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Development of a rice grinding machine using Hem-Fir wood material

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ABSTRACT

This study presents the development of a rice grinding machine using Hem-Fir wood material. The motivation behind this project was the health risks associated with the use of metal grinding machines, which expose consumers to heavy metal intake. The study aimed to create a simple grinding machine suitable for home use and low-income farmers, with minimal exposure to metals. Hem-Fir wood, a hybrid species of lumber known for its durability and versatility, was chosen as the construction material for the machine. The report provides detailed information on the materials and methodology used in the development of the machine, including the design considerations for its components. The machine consists of an electric motor, a frame made of Hem-Fir wood, a hopper for grain feeding, a grinding chamber, and grinding discs. The principle of operation involves the rotational motion of the grinding discs, which grind the grains fed through the hopper. The performance of the machine was evaluated based on workability, weight change, grinding efficiency, and cost. The results demonstrated that the machine effectively grinds rice with a minimal material loss of less than 1%. The machine had an estimated efficiency of 94% and a production cost of N35,000, making it a cost-effective alternative to existing grinding machines. Overall, this study successfully developed a rice grinding machine using Hem-Fir wood material, offering a solution with reduced health risks and competitive efficiency.

Keywords: Grinding machine, Hem-Fir, Performance, Efficiency, Cost

1. INTRODUCTION

Grinding machines used in agriculture are graded to obtain concentrated fodder mix, and food industry for grinding raw materials necessary for obtaining various types of flours. For several decades, men were faced with challenges of particles being grinded alongside spices or grains with the available grinders (Kareem and Akinode, 2018). Heavy metals disrupt basic metabolic functions in two ways: On one hand, they disrupt the functioning of vital organs and glands such as the heart, brain, kidney, bone or liver, on the other hand, they move nutrients that are essential minerals and prevent them from fulfilling their biological functions (Demi, 2014; Aniobi et al., 2022).

For example, aluminum as a chelator has the ability to prevent the uptake of essential elements such as calcium, zinc and copper, and disrupt the proper use of many of them (Dabonne et al., 2010). This metal is heavily involved in the onset of Alzheimer's disease. It is responsible for the alteration of neurons (Miu and Benga, 2006). According to Demi, (2014) over the years, there has been frantic effort to overcome this challenge. 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; Markmanuel et al., 2023).

Unhygienic grinding machines is the usual practice in Nigerian markets and the operators do not appreciate the health risks involved in the ir operations (Kareem and Akinode, 2018). This study therefore developed a simple grinding machine from Hem-Fir wood material 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). 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 METHOD

Materials

The materials used for the construction of the machine were classified into two (2); the component materials and the tool materials.

Component materials

These include, Hem-Fir wood, grinding paper, sand paper, switch, bearing, roller, electric motor

Material tools

These include, hack saw, hammer, plane, chisel, drilling machine, hammer, bolt and nut, measuring tape, and plane

Methodology

The machine was designed to enhance the grinding of agricultural produce for non-commercial purposes and to reduce the cost of producing grinding machines using alternative construction materials and simple technology.

Design consideration for parts

The design considerations for the different parts of the machine were classified into design criteria and functional requirement.

Design criteria

The components were designed to ensure ease of assemblage and maintenance, and the machine was fabricated with easily accessible materials to ensure low cost

Functional requirement

It should be able to grind small sized grain crops.

Description and design of the machine

The grinding machine comprises of the following components.

Electric motor

It converts electrical energy into rotational force or torque and transmits it to the grinding unit by a direct connection through the shelling shaft.

Table 1 Electric motor specification

S/No	Specification	Unit
1	Voltage	230 volts
2	Frequency	50/60Hz
3	Speed	1300rpm
4	Power	50W

Frame
High surface finish Hem-Fir wood was used to construct the frame. This frame houses the grinding unit and gives a physical outlook to the design. It also supports the entire weight of the machine. The total weights carried by the main frame are the weight of the electric motor and the weight of the bearings and pulleys.

Hopper
This is the grain container as the name implies, it is a device in which the grains to be grinded are fed through (transitionally), before they are gradual released into the furrowed chamber. The hopper is made from 2.5 mm thick Hem-Fir wood material. It has a height of 0.2m, an upper base of 0.22m and a lower base of 0.1m. The volume of the hopper is calculated using the formula:

$$Volume = h/3(A1 + A2 + \sqrt{A1A2}$$

Where A1 is the lower base, A2 is the upper base and h is the height of the frustum

Grinding chamber
The grinding chamber is cylindrical in shape. It is a drum-like compartment with a diameter of 0.18m and an effective height of 0.005m.

