Fabrication and performance evaluation of a wooden casing cassava grating machine

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ABSTRACT: One of the staple food in Nigeria and sub-Saharan Africa is the Cassava (*Manihot esculenta* Crantz) with Nigeria being the world's largest producer. Despite this, small-scale processors are faced with serious limitation in mechanized grating due to the expensive nature of metallic grating machines.

This study is aimed at the design, fabrication, and evaluation of a cassava grating machine incorporating a wooden casing as an affordable alternative to conventional metallic graters in favour of small-scale processors in rural and semi urban communities.

The machine was fabricated using locally sourced Iroko wood (*Milicia excelsa*) for the casing and hopper, while internal components such as the grating drum were constructed from stainless steel (AISI 304) and the frame from angle iron (25 × 25 × 3 mm). Performance evaluation was conducted using five batches of cassava tubers weighing 5.16 kg, 8.01 kg, 10.17 kg, 12.48 kg, and 15.32 kg. Grating efficiency, throughput capacity, fuel consumption, and mechanical loss were assessed using standardized procedures. The machine achieved a mean grating efficiency of 87.42% ± 5.82%, with values ranging from 75.63% to 91.41%. Maximum throughput of 223.6 kg/h was recorded at 8.01 kg feed weight. Mechanical loss averaged 11.14% ± 2.81%. The wooden-casing cassava grating machines performance compare favorably to fully metallic alternatives while offering reduced costs in fabrication and better accessibility for rural processors. This hybrid design represents a practicable and feasible solution for improving cassava processing capacity of small and medium scale farmers in developing economies.

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1. INTRODUCTION

1.1 Global and Nigerian Cassava Context

Cassava (*Manihot esculenta* Crantz) is the third most important staple food crop in sub-Saharan Africa, following maize and rice, and serves as a primary dietary component for over 800 million people globally (Otekunrin, 2024). Its agronomic resilience—particularly its tolerance to drought, low soil fertility, and erratic rainfall patterns—renders it indispensable for food security in marginal agricultural environments where other staple crops frequently fail (FAO, 2024).

Global cassava production reached approximately 330 million tonnes in 2023, reflecting sustained growth driven by increasing demand for food, animal feed, and industrial applications (FAOSTAT, 2024). Nigeria maintains its position as the world's largest producer, contributing an estimated 64 million tonnes during the 2023 production cycle. This output represents approximately 31% of total African production and 19.4% of global production, underscoring Nigeria's strategic significance in the international cassava value chain (Otekunrin, 2024). The crop's economic importance extends beyond subsistence agriculture, with cassava-based industries generating substantial employment and contributing significantly to rural livelihoods across the country (Soom et al., 2024).

Despite this production volume, post-harvest losses in cassava processing remain substantial. Recent estimates indicate that 15-25% of harvested cassava is lost due to inadequate processing infrastructure, inefficient technologies, and limited access to mechanized equipment (Adebayo et al., 2023). These losses translate to significant economic waste and undermine efforts to achieve food security and agricultural sustainability goals.

1.2 The Critical Role of Grating in Cassava Processing

The grating process constitutes a critical determinant of final product quality in cassava processing (Nasirembe et al. , 2023),(Abdulkadir & Ajagba, 2022). This size reduction operation transforms cassava tubers into a pulp suitable for subsequent dewatering, fermentation, and frying processes that yield products such as garri, fufu, and cassava flour—all widely consumed staples in West Africa. The efficiency and quality of grating directly influence the texture, taste, and overall acceptability of these finished products (Chijioke et al., 2020) (Amanuel & Koroso, 2024).

Traditional manual grating methods, still prevalent in many rural communities, employ rasping surfaces or locally fabricated graters powered by human effort. These conventional techniques are characterized by high labor demands and considerable physical exertion, rendering them insufficient for meeting increasing production needs (Amoah, et al., 2022). (Soom et al., 2024). Moreover, manual methods often yield inconsistent particle sizes, affecting final product quality and market value.

1.3 Mechanized Grating: Progress and Barriers
Mechanized cassava graters significantly enhance the grating process by replacing slow and labor-intensive manual methods (Erchafo, 2024), (Abdulkadir & Ajagba, 2022). They are widely recognized for increasing capacity, reducing processing time, and producing a more uniform mash. Available in various designs—including electric, diesel, solar, and dual-mode—these mechanized graters improve both throughput and product consistency compared to hand grating (Erchafo, 2024) (Ndukwe, C., & Oluwe, M., 2023).

