difficulty of the process depends on the variety grown, the moisture content and the degree of maturity of the crop (FAO, 1992). According to Bako and Boman, (2017), maize shelling is always a tedious and difficult job, so to make farmers less drudgery and put less effort, we need to develop a maize shelling machine, keeping in mind the cost economy. Engine powered technology involved the use of mechanical assistance in shelling the maize (Hassan et al., 2009; Aromuegbe et al., 2018).

Usage of unhygienic machines is the usual practice in Nigerian markets and the operators do not appreciate the health risks involved in their operations (Kareem and Akinode, 2018). The use of metal grinding machine exposes consumers to intake of heavy metals which may result in slowly progressing physical, muscular, and neurological degenerative conditions, as well as cancer (Llobet et al., 2003). This study therefore focused on demonstrating the importance of Hem-Fir wood material in constructing simple maize shelling machines that would be suitable for home use and low-income farmers with minimal exposure to metals.

Hemlock fir sometimes referred to as Hem-Fir, is a hybrid species of lumber. Produced by a combination of Western Hemlock and true firs, this type of wood is durable and versatile, making it a popular choice for framing and other construction applications (Westerlund, 2022). Just like other lumber species, Hem-Fir also has its various attributes, which makes it suitable for certain applications; these include: Usage, physical properties, cost, availability and workability.

2. MATERIALS AND METHODOLOGY

Materials

Component materials were selected based on the scope of the study, while relevant tools were employed to develop the machine. The following are some of the materials and tools used; Hem-Fir wood, Wood, Sand paper, Switch, Stainless steel, Bearing, Roller, Electric Motor, Grinding machine, Hack saw, Hammer, Plane, Drilling machine

Methodology

Design consideration

This includes the design criteria and the functional requirement of the Sheller.

Design criteria

The design criteria consist of the following; simple design and ease of fabrication and ease of operation, control and good efficiency.

Functional requirement

The functional requirements of the machine include: It would be a competitive alternative to metal and it would be able to shell all varieties of dry maize

Description and Design of Machine Parts

The machine was made up of four (4) major units namely: Framework, shelling unit, grain outlet and cob outlet.

The framework

It was made of Hem-Fir wood (HF) and it takes the shape of a rectangular box of 0.66m by 0.32m width and a height of 0.62m.

Shelling unit

The slicing compartment was made up of a HF wooden material and it houses the electric motor. It is a square based frustrum with an orifice at the base. It has a height of 20cm, an upper and lower width of 35cm and 22cm respectively.

Volume of shelling unit (V) $= h/3(S1 + S2 + \sqrt{\sqrt{S1S2}})$

(S_1 is the area of the lower base; S_2 is the area of the upper base; h is the height of the frustrum)

Shaft design

This is directly attached to the motor and it bears the spikes responsible for shelling. It does not undergo torsional stress; therefore, the shaft diameter considered was subject to the maximum width of available maize width.

$Shaft\ length\ = 0.32m\ ,\quad Shaft\ diameter\ = 0.04m$

$Weight(W) = mg$

$But\ M = \rho v = \rho \pi r^2 l \qquad (\rho\ for\ HF\ wood\ = 800kg/m^3)$

$M = 800\ x\ 3.14\ x\ 0.02^2\ x\ 0.32 = 0.32\text{kg}$

$Therefore\ \ W = 0.32\ x\ 9.81 = 3.15N$

Number of spikes on the shelling shaft

The number of spikes on the shelling cylinder was given by:

$Np = Lc\ x\ \pi d / Ssr\ SSc$

Where, Np = Number of spikes on shelling shaft, Lc = Length of shelling shaft = 0.35m
Ssr = Spike spacing on row = 0.03mm, Ssc = Spike spacing on circle = 0.03mm
d = diameter of shelling shaft = 0.04m
Therefore, $Np = 0.35 \, x \, 3.142 \, x \, 0.04/ \, 0.03 \, x \, 0.03$ = 44

Determination of machine speed

Angular velocity of shelling shaft is expressed as:

$\omega = 2\pi N/60(rad)$

While the velocity of shelled grains leaving the shelling-shaft is expressed as:

$v = \omega r$

Where, N is the speed of the shaft, and r is the radius if the shaft.