Therefore, volume may be determined: $V = \pi r^2 l$

Where, V = the total volume of the cylinder (m^3), r = effective radius of the cylinder (m), l = length of the cylinder (m)

Grinding discs
It is made up of two (2) sand-paper-cut hollow discs facing each other, and rotating relatively to one another. Each has an outer diameter of 30cm and an inner diameter of 0.5cm. The relative circular motion of these sandpapers grinds the grains that are fed into them through the hopper.

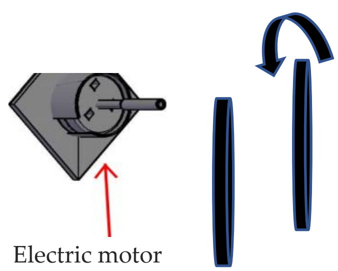

Figure 1 Electric motor and grinding disc positioning

Disc design
Peripheral grinding speed (V) = π (D1 – D2) x N/60

Where N is the rotational speed of 1300rpm, which is the same as the speed of the electric motor and D1 is the outer diameter and D2 is the inner diameter

Grinding force (F) = P/V,

Where, P … power (W), A … grinding speed (m/s)

Grain outlet
This is the opening where the grinded samples are collected. It had a dimension of 7cm x 4cm and the area of the outlet was determined by: Area of outlet = L x b

Table 2 Machine specifications

Machine component	Design value	Machine component	Design value
Volume of hopper	$0.01m^3$	Angle of inclination	60^0
Vol of grinding cylinder	$0.00013m^3$	Vol of grinding chamber	$1.27 \times 10^{-4}m^3$
Grinding speed	20.1 m/s	Grinding force	2.49N
Area of grain outlet	$0.0028m^2$		

