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Original Article

DESIGN AND CONSTRUCTION OF RICE TRESHING MACHINE

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ABSTRACT

This project presents the design, construction, and experimental testing of a low-cost rice threshing machine aimed at supporting smallholder farmers in rural areas. The machine is built using locally available materials, including mild steel sheets, angle iron, and a 2 HP electric motor. It employs a spike-tooth threshing drum, a vibrating sieve, and a blower system to effectively separate rice grains from panicles and chaff. The main design objectives were to reduce manual labor, minimize post-harvest grain losses, and ensure operational simplicity and affordability. Experimental trials were conducted using 10 kg batches of sun-dried rice panicles over five trials. Performance indicators such as threshed grain weight, unthreshed grain, grain loss, and threshing efficiency were recorded. The machine consistently achieved threshing efficiencies ranging from 85% to 88%, with an average of 86.4%. Grain loss remained constant at approximately 5%, indicating reliable grain separation and minimal breakage. The machine operated smoothly throughout the tests, with stable power transmission, minimal vibration, and no significant mechanical failures. The results demonstrate that the rice threshing machine meets essential design criteria and is suitable for deployment in small-scale farming contexts. The simplicity of the construction allows for easy repair and local fabrication, enhancing its accessibility and sustainability. Recommendations for future improvements include fine-tuning the blower and sieve system and exploring alternative power sources such as solar energy. In conclusion, the rice threshing machine offers a practical and efficient solution for improving post-harvest processing and supporting food security in rice-producing regions.

Keywords: Rice Threshing Machine, Post-Harvest Technology, Spike-Tooth Drum, Threshing Efficiency, Grain Loss Reduction, Smallholder Farmers, Local Fabrication, Agricultural Mechanization

INTRODUCTION

Rice (Oryza sativa) is a fundamental staple food crop consumed globally, especially in developing countries where it constitutes a major portion of daily caloric intake Pandey et al. (2011). As the global population increases, so does the demand for rice, necessitating innovations in rice production and post-harvest technologies. The threshing process, which involves separating the grain from the husk and straw, is a crucial step in post-harvest processing. Traditionally, rice threshing has been labor-intensive, involving manual beating or animal trampling, resulting in low efficiency, high labor demand, and significant grain losses Gupta and Das (2002), Mohammed et al. (2012).

Mechanization of post-harvest activities such as threshing is essential to improve productivity, reduce human drudgery, and minimize grain loss Hossain (2009). In many low- and middle-income countries, especially in rural regions, the high cost and

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unavailability of industrial threshing machines leave farmers dependent on outdated manual techniques Adejumo (2015). The design and construction of affordable, efficient, and locally adaptable rice threshing machines can significantly enhance post-harvest processing, income generation, and food security in these areas (FAO) (2017).

Despite the importance of rice to global food systems, smallholder farmers in rural communities continue to rely on manual or semi-manual methods for threshing, which are inefficient and laborious. These methods not only limit throughput but also result in high post-harvest grain losses (up to 15–20%) Jayas and Gokhale (2010), Baker et al. (2013). Moreover, commercially available threshing machines are often prohibitively expensive, require high maintenance, or are ill-suited to local farming practices and energy constraints Pande (2011).

Hence, there is a need for a simple, cost-effective, and energy-efficient rice threshing machine that can be fabricated using locally available materials and operated with minimal technical knowledge. This machine must be suitable for small-scale farmers, especially in sub-Saharan Africa and Southeast Asia, who form the bulk of rice producers globally (IFPRI) (2020).

The main objective of this study is to design and construct a functional rice threshing machine that:

1) Reduces labor intensity and time required for threshing.
2) Minimizes grain loss and breakage.
3) Is affordable and easy to operate and maintain.
4) Utilizes readily available materials for construction.

Developing a simple mechanical solution for rice threshing has significant implications for agricultural development. It promotes post-harvest efficiency, improves the livelihoods of smallholder farmers, and supports sustainable food systems Ayoola (2015). By focusing on local materials and low-cost fabrication techniques, this study contributes to rural technology empowerment and agricultural resilience.