Torque and force calculation

$F = \mu mg$

$T = F \, x \, r$

Maize Outlet

This is the opening through which the shelled maize exits the shelling unit for collection or bagging. It was dimensioned 0.08m by 0.20m.

$Area \, of \, outlet = L \, x \, b$

Cob Outlet

This is the opening through which the cob exits the shelling unit for collection or bagging. It is situated at the base end of the shelling compartment.

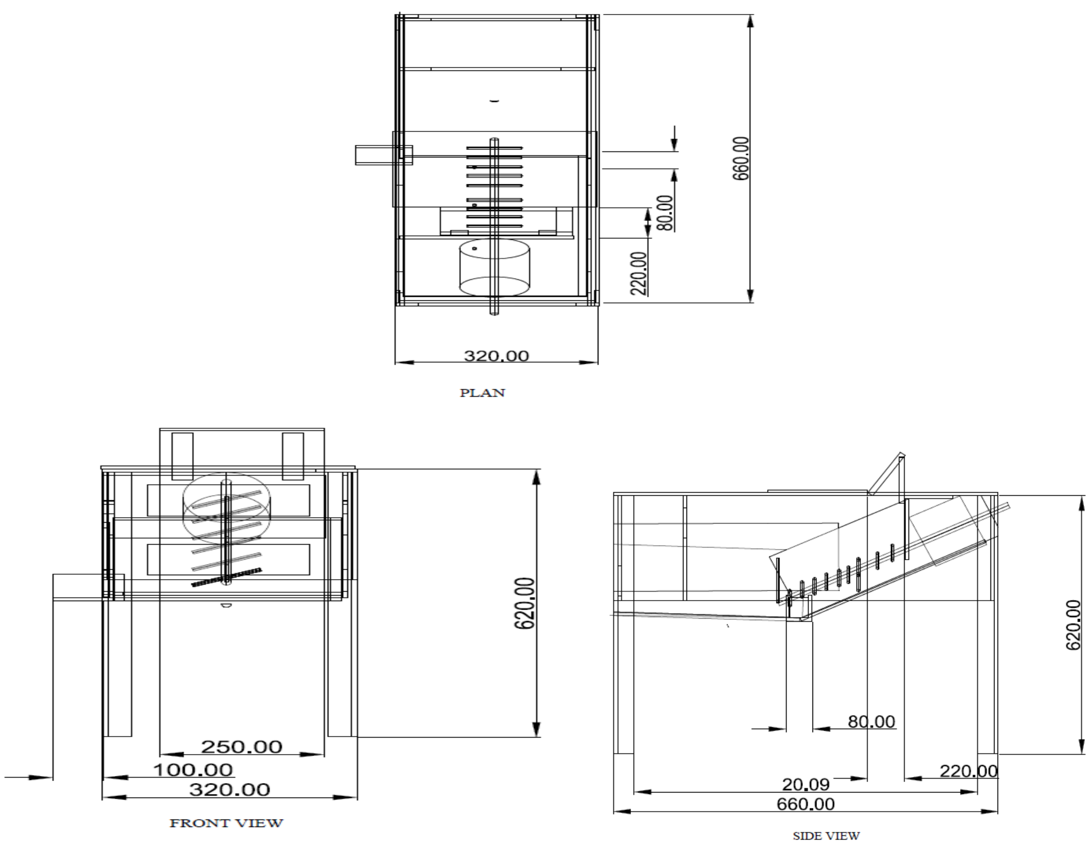

Figure 1 Orthographic drawing of the machine

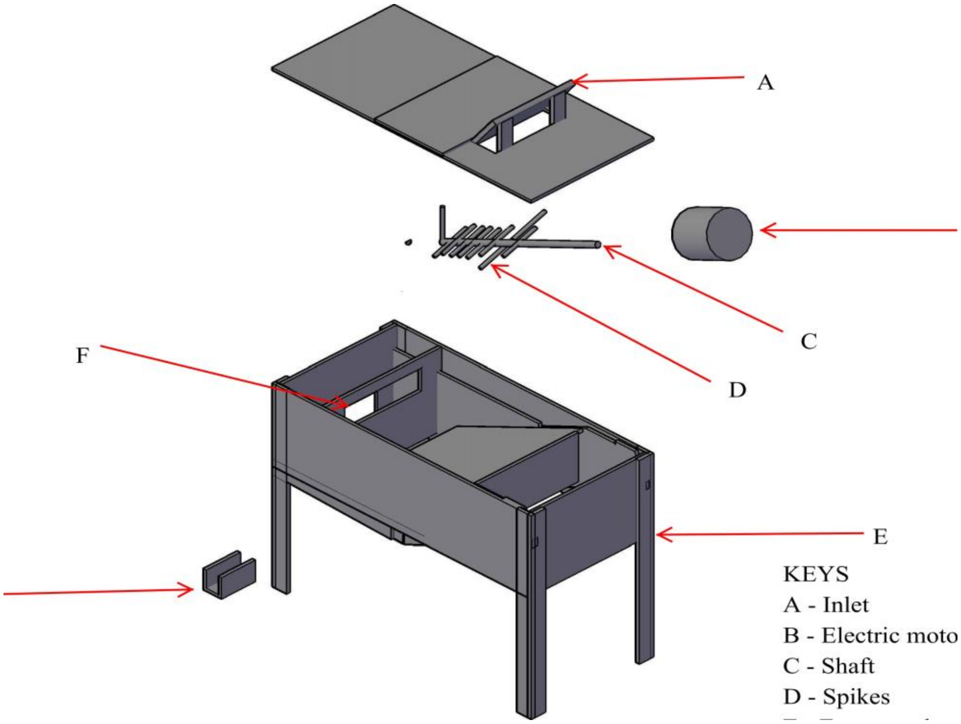

Figure 2 Exploded diagram of the machine

Table 1 Machine specifications

Machine component	Design value	Machine component	Design value
Volume of hopper	299cm^3	Angle of inclination	60^0
Angular velocity of shaft	83.79rad	Velocity of grains	1.68m/s
Torque on shaft	0.035Nm	Area of grain outlet	0.016m^2
Power rating of motor	1000W		

Principle of operation

To operate this machine, unshelled maize was fed carefully into the shelling unit which was inclined at an angle. The fed maize goes through the shelling unit where shelling takes place. The shelling shaft is well "spiked", and is driven by the electric motor. The rotational movement of the shelling shaft throws the maize to the surrounding walls; this random motion and collisions of the maize against the spikes and the walls, shell off the grains from the cob. The shelled grains fall out through the grain outlet just below the shelling unit. While the cob travels through the inclination to be pushed out at the other end of the unit.

Side view

Front view

Figure 3 Assembly of developed machine

Shelling machine performance evaluation

Maize physical characteristics

Assessments of the physical characteristics of unshelled maize was carried out while the moisture content was determined using a moisture analyzer.

Machine

The following performance indicators were evaluated; workability test, throughput capacity and efficiency of the machine.