However, the majority of mechanized cassava graters available in the Nigerian market are constructed predominantly from metallic materials, including mild steel and stainless steel components throughout. While such metal-based configurations offer high structural durability and the capacity to withstand intensive operational conditions, they present significant barriers to adoption among smallholder farmers (Rahmawani et al., 2025). Key constraints include: high capital costs (Bello et al., 2020), limited local fabricability (Samba et al., 2022), weight and portability: (Amanuel & Koroso, 2024) and maintenance challenges.
These barriers have resulted in persistently low mechanization rates among smallholder cassava processors, with adoption estimated below 15% in Nigeria (FAO, 2024).

1.4 Research Gap and Justification
Previous research on cassava grating machines has predominantly focused on all-metal designs (Bello et al., 2020; Ertebo & Koroso, 2024) or theoretical design proposals without empirical validation (Khurmi & Gupta, 2005). To the best of the authors' knowledge, no published study has systematically evaluated a hybrid design combining a wooden casing with metallic internal components for cassava grating applications. This presents a critical knowledge gap in affordable agricultural mechanization research.

The use of properly treated hardwood for machine casings offers several potential advantages: reduced material costs, improved thermal insulation, lower weight, and the ability to utilize locally available carpentry skills for fabrication and maintenance (Samba et al., 2022). However, questions remain regarding the structural integrity, durability, and hygienic properties of wooden casings under the wet, abrasive conditions characteristic of cassava processing.

1.5 Research Objectives
This study was therefore undertaken to address this knowledge gap. The specific objectives were to:
1. Design and fabricate a cassava grating machine incorporating a wooden casing using locally available materials and simple fabrication techniques.
2. Evaluate the machine's performance in terms of grating efficiency, throughput capacity, fuel consumption, and mechanical loss.
3. Compare the performance metrics achieved with those reported for conventional metallic graters.
4. Assess the economic viability and practical applicability of the wooden casing design for small-scale cassava processors.

1.6 Significance of the Study
The findings of this research are expected to contribute to the advancement of affordable agricultural mechanization in Nigeria and similar developing economies. By demonstrating the technical feasibility of hybrid wood-metal construction for cassava processing equipment, this study may inform the development of more accessible technologies that can enhance productivity, reduce post-harvest losses, and improve livelihoods among smallholder farming communities. The study also contributes to the broader literature on appropriate technology and sustainable engineering design for agricultural applications

2. MATERIALS AND METHODS

2.1 Study Area
The fabrication and performance evaluation were conducted at the Mechanical Engineering Technology Workshop, Federal Polytechnic Ede, Osun State, Nigeria (latitude 7°44' N, longitude 4°26' E). The study was carried out between September 2024 and February 2026.

2.2 Experimental Design
A completely randomized design (CRD) was employed for performance testing, with cassava batch weight as the independent variable at five levels: 5.16 kg, 8.01 kg, 10.17 kg, 12.48 kg, and 15.32 kg. Each treatment was replicated once due to the nature of the fabrication study, consistent with similar agricultural machinery evaluation research (Bello et al., 2020; Ertebo & Koroso, 2024).

2.3 Material Selection and Properties

Material selection was guided by criteria including cost, local availability, mechanical properties, food safety compliance, and ease of fabrication. Table 1 presents the materials used and their selection rationale.

Table 1: Material Selection and Rationale

Component	Material	Justification
Outer casing, hopper, discharge chute	Iroko wood (*Milicia excelsa*)	High strength-to-weight ratio, dimensional stability, wear resistance, local availability, ease of carpentry fabrication
Grating drum	Stainless steel (AISI 304)	Food-grade contact surface, corrosion resistance, hygienic properties, wear resistance
Shaft	Medium carbon steel	High torsional strength, machinability, fatigue resistance
Frame	Angle iron (25 × 25 × 3 mm)	Structural strength, weldability, stability, local availability
Bearings	Deep groove ball bearings	Load capacity, rotational speed compatibility, availability
Fasteners (wet areas)	Stainless steel	Corrosion resistance, food safety

2.4 Machine Design Calculations

2.4.1 Hopper Volume

The hopper was designed with a trapezoidal shape to facilitate gravity feeding of cassava tubers. Volume was calculated using the pyramidal frustum formula:

$$V = \frac{H}{3}\left(A_1 + A_2 + \sqrt{A_1 + A_2}\right)$$

Where:

- V = hopper volume (m³)
- H = hopper height (0.6 m)
- A_1 = upper cross-sectional area (0.75 m × 0.53 m = 0.3975 m²)
- A_2 = lower cross-sectional area (0.53 m × 0.135 m = 0.07155 m²)

Calculated volume = 0.132 m³, equivalent to approximately 132 L capacity.