TRADITIONAL THRESHING METHODS AND THEIR LIMITATIONS

Manual threshing, widely practiced in regions of Asia and Africa, typically involves beating the harvested rice against a hard surface or trampling by animals Singh et al. (2013). While this method requires minimal equipment, it is highly labor-intensive and time-consuming, and often results in substantial grain loss and contamination Patel (2014). Several studies have reported inefficiencies of manual threshing with throughput rates as low as 50–100 kg/hour and grain loss exceeding 10% Onwualu (2005).

Animal-powered methods, though slightly more efficient, still present issues related to hygiene, cost of maintaining animals, and uneven threshing Ishaq et al. (2016). Furthermore, these methods are inconsistent with modern quality standards required by large-scale processors and exporters Raut (2015).

MECHANIZED THRESHING TECHNOLOGIES

Mechanization in threshing enhances processing speed, reduces labor input, and improves grain recovery rates. Various types of threshers have been developed over the years, including spike-tooth, axial flow, rasp-bar, and hammer mill threshers Dange and Sangle (2015). Among these, the spike-tooth thresher is widely adopted in small-scale applications due to its simple design, cost-effectiveness, and satisfactory performance on rice and similar cereals Okonkwo et al. (2014).

Studies have shown that mechanized threshers can increase productivity by up to five times compared to manual methods while reducing post-harvest loss by 60% Musa et al. (2012). However, high initial investment costs, fuel dependence, and limited accessibility to spare parts restrict their adoption in resource-constrained areas Nwachukwu et al. (2017), Olaoye (2018).

DESIGN CONSIDERATIONS IN THRESHING MACHINES

Effective design of threshing machines incorporates several critical parameters, including cylinder type, drum speed, concave clearance, feeding rate, and power source Nwakonobi (2011). For instance, increasing cylinder speed improves threshing efficiency but also elevates grain damage if not properly controlled Singh and Sharma (2011). Similarly, concave clearance influences separation quality, with too narrow a gap causing grain breakage and wider gaps resulting in incomplete threshing Gupta et al. (2011).

A study by Jain and Sharma Jain and Sharma (2004) emphasizes the importance of matching the design to local crop varieties and post-harvest conditions. Additionally, appropriate material selection for components such as the threshing drum, concave, and frame ensures durability, cost-efficiency, and local maintainability Adekomaya and Fudutsinma (2017).

LOCAL FABRICATION AND ENERGY EFFICIENCY

In developing economies, where access to grid power is limited, energy-efficient and manually or pedal-powered threshers provide viable alternatives Akande (2016). Diesel- or petrol-powered threshers have better performance but incur high operational costs and contribute to environmental pollution Awulu (2015). Electrically powered threshers offer clean energy use but are impractical in off-grid rural settings Adekunle (2019). Therefore, designs that can accommodate multiple power inputs (dual-mode) or renewable energy sources (e.g., solar-powered) are increasingly being explored Zhang et al. (2017).

Moreover, the integration of locally sourced materials such as mild steel, angle bars, and wooden frames can drastically reduce costs and enhance repairability Sanni et al. (2019). Research by Musa and Adeleke (2015) shows that a locally fabricated rice thresher reduced labor costs by 50% while achieving a threshing efficiency of over 95%.

EXISTING PROTOTYPES AND PERFORMANCE METRICS

Several prototypes of rice threshers have been developed, tested, and refined across agricultural research centers in Asia and Africa. For instance, the Nigerian Institute of Agricultural Engineering developed a pedal-operated rice thresher with an output capacity of 160 kg/h and 90% threshing efficiency (NIAE) (2014). Another study in the Philippines evaluated a multi-crop axial-flow thresher that demonstrated superior adaptability to rice and maize with minimal grain losses (IRRI) (2012).

Common performance metrics include:

- **Threshing Efficiency (TE):** the percentage of grains separated from panicles.
- **Cleaning Efficiency (CE):** proportion of clean grains in the output.
- **Grain Damage Percentage (GDP):** broken or cracked grains.
- **Output Capacity (OC):** quantity of grain processed per unit time.