Workability test: This was the test assessment of the machine to shell dry maize product of different sizes successfully. A machine passes the "workability test" if it functions properly before loading and when loaded.

Throughput capacity (Kg/h): Throughput is the rate of shelling; it is the quantity of shelled maize divided by the time taken.

$Throughput = weight/t$ (Kg/h)

Where Weight = weight of shelled maize, t = total time taken to shell

Efficiency (%): The efficiency of the machine was determined using the equation: $Efficiency = [\{W1 - W2\}/ W1]\ x\ 100$

Where W1 ------ weight of unshelled cobs, W2 ------ weight of not well shelled cobs

Machine cost valuation: For this study, the cost of materials, fabrication, transportation, labor and miscellaneous were considered as the cost incurred for production.

3. RESULTS AND DISCUSSION

Maize physical characteristics

Assessments showed that for most, moisture content was between 13% to 14%, while density was averagely 1200kg/m^3. However, a consistent weight of 20kg was suitable for shelling in one pass per time.

Workability

The Hem-Fir wood machine ran satisfactorily with a reduced noise level at idle operation without component failure. Subsequently, it shelled dry maize and separated the shelled maize from the cobs into different sections at permissible noise level.

Throughput capacity (kg/h)

Table 2 shows the result of the throughput capacity of the machine, while Figure 4 shows the pattern of initial weight of maize against the throughput values; it was observed that the average time to shell a sample of 20kg of maize was 9.4 minutes; variations in time spent could imply that the machine worked best at the beginning, could also be as a result of machine or human factor. The shelling machine had an average throughput capacity of 1.85kg/min and this is projected to optimally yield a throughput capacity of 111kg/hr. This is considered far better than human throughput capacity which was determined to be 21kg/hr (Adedeji et al., 2018).

