Design and Construction of A Locally Made Rice Dehuller

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Abstract: This paperwork presents the design and construction of a rice dehuller. The traditional manual dehulling of paddyrice has been a tedious, time-consuming, and laborious operation. A motorized rice de-huller was designed fabricated locally and tested. The key components parts of the rice dehulling machine are The hopper, Frame, Inner collector, Rubber roller, Blower, outlets, Motor, and power transmission. The power requirement of the machine was 2.22Kw. The hopper is a frustum of a rectangular pyramid shape used to feed the paddy rice into the huller. The hopper body was made from 2mm thick mild steel, measuring 350mm by 350mm respectively. The inner collector was made from a 1.5mm mild steel plate to gather or collect rice grains. The frame serves as support on which all other component parts are mounted. The frame support was made of 2 inches of angle iron (mild steel) of 1,100mm by 400mm and horizontal of 400mm by 400mm. The rubber roller was made of wood with a driven pulley diameter of 800mm and 100mm pulley diameter. The results of the test conducted on the machine show that the machine has a dehulling efficiency of 91.44%, Throughput capacity of 1kg, 3kg, and 5kg were 3.9kg/hr, 11.19kg/hr and 13.16kg/hr respectively. The cleaning efficiency was 0.07%, 0.19% and 0.28% respectively.

Keywords: *Rice dehuller, Locally made, and Rice grain*

I. INTRODUCTION

Paddy rice is recognized for its oval shape and measures approximately 1.5 mm in length and 0.9 mm in width .(Idris et al., 2018). It has a specific gravity of 1.47 and an average grain size of 1.18. When dry, paddy rice can be dehusked more efficiently, revealing a brown shell. Its protein content is comparable to other grains like millet, and it is rich in high-nutrient carbohydrates and essential amino acids such as methionine, riboflavin (vitamin B2), and niacin (vitamin B3), all of which are crucial for human health.(Idris et al., 2018).

Recent research continues to underscore the nutritional significance of paddy rice. It provides a vital source of energy and essential nutrients that support various bodily functions, including metabolism, DNA repair, and cognitive health (FAO, 2022). Advances in agricultural practices and dehusking technologies have further enhanced the nutritional profile and accessibility of paddy rice, making it an indispensable component of diets worldwide (IRRI, 2023).

Traditionally, hulling rice involves the use of a mortar and pestle, a method that is both labor-intensive and inefficient (Bisen et al., 2014). This traditional technique not only requires significant physical effort but also typically results in rice that contains stones due to the unsanitary conditions of the hulling process. This contamination poses health risks to consumers, such as appendicitis, and leads to excessive rice breakage, reducing the overall yield and quality of the hulled rice. Furthermore, the manual hulling process creates a significant bottleneck in rice production, making it extremely difficult to meet the rising rice consumption demand in Nigeria (Kayode and Olorunfemi, 2021).

Recent studies emphasize the urgent need for improved rice hulling methods to enhance efficiency and food safety. Modern hulling technologies offer more sanitary processing conditions, reducing the presence of foreign materials and improving the overall quality and yield of hulled rice (FAO, 2023). These advancements are crucial in addressing the growing demand for rice and ensuring the health and well-being of consumers (IRRI, 2023).

Rice processing involves several crucial steps: harvesting, drying, threshing, and milling. Each step is integral to transforming paddy rice into polished grains ready for consumption. Harvesting marks the initial phase, where mature rice crops are collected from the fields. Following harvesting, the rice undergoes drying to reduce its moisture content, a vital process to prevent spoilage and ensure safe storage.

Threshing comes next, separating the rice grains from the stalks. This step is traditionally labor-intensive but can be mechanized for efficiency. The final stage, milling, involves removing the protective hull, bran, and other unwanted materials from each rice grain. This process ensures the rice is clean, polished, and suitable for consumption (Anderson and Almeida, 2019).

Modern advancements in rice processing technologies have significantly improved the efficiency and quality of these steps. Improved machinery and techniques have reduced labor intensity and increased the yield and quality of the final product. Additionally, innovations in drying and milling processes help maintain the nutritional integrity of rice, ensuring that essential nutrients are preserved (International Rice Research Institute, 2023).