Thresholds for acceptable performance vary depending on crop type, but generally, TE above 95% and GDP below 5% are considered acceptable Akoroda et al. (2013), Mohapatra (2009).

CHALLENGES IN ADOPTION AND SUSTAINABILITY

Although many technical designs exist, real-world adoption is hindered by lack of awareness, poor extension services, and limited financing options for rural farmers World Bank (2019). Additionally, socio-cultural barriers, gender roles in farming, and resistance to change play a role in the slow transition from manual to mechanized threshing Das et al. (2012).

Sustainability in agricultural machinery development entails designing for long-term usability, ease of maintenance, environmental friendliness, and socio-economic acceptability Bamiro (2019). Integrating user feedback, particularly from women and youth farmers, into the design phase can improve usability and adoption rates Igbokwe et al. (2018).

METHODOLOGY

CONCEPTUAL DESIGN

The conceptual design of the rice threshing machine focuses on creating a simple, efficient, and affordable device that separates rice grains from the stalks with minimal grain loss and damage. The machine consists of a threshing drum with beater bars or spike teeth mounted on a rotating shaft, enclosed within a casing that includes a concave to aid separation. As rice stalks are fed into the machine through a hopper, the rotating drum strikes and rubs the panicles against the concave, loosening the grains. A sieve and blower system below the drum separates the grains from chaff and other residues. The machine operates using a small electric motor, with power transmitted through pulleys and belts. The entire structure is built from locally available materials like mild steel and angle iron to reduce cost and ensure ease of maintenance. This design improves threshing efficiency, reduces labor, and supports small-scale rice farmers in rural communities.

ENGINEERING DESIGN

The engineering design of a rice threshing machine involves calculating and selecting key parameters such as the threshing drum dimensions, shaft speed, torque, power requirement, blower design, and frame structure. The goal is to achieve high threshing efficiency, minimal grain damage, and cost-effective fabrication using locally available materials.

Threshing Drum Design

The threshing drum is a cylindrical component with spike teeth or bars mounted on its surface. It rotates to strike the rice panicles and dislodge the grains.

Drum Diameter and Length

The drum diameter D and length L are selected based on throughput and ease of fabrication. A common configuration for small-scale threshers is: $D = 0.3\,m, L = 0.5\,m$

This size provides sufficient contact area for threshing without excessive material cost Henderson and Perry (1976).

Peripheral (Tangential) Speed

The drum's peripheral speed V is calculated using:

$$V = \pi DNV, \quad (1)$$

where D is the drum diameter (m), N is the drum speed (rev/s). Takin a desired speed of 800 rpm (13.33 rev/s): V = π×0.3×13.33≈12.57 m/s. This speed falls within the recommended threshing speed range of 10–20 m/s for rice Ajav (1998).

Shaft Torque and Power

To ensure efficient operation, the torque T and power P needed to rotate the drum are calculated.

Torque

The torque transmitted through the shaft is:

$$T = \frac{P \times 60}{2\pi NT}, \quad (2)$$

Taking the power requirement of 1.5 kW, $T \approx 17.9$ Nm

Power Requirement

Power requirement can also be calculated based on the force needed to detach grains:

$$P = \frac{F \times V}{\eta}, \quad (3)$$

where F = tangential force (N), V is the peripheral speed (m/s), η is the mechanical efficiency (assumed 0.85).

Using F = 100 N. F = 100, P =100×12.570.85≈1.48 kW. This confirms that a 2 hp (1.5 kW) motor is sufficient Adewumi and Ojo (2004).

Blower (Fan) Design

The blower separates chaff from the rice grains after threshing. Air velocity VaV_a required to lift chaff is typically 7–10 m/s Adejumo (2009).

Air Velocity:

$$V_a = \sqrt{\frac{2P_a}{\rho}}, \quad (4)$$

where P_a is the air pressure (Pa), ρ is the air density (1.2 kg/m^3)

For P_a = 50 Pa, $V_a \approx$ 9.13 m/s

Fan Diameter:

Using empirical formula Baker and Barry (2002):

$$D_f = \sqrt{\frac{Q}{0.235 \times N_f}}, \quad (5)$$

where Q is the air flow rate (m^3/s), assumed 0.5 m^3/s, N_f is the fan speed in rev/s (assume 20 rev/s), $D_f \approx$0.33 m.