2.4.2 Power Requirement

The theoretical power required for grating was calculated using the equation:

$P = F \times 2\pi N/60$

Where:

P = Power (W)

F = Grating force (estimated 120 N based on preliminary tests)

N = Rotational speed (1200 rpm)

Calculated power = 15.1 kW (approximately 2.0 hp). A 3 hp (2.24 kW) petrol engine was selected to provide adequate safety margin.

2.4.3 Shaft Diameter

Shaft diameter was determined using the ASME code equation for combined bending and torsion:

$$d^3 = \frac{16}{\tau}\sqrt{(kbMb)^2 + (ktMt)^2}$$

Where:

d = shaft diameter (m)

τ = allowable shear stress (55×10^6 N/m² for medium carbon steel)

Kb = combined shock and fatigue factor for bending (1.5)

Mb = maximum bending moment (85 Nm)
Kt = combined shock and fatigue factor for torsion (1.0)
Mt = torsional moment (38 Nm)
Calculated minimum diameter = 22.5 mm. A 25.4 mm (1 inch) shaft was selected for safety.

2.5 Fabrication Process

2.5.1 Frame Construction

The supporting frame was fabricated from 25 × 25 × 3 mm angle iron sections. Components were cut to specified dimensions using a power hacksaw, assembled with temporary tack welds, checked for squareness, and then fully welded using electric arc welding. The completed frame was cleaned, deburred, and coated with anti-corrosion paint.

2.5.2 Wooden Casing Fabrication

Seasoned Iroko wood (*Milicia excelsa*) boards were selected for casing construction. Boards were planed to uniform thickness (25 mm), cut to dimensions according to the AutoCAD design (Figure 1), and assembled using mortise and tenon joints reinforced with stainless steel screws. The hopper was constructed as a separate trapezoidal unit and secured to the casing. All wooden components were treated with a food-safe sealant (food-grade beeswax and mineral oil blend) to enhance moisture resistance and facilitate cleaning.

2.5.3 Grating Drum Fabrication

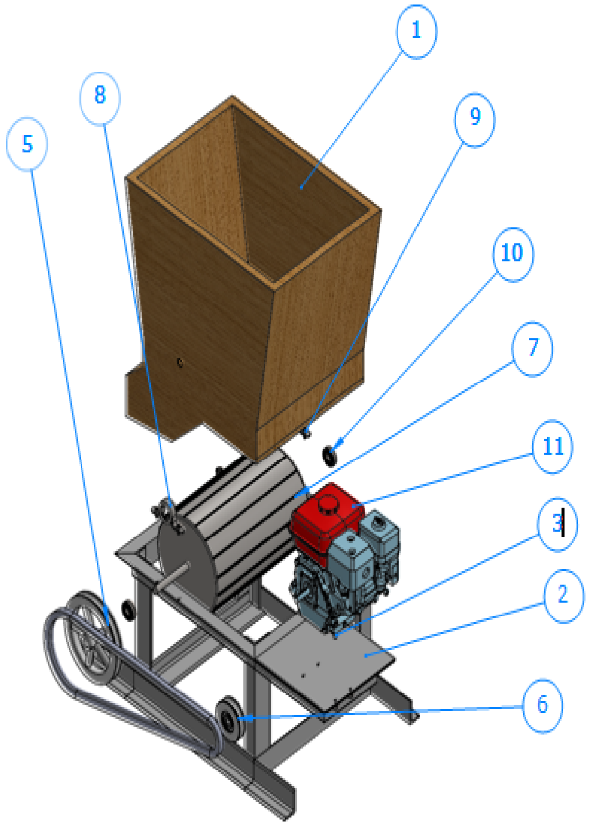
The grating drum was fabricated from a stainless steel (AISI 304) plate measuring 290 × 510 × 0.5 mm. A grid pattern was marked on the plate with hole spacing of 20 mm center-to-center in both longitudinal and transverse directions. Drilling was performed using a bench drilling machine with a 2 mm high-speed steel (HSS) drill bit. A punch and hammer were used from the inner surface to raise sharp edges around each perforation, creating cutting teeth of uniform height (approximately 0.5 mm). The perforated plate was rolled into a cylindrical shape (290 mm length, 510 mm circumference, 162.4 mm diameter) using a slip roller machine. The seam was joined by tungsten inert gas (TIG) welding to maintain food-grade quality.