The milling process is particularly crucial, as it not only enhances the rice's edibility but also extends its shelf life by removing the perishable outer layers. Effective milling is essential to produce high-quality rice that meets consumer preferences and market standards (Food and Agriculture Organization of the United Nations, 2022).

Cleaning, shelling, bran removal, and size separation are all part of the rice mill operations. Rice milling is done to get rid of the chaff (Halimatuddini, 2019). In certain regions where rice is grown, rice milling is traditionally done using extremely antiquated methods after harvest. Techniques like using a wooden mortar and pestle to pound the rough rice and then winnowing it to separate the grain from the chaff. Due to this practice, the quality and quantity of rice produced locally are extremely low (Olufemi*et al.,* 2016). The nation imports a lot of goods from abroad. The conventional rice winnower has been improved by the rice milling machine. It is made up of the delivery unit, hopper, sheller, cleaner, separator (sieve), and frame.

Mode of Operation of Rice Dehuller

The primary mode of operation of a rice dehuller begins with the feeding of paddy rice into the machine. This process can be manual or automated depending on the scale and sophistication of the mill. Once the paddy is fed into the dehuller, it falls into a revolving drum that has an abrasive surface. The drum, also known as the hulling chamber, is designed to revolve at high speeds.As the drum revolves, friction is generated between the paddy rice and the abrasive surface of the drum. This friction facilitates the removal of the rice hulls from the kernel. To ensure efficiency, grains that are not dehulled in the first pass are usually collected and reintroduced into the system for another round of dehulling.One significant aspect of a rice dehuller's operation is its efficiency, which is optimized through multiple processes. These processes primarily include the adjustment of the drum's revolving speed, the pressure exerted against the grains, and the roughness of the drum's abrasive surface. By fine-tuning these elements, operators can enhance the dehuller's effectiveness while reducing the rate of broken grains.

Modern rice dehullers also leverage electronic sorting systems for separating the dehulled rice, hulls, and any remaining paddy rice. The sorted hulls are typically expelled from the machine and can be used as compost, animal feed, or as fuel for kilns and boilers in the mill. The separated rice is then processed further to become edible white rice or brown rice.

It is important to note that while the rice dehuller plays a crucial role in the milling process, it is part of a larger system. The operation of a rice dehuller is often integrated with other processes such as cleaning, grading, and polishing to ensure high-quality and safe production of consumable rice.Rice consumption provides Asians with half of their daily energy needs. It makes sense that the phrase "to eat" literally means "to eat rice" in Asian nations like the Philippines. Due to Nigeria's porous border, preference is given to foreign rice that is smuggled in. is high among Nigerians, which is harmful to the government's ability to generate revenue. The necessity of designing and building a rice hulling machine using locally sourced materials and a gasoline engine has arisen due to Nigeria's intermittent power supply, particularly in the majority of rural areas where this project holds significant importance and is not connected to the national grid. The objective of this research, therefore, is to design and construct a rice dehuller. (Ravichandran, and Antony 2019).

II. METHODOLOGY

Table 1: Materials selections for machine components

S/N	Machine component	Material selected	Reason for selection
1.	Frame	Mild steel angle iron	Doesn't twist easily, with vibration, and maintains firm stability
2.	Shaft	Carbon steel	High torsional strength. high criteria speed and resistance to wear.
3.	Chain	Mild steel	Readily available and allowable
4.	Bearing	Flange bearing	Proper alignment and easily fixed to the frame

Description of the machine: The rice dehuller is comprised of the following components; 1. The hopper, 2. Rubber rollers, 3. Shaft, 4. Chain, 5. Bearing, 6. Inner collector, 7 Blower, 8 Outlet, 9 Electric motor. The machine hopper was made of a 2mm plate. A blower was attached to blow air to separate the chaff from the grains. There are three outlets in the machine, the outlet for grains, the outlet for chaff, and the outlet for grain and chaff. The rice dehuller machine makes use of a high-speed electric motor of 3 horsepower and the speed for the motor is 2880rpm. The height, breadth, and length of the machine were measured to be 1100mm, 400mm, and 160mm. The diameter of the motor pulley was measured to be 0.02mm and the diameter of the machine pulley was measured to be 0.04mm.