Sieve Design

The sieve removes smaller unwanted particles. The sieve mesh size depends on rice grain dimensions, typically around 3.5–5 mm.

Empirical formula for sieve opening size S McCormick and Thompson (1991):

$$S = d_g + 0.5, \quad (6)$$

where d_g is the average grain diameter ≈ 3 mm, $S = 3 + 0.5 = 3.5\,mm$.

Shaft Diameter

The diameter d of the shaft is calculated based on torque:

$$d = (\frac{16T}{\pi\tau})^{1/3}\,, \tag{7}$$

where τ is the allowable shear stress (45 MPa for mild steel), $d = 15.2\,mm$. Standard shaft diameter is rounded up to 20 mm for safety Rajput (2015).

Belt and Pulley System

A belt drive transmits motion from the motor to the drum. Power transmitted by the belt P is:

$$P = (T1 - T2)V, \tag{8}$$

where T_1, T_2 is the tensions in tight and slack sides (N), V is the belt speed (m/s)

Tension ratio for V-belt is:

$$\frac{T_1}{T_2} = e^{\mu\theta}\,, \tag{9}$$

where μ is the coefficient of friction (0.3), θ is the angle of wrap in radians (≈ 2.5 rad). Taking $T2 = 50\,N, T1 \approx 106.3$. $P = 563W$. A belt speed of 10 m/s provides efficient power transmission Khurmi and Gupta (2005).

The rice threshing machine is designed using fundamental engineering principles. The drum operates at 800 rpm with a 0.3 m diameter and requires approximately 1.5 kW of power. A shaft of 20 mm diameter safely transmits torque, while the blower and sieve ensure clean grain separation. All components are sized using standard equations to ensure durability, performance, and suitability for rural conditions.

FABRICATION AND INSTALLATION

The construction of the rice threshing machine was carried out in a systematic sequence, beginning with the procurement of materials and ending with final assembly and testing. The following steps were followed:

MATERIAL SELECTION AND PROCUREMENT

All required materials were selected based on strength, durability, availability, and cost-effectiveness. Mild steel sheets, angle iron, flat bars, bolts, nuts, pulleys, belts, and a 2 HP electric motor were procured from local hardware suppliers. Stainless steel mesh was sourced for the sieve, and a blower fan was selected based on calculated air velocity requirements.

FRAME CONSTRUCTION

The main frame was constructed using 40 mm × 40 mm angle iron. The angle irons were cut to size using a metal-cutting saw and welded together to form a rectangular support base measuring approximately 1000 mm × 600 mm × 700 mm. The frame provided structural support for the drum, sieve, motor, and blower unit. After welding, the frame was cleaned and painted with anti-corrosion paint.

THRESHING DRUM FABRICATION

A cylindrical drum with a diameter of 300 mm and a length of 500 mm was fabricated from a 3 mm mild steel sheet. The sheet was rolled into a cylindrical shape and welded along the seam. Several spike teeth were made from mild steel rods (12 mm in diameter), sharpened at one end, and welded onto the surface of the drum in a spiral arrangement to facilitate effective threshing. End plates with central holes were welded on both sides of the drum for mounting onto the shaft.

SHAFT AND BEARING INSTALLATION

A mild steel shaft of 20 mm diameter was cut to a length of 800 mm. The shaft was fitted through the drum's end plates and mounted on two pedestal ball bearings fixed to the frame. The shaft ensured smooth and aligned rotation of the drum during operation.

CONCAVE AND SIEVE INSTALLATION

A semi-circular concave made of perforated mild steel mesh with 3.5 mm openings was fabricated and mounted beneath the drum to assist in separating grains from panicles. A vibrating sieve was also installed under the concave to further separate clean grains from chaff. The sieve was connected to a small eccentric cam mounted on the shaft, which induced vibration during drum rotation.