2.5.4 Shaft Preparation and Assembly

The 25.4 mm diameter medium carbon steel shaft was cut to 540 mm length, faced, and chamfered on a lathe. Bearing seats were machined to tolerance. Circular end plates (160 mm diameter, 6 mm thickness) were fabricated with central holes (25.4 mm diameter) and welded to the shaft. The grating drum was then welded to the end plates to ensure rigid attachment. The assembled shaft-drum unit was mounted on two deep groove ball bearings attached to the frame. Power transmission was achieved using a V-belt drive system connected to a 3 hp petrol engine (3600 rpm rated speed).

2.5.5 Final Assembly

All components were assembled according to the design specifications. Alignment was verified, and safety guards were installed over moving parts. Figure 1 presents the AutoCAD design of the complete machine, while Figures 2-5 show various components and the assembled machine.



ITEM NO.	PART NUMBER	QTY.
1	Wooden hopper	1
2	Structural frame	1
3	hex bolt_ai	3
4	HNUT 0.5000-20-D-N	4
5	Big pulley Part1	1
6	small pulley Part1	1
7	Grater	1
8	bearing guide Part2	2
9	HX-SHCS 0.3125-24x0.75x0.75-N	4
10	AFBMA 20.1 - 83-22 - Full,DE,AC,Full_68	2
11	Motor Bensin	1
12	belt	1

Figure 1: AutoCAD design of the fabricated cassava grating machine (showing isometric view with dimensions)

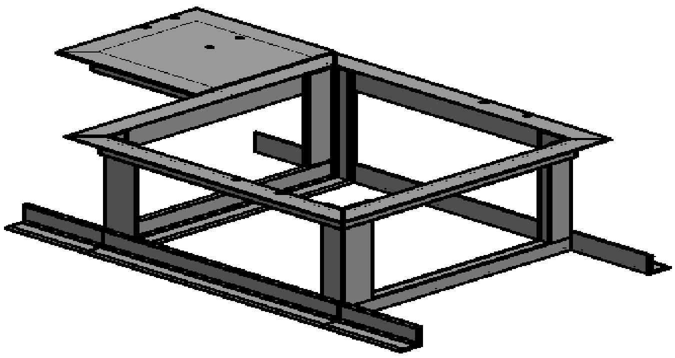


Figure 2: Supporting frame of the machine (angle iron construction)