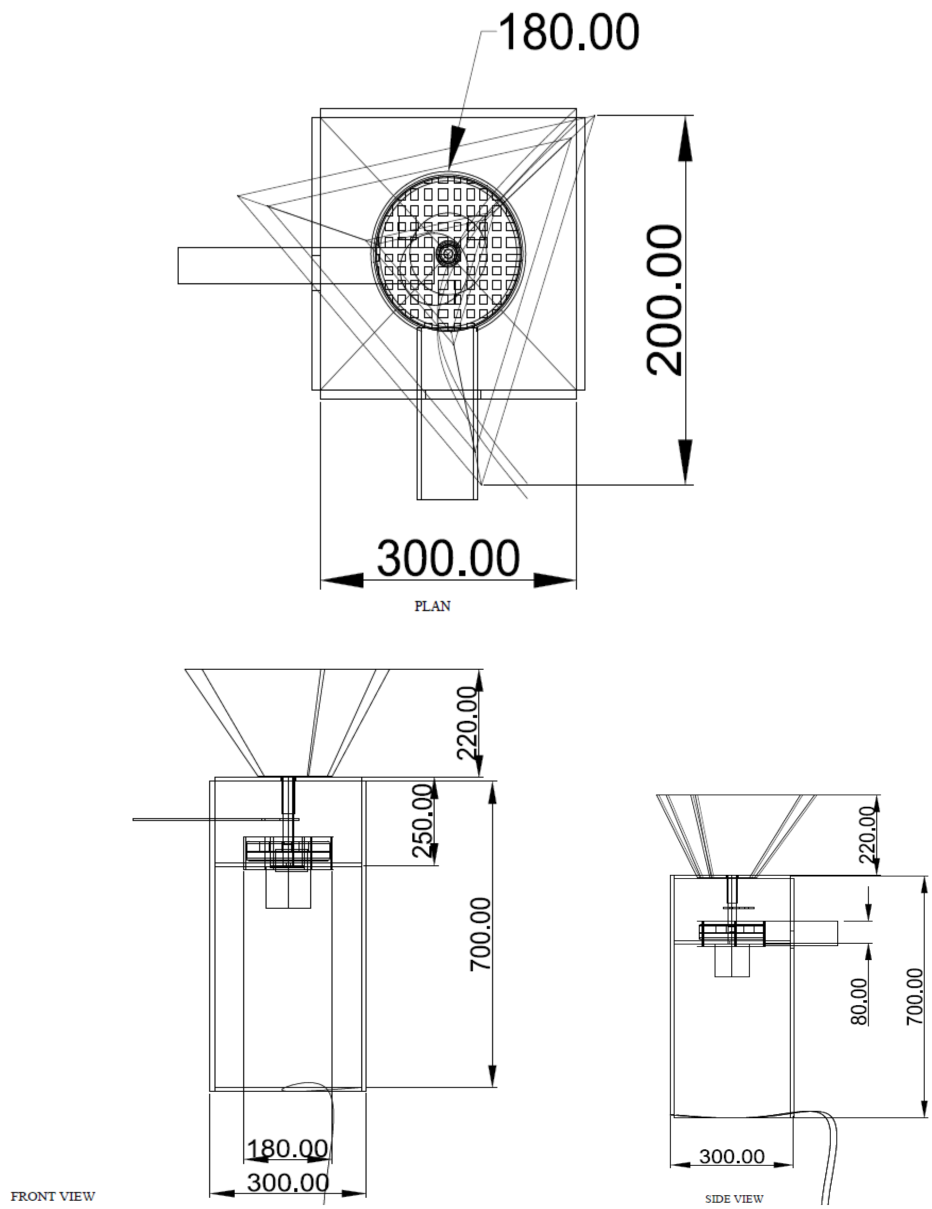

Figure 2 Orthographic drawing

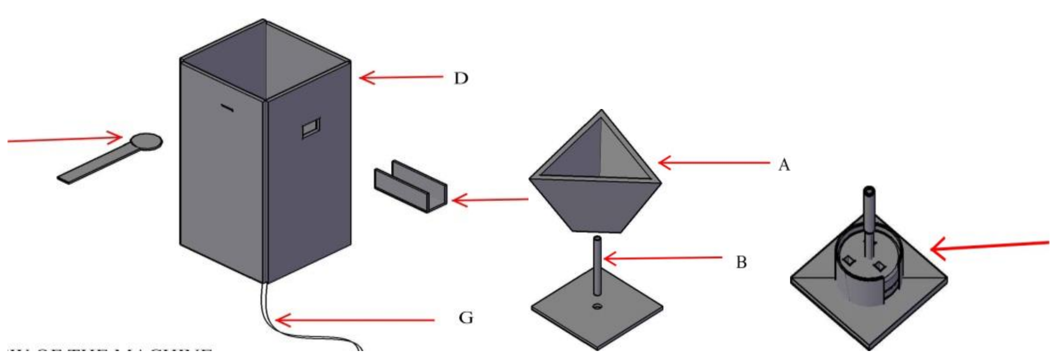

Figure 3 Exploded view of the machine keys; A- Hopper; B- Grain pipe; C- Grinding chamber; D- Framework; E- Outlet; F- Gate; G- Electric cable

Principle of Operation

The operation of the machine is easy and requires only an individual to operate. Grinding was accomplished by powering the electric motor; the electric shaft drives through the static grinding disc, but turns the other one. The bearing holds the shaft firmly at the base of the grinding unit to avoid wobbling. The constant relative motion of the discs the rotational motion of the fed-materials and the effect of gravity forces grinded particles that can pass through the mesh to fall through to the lower layer. The grinded products are collected at the collection outlet. Figure 4 is the pictorial view of the fabricated machine.

Front View Side View Top View

Figure 4 Pictorial view of the Hem-Fir wood maize shelling machine

Performance Test

A grinding performance test was carried out in the Federal College of Forestry, Jericho, Ibadan. For this study, 10kg of rice sample was weighed before grinding, and then grinded. The sample was gradually fed through the hopper and given time to be grinded before more were fed in; this was to avoid "machine jam" due to excessive material. The time to completely grind the sample to fine particles was recorded and the weight after grinding was also recorded. This procedure was replicated five (5) times.

Evaluation parameters

The fabricated machine was evaluated considering the following factors; workability, weight change, grinding efficiency and cost.

Workability: This was to ascertain if the machine worked successfully at idle operation and after loading rice grain samples.

Change in weight (kg): This is the difference in the weight input and the output of materials after grinding.

Mathematically $Change\ in\ weight\ (\Delta W) = W1 - W2$

Where, W1 … Weight before grinding, W2 … Weight after grinding

Grinding efficiency (%): This is the ratio of the mean change in weight of the samples to the expected weight and measured in percentage.

$Mean\ efficiency = W1 - \Delta W / W1\ x\ 100$

Where ΔW … mean change in weight W1 … mean weight

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

Workability

The machine was able to perform the specific function of grinding rice grain samples like other grinding machines made out of metal/steel materials. It was also observed that noise level during grinding was significantly low when compared to other existing grinding machines; this could be because there were no metals rubbing against themselves. The use of the Hem-Fir wood as the frame also served as a sound-proof compartment.