III. PRINCIPLE OF OPERATION

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As the drum revolves, friction is generated between the paddy rice and the abrasive surface of the drum. This friction facilitates the removal of the rice hulls from the kernel. One significant aspect of a rice dehuller's operation is its efficiency, which is optimized through multiple processes. These processes primarily include the adjustment of the drum's revolving speed, the pressure exerted against the grains, and the roughness of the drum's abrasive surface. By fine-tuning these elements, operators can enhance the dehuller's effectiveness while reducing the rate of broken grains.

Design Considerations of the Rice Dehuller

In the design of the rice dehuller machine, the following factors were put into consideration; the size of the hopper, the shape of the frame, and the speed of the electric motor. Other factors considered are the durability of the machine, efficiency, safety, capacity, and maintenance.

Design Calculations

In view of the literature studies the following were designed for, hopper capacity, dehulling speed, stress in shaft, and dehulling force

Determination of hopper volume

The shape of the hopper was taken as a frustum of a rectangular pyramid. Thus the volume of the hopper was determined by Danilo Marco (2022) using Equation 1

$$V = \frac{1}{3}\text{h}(A_1 + A_2 + (\sqrt{A_1 X A_2}) \qquad (1)$$

Where:

V is the volume of a frustum of a rectangle pyramid (M^3), h is the height of the pyramid (M), A_1 is the area of the first base of the pyramid (M^2) $and\ A^2$ is an area of the second base of the pyramid (M^2)

The area (A_1) of the first base of the pyramid was determined by using Equation 2

$$A_1\ is\ \ L_1\, X\, B_1 \qquad (2)$$

Where:

L_1 is the length of the first base (M) and B_1 is the breadth of the first base (M)

Equation 3.3 was used to determine the area of the second base of the pyramid

$A_2 = L_2 X B_2$ (3)

Where:

L_2 is the length of the second base (M) and B_2 is the breadth of the second base (M)

Thus

$A_1 = 0.25 X 0.35 = 0.1225M^2$

$A_2 = 0.25 X 0.005 = 0.00125M^2$

Therefore from Equation 3.1

$$V = \frac{0.24}{3}(0.1225 + 0.00125 + (\sqrt{0.1225 X 0.0125})$$

$V = 0.08(0.136104)$

$V = 0.0108M^3$

Determination of de-hulling speed

De-hulling machine with two rubbing rolls requires an appreciable high speed to give an efficient de-hulling process. An electric motor of 3hp with a speed of 1400pm was selected. A driver pulley diameter of 80mm and 100mm pulley diameter for driven was selected.

Therefore, the speed of the de-hulling rollers was determined according to Adedeji*et al.* (2020) by using equation 3.4

$d_1 N_1 = d_2 N_2$ (4)

Where:

d_1 is the diameter of the drivers' pulley in m, N_1 is the speed of the driven in rpm, d_2 is the diameter of the driven pulley in M and N_2 is the speed of the driven in rpm

The speed of the drive was calculated using equation 3.5

$N_2 = \frac{d_1 N_1}{d_2}$ (5)

$N_2 = \frac{0.08 X 1400}{0.100} = 1120 \, rpm$

Determination of de-hulling torque

The de-hulling torque was calculated According to Adedeji*et al.* (2020) by using equation 6

$P = \frac{2\pi NT}{60}$ (6)

Where:

$N \text{ is speed in rpm,}$

$T \text{ is Torque in } NM$

$P \text{ is Power in}$

$T = \frac{p60}{2\pi N}$ (7)

for power of 3hp = 2220w

$$T = \frac{2220 X 60}{2 X \pi 1120}$$

$$T = \frac{133200}{7038.08}$$

$T = 18.9$

$T \cong 19NM$

Determination of stress in shaft

The stress in the shaft due to torsion was calculated according to Kharagpur (2020) using Equation 8

$T_{xy} = \frac{16T}{\pi d^3(1-k^4)}$ (8)