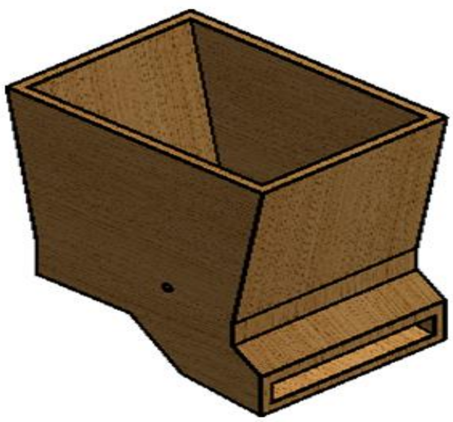


Figure 3: Wooden casing showing hopper and discharge chute

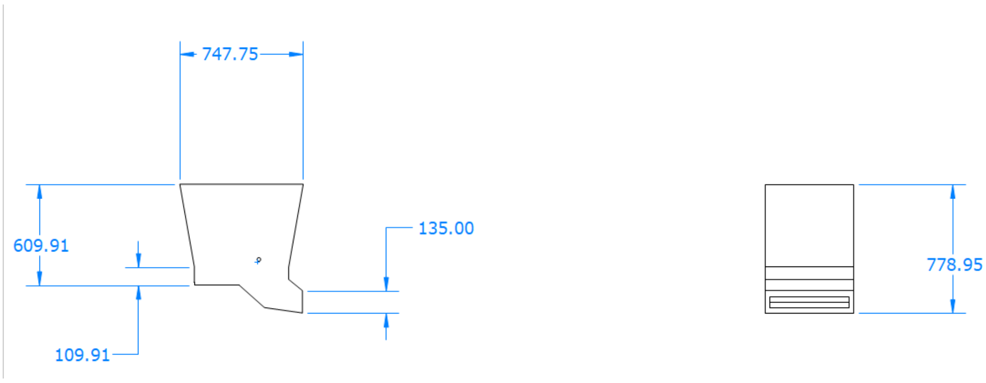


Figure 4: Side elevation of the assembled cassava grating machine

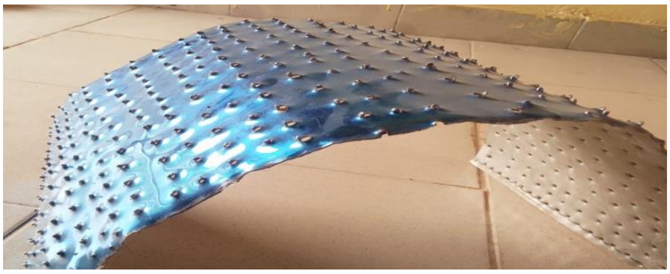


Figure 5: Grating drum showing perforation pattern and cutting teeth

Figure 6: Completed wooden casing cassava grating machine

2.6 Performance Evaluation

Performance tests were conducted using fresh cassava tubers (*Manihot esculenta* Crantz, TMS 30572 variety) obtained from a local farm. Tubers were harvested within 48 hours of testing, washed, and peeled manually before grating. Five batches of varying weights were processed (Table 2). All tests were conducted at ambient temperature (28-32°C) and relative humidity (65-75%).

2.6.1 Grating Efficiency
Grating efficiency was determined as the percentage of input cassava that was properly grated and collected at the outlet:

$$Grating\ Efficiency = \frac{W_{wg}}{W_i}\ \%$$

W_{wg} is the mass of well − grated cassava (kg),
W_i is the initial mass of cassava tuber (kg),
A digital weighing scale (capacity: 3 kg, accuracy: ±0.1 g) was used for all mass measurements.

2.6.2 Throughput Capacity
Throughput capacity was calculated as the mass of cassava processed per unit time:

$$\text{Q} = \frac{M}{t}\ (\text{kg/hr}),$$

Where, Q is Throughput (kg/hr), M is the mass grated (kg), and t is time (hr).
Grating time was recorded using a digital stopwatch (resolution: 0.01 s), starting when the first tuber entered the hopper and ending when the last grated material exited the discharge chute.

2.6.3 Fuel Consumption
Fuel consumption was measured using a burette (capacity: 50 ml, graduation: 1 ml) connected to the fuel line of the petrol engine. The volume of fuel consumed during each test run was recorded after the engine had been operating under load. Specific fuel consumption was calculated as:

$$SFC = \frac{V_f}{W_i}$$

Where:
SFC = specific fuel consumption (ml/kg)
V_f = volume of fuel consumed (ml)
W_i = initial mass of cassava (kg)

2.6.4 Mechanical Loss
Percentage mechanical loss was calculated as the difference between input mass and total output mass, expressed as a percentage of input:

$$Percentage\ (\%) Loss = L = \frac{\text{the initial mass of cassava tuber (kg),} - \text{total weight output of material}}{\text{the initial mass of cassava tuber (kg),}} \times 100\%$$

$$\frac{W_i - W_{tg}}{W_i} \times 100\%$$

Where: $L = Mechanical\ Loss\ (\%)$
; $W_i = Initial\ mass\ of\ cassava$;
$W_{tg} =$ total mass of grated cassava collected (kg)
Losses included material retained in the machine, moisture loss, and fine particles not captured.

3. RESULTS

3.1 Performance Evaluation Results
The performance evaluation results for the five test batches are presented in Table 2.