The result is also similar to the report of Adewumi, (2015), who obtained a throughput capacity of 450.65kg/hr in his research, but considered driving the machine with an electric motor engine of 4,500W (i.e., over four (4) times bigger than the motor used for this study); this suggests that the expected throughput capacity of this machine would be 499.5kg/hr if driven by same power capacity.

Table 2 Average throughput capacity of the Hem-Fir wood shelling machine

Replicates	Initial weight (kg)	Unshelled maize (kg)	Time (mins)	Throughput (kg/min)
1	20	2	9	2.00
2	20	2	8	2.25
3	20	3	10	1.70
4	20	3	10	1.70
5	20	4	10	1.60
Mean	20	2.8	9.4	1.85

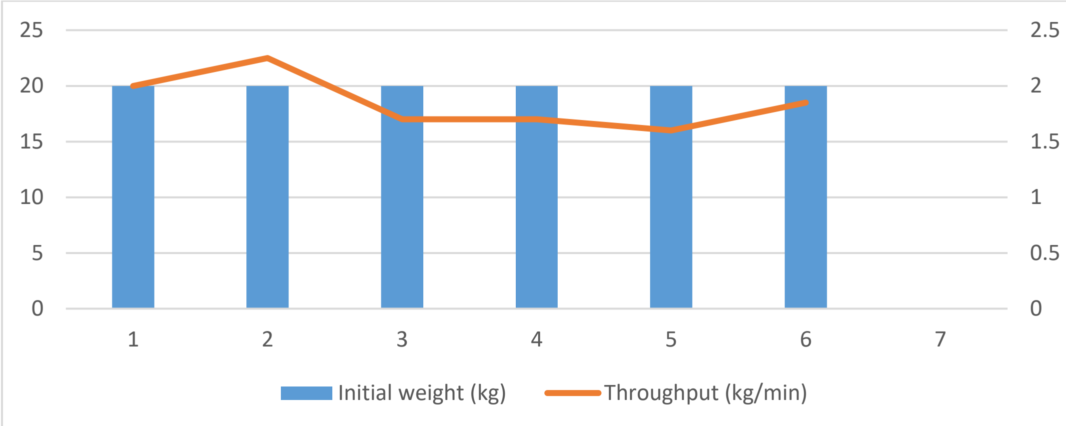

Figure 4 Pattern of initial weight of maize against the throughput values

Efficiency of the machine

$Weight\ of\ unshelled\ =\ 20kg, \qquad Weight\ of\ not\ well\ shelled\ =\ 2.8kg$

$Efficiency\ =\ [\{W1 - W2\}/\ W1]\ x\ 100$

$Efficiency\ =\ [\{20 - 2.8\}/\ 20]\ x\ 100\ =\ 86\%$

This implies that the machine runs at an efficiency rate of 86%; and is assumed to be considerable high. Energy could have been lost through heat or due to human factor, as the operator may delay in feeding the maize into the machine. This result is not far from (Adewumi, 2015) who reported an efficiency of 87%; this slight difference could be the effect of variations in the moisture content of selected maize samples.

Machine cost valuation

Table 3 showed that the estimate of the cost of fabricating the machine is approximately ₦42,000. A public price survey of economic reality and cost of existing shelling machines showed this value is very economical. It indicates that this machine is relatively cheap and can be conveniently purchased by small scale farmers.

Table 3 Bill of engineering measurement and evaluation of production

S/N	Component/Material	Cost (₦)
1	Electric motor/bearing	13,000
2	Nails/screws/switch	5,000
3	Hem-Fir wood material	15,000
4	Transportation	1,000
5	Labor	8,000
Total		42,000

4. CONCLUSION

The study successfully developed a maize shelling machine from the Hem-Fir wood and with the use of very simple technology. The machine was able to carry out the specific function of shelling maize and separating the cob from the grains in different outlets. Result showed that it had a throughput value of 111kg/hr and an efficiency of 86%; The cost of developing the machine was ₦ 42,000 which was considerably economical compared to the cost price of ₦75,000 for a shelling machine made out of metal. The cost of usage was also perceived cheaper and safer when compared to existing local shelling methods.

Ethical issues

Not applicable.

Informed consent

Not applicable.

Funding

This study has not received any external funding.

Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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