For solid shaft, $K = 0$

Where:

$T \text{ is Torque in } NM$

$d \text{ is diameter in } M$

$K \text{ is ratio of inner diameter to outside diameter}$

From equation 3.8

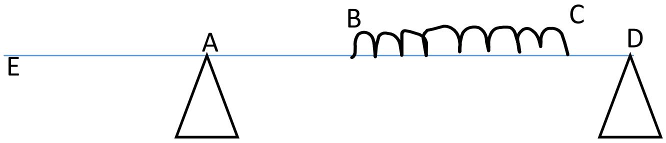
$$T_{xy} = \frac{16 X 20}{\pi(0.025)^3}$$

$$T_{xy} = \frac{320}{4.90 X 10^{-5}}$$

$T_{xy} = 172Mpa$

Determination of the shear force and bending moment of the roller

The below diagram shows the free body diagram for the de-huller roller.



Determination of the de-hulling force

The de-hulling force was calculated according to Osore(2018) using Equation 9

$T = Fr$ (9)

Where:

$F \text{ is Force in } N$

$r \text{ is radius of shaft in } M$

A shaft diameter of 25mm was selected

Thus

$$r = \frac{d}{2}$$

$r = \frac{0.025}{2} = 0.125m$

From equation 3.9

$$F = \frac{T}{r}$$

$$F = \frac{19}{0.0125} = 1520N$$

The uniform load was considered to be the weight of the wooden part and the weight of the full-load hopper filled with rice. 563kg/M^3 was considered to be the density of rice.(Aremu*et al.*, 2014)

Where the total weight of the hopper filled with rice was determined using Equation 10

$d = \frac{m}{v}$ (10)

Where:

$d \text{ is density in } kg/m^3$

$m \text{ is mass in } kg$

V is volume in M^3

$M = d \times v$

$M = 563\ X\ 0.00125 = 0.7kg$

The weight of the wood was thus calculated as

$$M = d \times v \quad (11)$$

Where 497 kg/m^3 is considered to be the density of the wood (UltimateGuide, 2022)

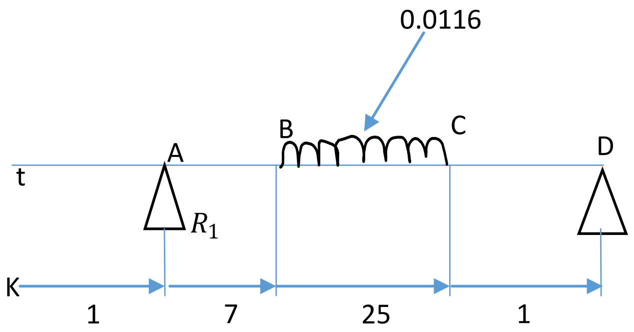
The volume is $0.00270507m^3$

$M = 497\ X\ 0.00270507$

$M = 1.34\ kg$

$M \cong 1.3kg$

Total weight $= 0.7 + 1.3 = 2kg$



Taking a moment about A

$$A_2\ X\ 0.425 = 1.60\ X\ 105 + 0.0116\ X\ 0.25\ X \frac{0.25}{2}$$

$$A_2 = \frac{0.1683}{0.425}$$

$A_2 = 0.3kg$

$A_2 \cong 0.4\ kg$

$R_1 = Total\ loadon\ the\ shaft - R_1$

$R_1 = 0.7 + 0.0029 - 0.4$

$R_1 = 0.303\text{N}$

Plate 6: Front view of the Fabricated Rice Dehuller

III. RESULT AND DISCUSSION

Table 1. The testing parameters of the Machine

S/N	Mass of paddy rice (kg)	Mass of grain (g)	Mass of husk (g)	Mass of grain + Husk (g)	Grain loss (g)	Throughput capacity (kg/h)	Cleaning efficiency (%)	% breakage	Processing time (sec)
1.	1	0.65	0.10	0.05	0.20	3.91	0.07	1.20	923
2.	3	1.86	0.50	0.25	0.39	11.19	0.19	0.03	965
3.	5	3.90	0.73	0.19	0.18	13.16	0.28	0.04	1369