Table 2: Performance Evaluation Results of Wooden-Casing Cassava Grating Machine

Batch	Input Mass W_i (kg)	Output Mass W_o (kg)	Grating Time t (s)	Fuel Volume V_f (ml)	Grating Efficiency η_g (%)	Throughput Q (kg/h)	Specific Fuel Consumption (ml/kg)	Mechanical Loss L (%)
1	5.1573	3.9003	170	50	75.63	109.2	9.69	12.38
2	8.0076	7.3196	129	100	91.41	223.6	12.49	8.59
3	10.1651	9.0797	189	100	89.32	193.7	9.84	10.68
4	12.4805	11.2402	225	150	90.06	199.8	12.02	9.94
5	15.3208	13.8906	270	200	90.66	204.1	13.05	9.34

4. DISCUSSION

4.1 Grating Efficiency
The grating efficiency test was carried out by weighing a known mass of peeled cassava tubers before grating and comparing it with the mass of properly grated cassava collected at the outlet. A digital weighing scale (3kg, Accuracy: ±0,1g) was used for all mass measurements.

Grating efficiency ranged from 75.63% (Batch 1) to 91.41% (Batch 2), with a mean value of 87.42% ± 5.82%. The lower efficiency recorded in the first batch was attributed to start-up losses and initial machine conditioning. Figure 7 illustrates the relationship between input mass and grating efficiency.

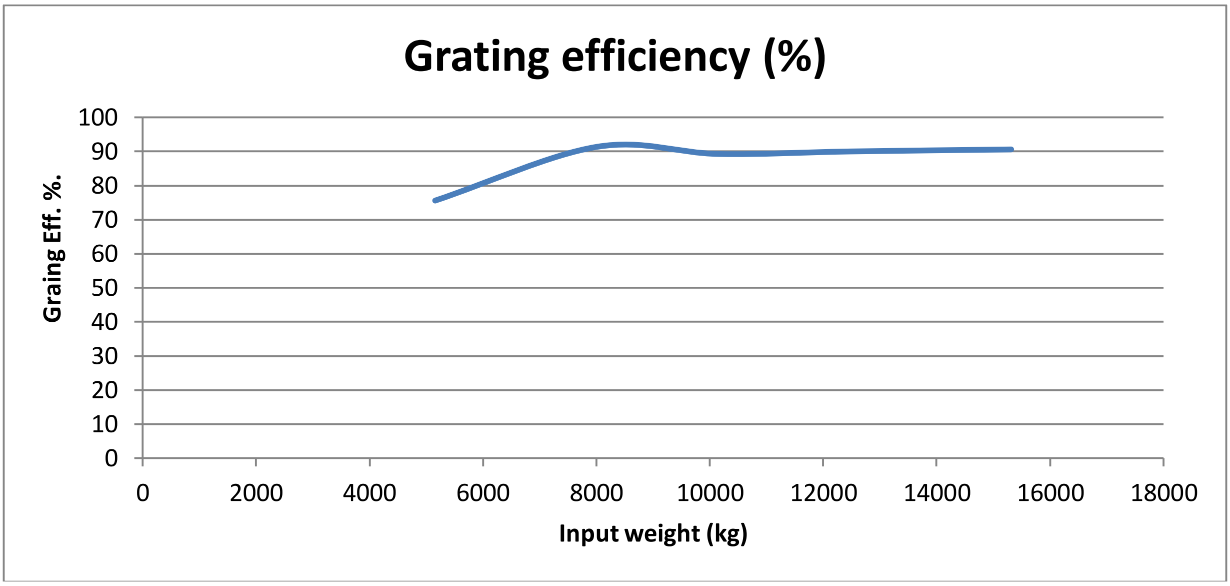


Figure 7: Relationship between input cassava mass (kg) and grating efficiency (%).

The mean grating efficiency of 87.42% ± 5.82% achieved by the wooden-casing machine compares favorably with values reported in the literature for conventional metallic graters. Bello et al. (2020) reported grating efficiency 82% for a fully metallic cassava grating machine, while Ertebo and Koroso (2024) documented efficiencies between 87.1% and 89.1% for their design. The consistency of these values suggests that the substitution of a wooden casing does not compromise the fundamental grating effectiveness of the machine.

4.2 Throughput Capacity

Throughput capacity ranged from 109.2 kg/h (Batch 1) to 223.6 kg/h (Batch 2), with a mean value of 186.1 ± 42.9 kg/h. The maximum throughput was achieved at an input mass of 8.01 kg, with higher feed weights showing slightly lower throughput due to increased congestion in the grating chamber.