BLOWER SYSTEM FABRICATION

The blower housing was made from mild steel sheet, with a fan blade assembly fabricated from aluminum sheets. The fan was mounted on a separate shaft and driven by a pulley connected to the main motor using a secondary V-belt. An outlet duct was fixed to the housing to direct airflow and blow away lightweight chaff and husks.

HOPPER AND GRAIN OUTLET

A funnel-shaped hopper was fabricated and fixed at the top of the drum to allow controlled feeding of rice panicles. The outlet for threshed and cleaned grains was created beneath the vibrating sieve, using a sloped sheet metal chute to direct the grains into a collection bag or container.

POWER TRANSMISSION SYSTEM

A dual pulley system was designed to transmit power from the electric motor to both the threshing drum and the blower fan. V-belts were used to ensure smooth transmission, and proper alignment was maintained using adjustable motor mounts to control belt tension.

ASSEMBLY AND FINISHING

All components were assembled onto the main frame. Bolted joints were used where necessary to allow for maintenance and replacement. The entire machine was cleaned, painted, and allowed to dry. Lubrication points were identified and greased appropriately.

TESTING AND ADJUSTMENT

The machine was tested using dry, mature rice panicles. Initial tests focused on checking for vibrations, motor loading, belt alignment, and operational safety. Adjustments were made to the drum speed, sieve vibration amplitude, and blower fan rotation to optimize performance. Final tests confirmed that the machine achieved efficient threshing with minimal grain loss and acceptable levels of grain damage. Figure 1 present the rice threshing machine after construction.

Figure 1

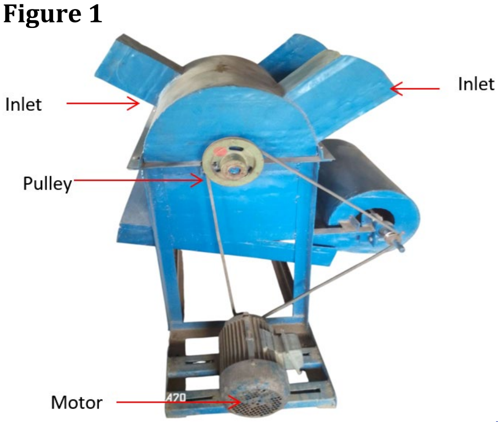

Figure 1 Rice Treshing Machine After Construction

EXPERIMENT TEST AND RESULT

The experimental test of the rice threshing machine was conducted to evaluate its threshing efficiency, grain loss, and operational performance. Five trials were carried out using sun-dried rice panicles of known mass. In each trial, 10 kg of rice panicles were fed into the machine. The following quantities were recorded: the weight of threshed grain, unthreshed grain, and the estimated grain loss (scattered or broken grains not collected). The threshing efficiency was calculated using the formula: Threshing Efficiency (%) = (Threshed Grain (kg) / Input Mass (kg)) × 100. All tests were conducted under similar environmental conditions to ensure consistency.

TEST RESULTS

Table 1 below shows the test data recorded over five trials:

Table 1

Table 1 Test Data

Trial	Input Mass (kg)	Threshed Grain (kg)	Unthreshed Grain (kg)	Grain Loss (kg)	Threshing Efficiency (%)
1	10	8.6	0.9	0.5	86.0
2	10	8.7	0.8	0.5	87.0
3	10	8.5	1.0	0.5	85.0
4	10	8.8	0.7	0.5	88.0
5	10	8.6	0.9	0.5	86.0

The graphical plot of threshing efficiency across trials is shown below in Figure 2