Change in weight (kg)

Table 3 shows the change in weight of the grain-samples and the time spent for complete grinding. Table 3 reveals that it took an average time of two (2) minutes to completely grind 10kg of grain sample and there was an average loss of 0.6kg which was stuck in the machine. This suggests that the machine can effectively grind rice with a material loss of less than 1%. These lost materials can be recovered during clean-up operations after grinding.

Table 3 Weight difference after grinding

Replicates	Weight before grinding (kg)	Weight after grinding (kg)	Weight loss (kg)	Time (s)
1	10	9.50	0.50	125
2	10	9.00	1.00	123
3	10	9.00	1.00	117
4	10	9.50	0.50	115
5	10	10.00	0.00	120
Mean	10	9.4	0.6	120

Mean efficiency of the machine

$Mean\ efficiency\ = W1 - \Delta W\ / W1\ x\ 100$

$Mean\ efficiency\ = (10 - 0.6/10)\ x\ 100$

$Mean\ efficiency\ = 94\%$

This implies that the developed machine had an estimated efficiency value of 94%; this was considerable high for any machine and it is very similar to the findings by Kareem and Akinode, (2018), whose grinding machine had an efficiency of 97%. This suggests that the machine can conveniently compete with existing grinding machines made from metals in terms of efficiency. This further makes it even more preferable as it provides a machine with a high percentage in efficiency, a cheaper cost and less minimal exposure to heavy metals.

Weight loss variations

Figure 4 illustrates the relationship between the weights of the samples before grinding against the weight lost after grinding. It shows that there were variations in weight loss values. Replicates 2 and 3 performed lowest with weight loss of 1kg each while replicate 5 performed best with no weight loss. This suggests that the longer the usage, the lesser the losses in weight of grinded materials. This could be because some already grinded particles from previous particles added up to its weight and the grinding machine productivity is directly proportional to all levels of feeding quantity and speed. This is in line with the findings of Suliman et al., (2013) which stated that the weight of loss in operations of batch 'A' and batch 'B' were almost the same in approximation. Therefore, the percentage loss in the total weight loss is minimal

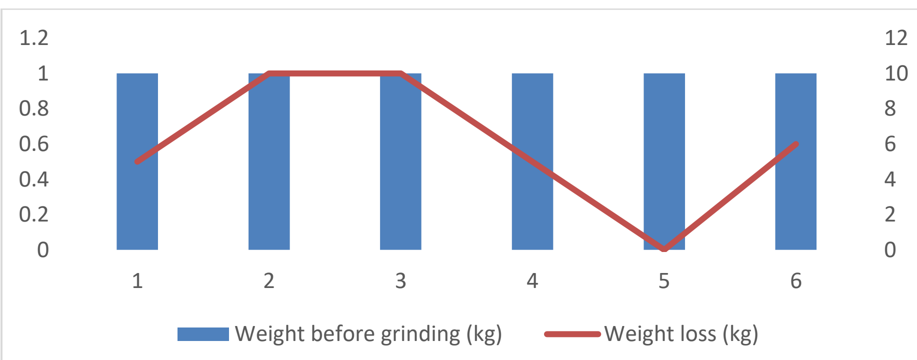

Figure 4 Graphical relationship between actual weight and lost weight

Machine cost valuation

Table 4 summarizes the machine cost valuation of developing the Hem-Fir wood grain grinding machine. This value is considered economical when compared against other grinding machines built with metals or other crude methods of grinding.

Table 4 Bill of Engineering Measurement and Evaluation (BEME)

S/N	Component/Material	Cost (₦)
1	Electric motor/switch	7,000
2	Sand paper	3,000
3	Hem-Fir wood	15,000

4	Bearings/screws	4,000
5	Transportation	1000
6	Labor	5,000
Total		35,000

4. CONCLUSION

The study was able to successfully develop a rice grinding machine using Hem-Fir with the adoption of very simple technology. The machine was able to carry out the specific function of grinding rice samples. It had low noise production, thus reducing noise pollution as a result of machine usage. It was able to grind 10kg of fed rice samples in 120 seconds, and recorded an average weight loss of 0.6kg. This could imply that there are corners within the grinding compartments where materials can easily hide. The machine also had an efficiency of 94% which is considered significantly high when compared to existing grinding machines made from metals. The cost of production was ₦35,000; this value is considered economical as it is cheaper to grinding machines in the market. The machine would also prevent exposure to health risks as a result of heavy metals.

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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