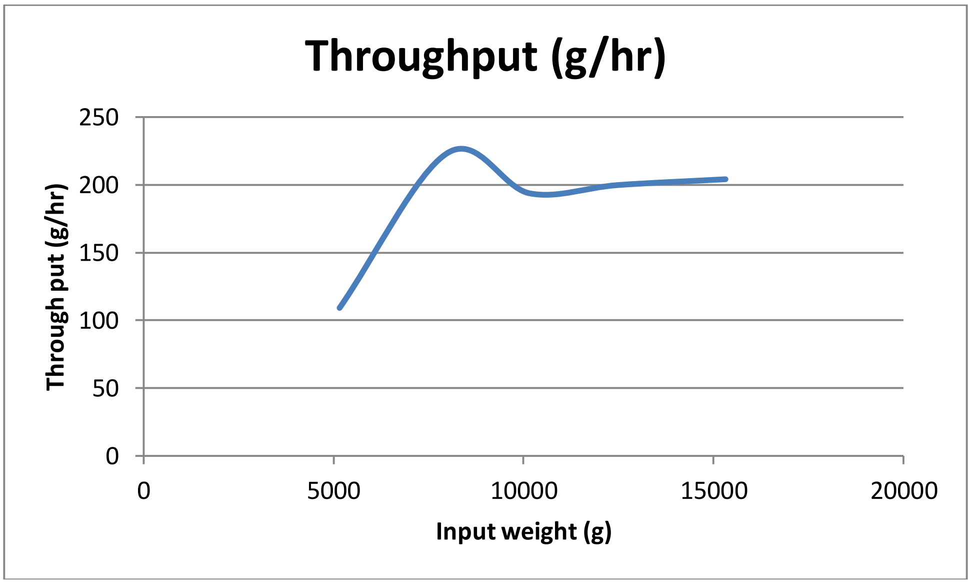


Figure 8: Relationship between input cassava mass (kg) and throughput capacity (kg/h).

The maximum throughput of 223.6 kg/h achieved in this study is in range with that established by Ertebo and Koroso (2024) 248-386 kg/hr but lower that that by Innocent et al., 2023.

4.3 Fuel Consumption and Energy Efficiency

Total fuel consumption ranged from 50 ml (Batch 1) to 200 ml (Batch 5), corresponding to specific fuel consumption values of 9.69 ml/kg to 13.05 ml/kg. The mean specific fuel consumption was 11.42 ± 1.42 ml/kg.