DISCUSSION

Three trial runs were carried out on the rice dehuller. The machine was tested with paddy rice at loads of 1kg, 3kg, and 5kg of moisture content (16.4%) given that the electric motor provides a constant speed of 1400rpm.Also, the result obtained from the test carried out on the rice dehuller machine shows that there was an increase in the mass of grains obtained from the discharge end as the mass of grains fed into the machine. This result was found to be similar to the result obtained by Adedeji*et al.* (2020) In addition, the time taken for processing the paddy rice was found to be 54 minutes, and this was higher than that obtained by Osore and Adio (2018) (11.69 minute) This could be due to the that the quantity of grains used in the testing of their machine was 1 kg. Furthermore, the percentage breakage was found to be higher (1.20%) when the machine was loaded with 1kg of paddy rice but decreased with an increase in the mass of the paddy rice (3kg and 5kg). This result contradicts the result obtained by Adedeji*et al.* (2020) where the percentage increases with an increase in the mass of grains. Also, the efficiency of the machine was obtained as 91.4%. This is close to the value (91.3% and 88.80%) obtained by Dauda*et al.* (2012) and Adedeji*et al.* (2020) respectively.3.91, 11.19, and 13.16 kg/hr were obtained as the throughput capacity for 1kg, 3kg, and 5kg of paddy rice respectively. The values (16.41 – 16.47 kg/hr) obtained were lower than that obtained by Dauda*et al.* (2020). This could be due to the fact that different moisture content (14 – 15%) of the paddy rice used by the research as against 16.4% moisture content used in this research.

CONCLUSION

The rice dehuller machine was successfully designed and fabricated using readily local materials. The rice dehuller was tested and all the component parts worked . The machine was able to dehull 9kg of paddy rice at 0.0099kg/h.

References

[1] Idris, R. M., and Yawas, D. S., (2018). Development and Performance Evaluation of a Three Rollers Acha (Digitariaexilis) Dehusking Machine. Arid Zone Journal of Engineering, Technology and Environment, 14(2), 261-271.

[2] Bisen, R., Jhariya, A. N., and Jain, S. K. (2014). "Traditional and mechanical methods of the rice processing." Agricultural Engineering International: CIGR Journal, 16(1), 121-130.

[3] Kayode, O. and Olorunfemi, T. (2021). "Addressing Rice Production Challenges in Nigeria." Journal of Agricultural and Food Information, 22(2), 145-158.

[4] Food and Agriculture Organization of the United Nations. (2023). "Rice: Post-harvest handling and processing." Retrieved from FAO website

[5] International Rice Research Institute. (2023). "Advancements in Rice Processing." Retrieved from IRRI website

[6] Anderson, B., and Almeida, R. (2019). "Rice Processing: An Overview." Journal of Food Processing and Preservation, 43(6), e13901.

[7] Food and Agriculture Organization of the United Nations. (2022). "Rice: Post-harvest handling and processing." Retrieved from FAO website

[8] International Rice Research Institute. (2023). "Advancements in Rice Processing." Retrieved from IRRI website

[9] Olufemi, B. B., Olayide, R. A., Peter, O. A., and G A, S. (2016): Development of a low-cost rice milling machine. LAUTECH Journal of Engineering and Technology, 10(2), 85-91.

[10] Osore, O.A., and Adio, M.A. (2018): Design and development of an Ofada Rice Hulling Machine. International Research Journal of Engineering and Technology (IRJET), 5(11).

[11] Adedeji, K. A., Raji, N. A., Oyetunji, E. O., and Ishola, B. (2020): Design and fabrication of a motorized rice hulling machine. Journal of Engineering Research, 1(2), 4-5.

[12] Danilo, Marco (2022): Frustum of a Pyramid and Cone: Volume and Formulas IIT Kharagpur, (2009): Shaft and its design based on strength [Lecture notes]. Version 2 ME. 12-31

[13] Aremu, D.O., Babajide, N. A and Ogunlade, C. A (2014): Comparison of some Engineering Properties of Common Cereal Grains in Nigeria. International Journal of Enginering Science Invention, 3(4) 10-14.