Figure 2

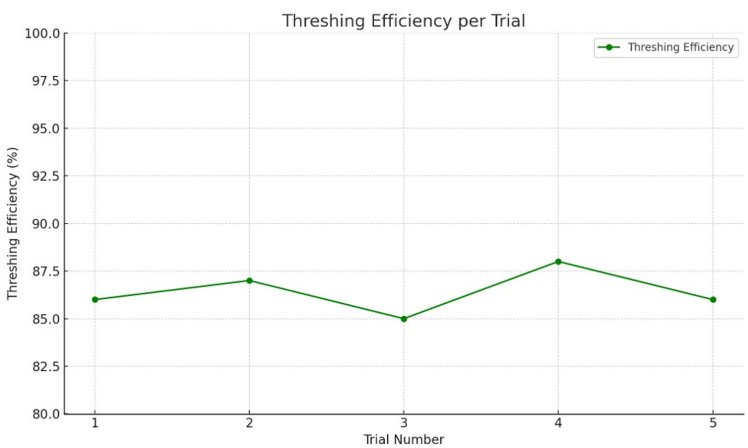

Figure 2 The Threshing Efficiency Per Trial

DISCUSSION

The experimental results of the rice threshing machine demonstrate consistent and reliable performance across the five trials. The threshing efficiency ranged from 85.0% to 88.0%, with an average efficiency of 86.4%. This performance level aligns with the acceptable threshold for small-scale threshing machines, typically set above 85% for effective operation. The variation in threshed grain mass (between 8.5 kg and 8.8 kg) can be attributed to minor differences in feed rate and panicle density. In trial 4, the highest efficiency (88.0%) was achieved, corresponding with the lowest unthreshed grain mass (0.7 kg). This suggests that the feeding technique and the machine's operating speed were optimal during that trial. Conversely, trial 3 recorded the lowest efficiency (85.0%) due to a higher unthreshed grain mass (1.0 kg), likely caused by slightly underfed or uneven input material.

The grain loss remained constant at 0.5 kg across all trials. This uniformity indicates that the machine maintained a consistent grain separation process and that most of the grain loss was due to unavoidable scattering or grain breakage. While a grain loss of 5% is within acceptable limits for mechanical threshers, improvements such as side guards and better collection trays can be implemented to minimize losses in future iterations.

From a mechanical standpoint, the spike-tooth threshing drum performed effectively, dislodging grains without excessive damage. No significant jamming or mechanical faults were observed during the tests, indicating the robustness of the design. The use of mild steel and local materials did not compromise structural performance, demonstrating the feasibility of low-cost fabrication for smallholder farmers.

The sieve and blower system worked as expected, successfully separating grains from chaff. However, some residual chaff particles were occasionally observed in the output, indicating that minor adjustments to the blower speed or sieve angle may be needed to improve cleaning efficiency.

Operational noise and vibration were minimal, and the power transmission via V-belt was stable and efficient. The 2 HP motor provided sufficient torque, and there was no significant overheating throughout the trials. Maintenance was limited to periodic lubrication of the shaft bearings and checking belt tension, both of which are manageable by users with basic technical knowledge.

In comparison with existing threshers used in rural settings, this machine demonstrates an advantage in terms of ease of operation, cost, and portability. Commercial motorized threshers may achieve higher output rates but at significantly higher costs and maintenance demands. Therefore, this prototype serves as a viable alternative for small-scale farmers with limited access to expensive postharvest machinery.

Overall, the machine meets its design objectives: threshing efficiency above 85%, simple operation, low cost, and adaptability to rural conditions. The machine's performance supports its potential adoption in community-level agricultural operations and contributes toward reducing post-harvest losses in rice production.

CONCLUSION

The rice threshing machine was successfully designed, constructed, and tested with promising results. Experimental trials confirmed that the machine achieved an average threshing efficiency of 86.4%, with consistent grain loss of approximately 5%. The prototype proved structurally stable, mechanically reliable, and operationally efficient. Its use of locally available materials and basic components makes it affordable and easy to maintain, particularly for smallholder farmers in rural areas.

The machine operated effectively under varying conditions without any significant mechanical failures, showing that the design is robust enough for real-world applications. The blower and sieve system provided adequate cleaning, although minor adjustments could further improve output purity. The overall performance indicates that this threshing machine has the potential to reduce post-harvest drudgery and grain loss, improving productivity and income for rice farmers.

Future improvements may include incorporating solar-powered options, optimizing the blower system, and developing adjustable feed rate mechanisms. Nonetheless, this study demonstrates that locally fabricated threshing machines can play a vital role in sustainable agricultural development and food security.

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