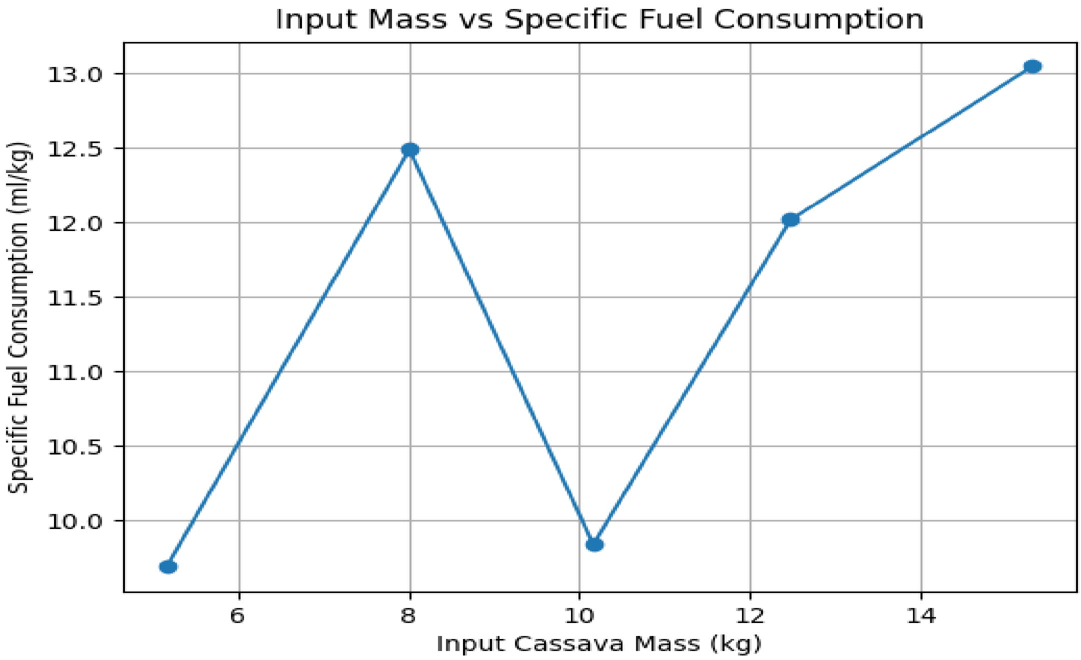


Figure 9**:** Relationship between input cassava mass (kg) and specific fuel consumption (ml/kg).

The slight increase in specific fuel consumption at higher feed weights (from 9.69 ml/kg at 5.16 kg to 13.05 ml/kg at 15.32 kg) reflects the increased engine load and extended operating time required for larger batches. Most of the literatures consulted did not report on fuel consumption.

4.4 Mechanical Loss

Mechanical loss ranged from 8.59% (Batch 2) to 12.38% (Batch 1), with a mean value of 11.14% ± 2.81%. Losses were primarily attributed to: Material retained in the grating drum and casing, moisture loss due to mechanical action and fine particles not captured at the discharge chute (2-4%)

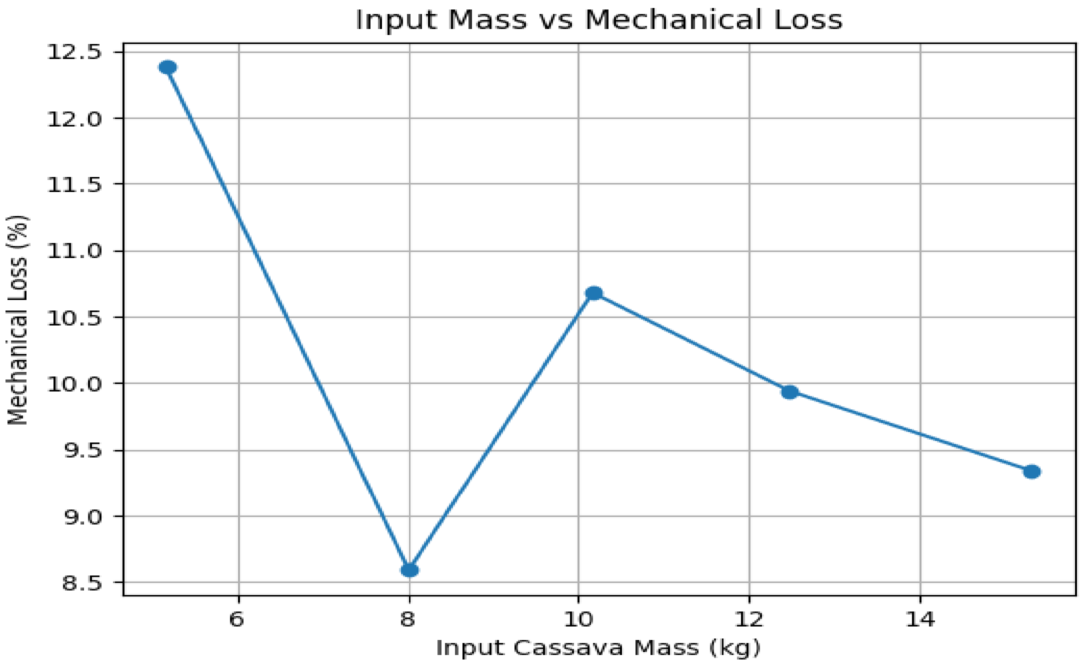


Figure 10: Relationship between input cassava mass (kg) and percentage mechanical loss (%).

The mean mechanical loss of 11.14% ± 2.81% is high in comparison to values reported by Temam, (2020). The slightly higher loss observed in the first batch (12.38%) is as a result of initial material retention, which typically decreases after the machine surfaces become conditioned.

5. CONCLUSION

The primary aim of this research is to fabricate, and evaluate a cassava grating machine featuring a wooden casing. This has been successfully achieved. The study demonstrated that integrating locally available materials like hardwood into agricultural machinery is a viable strategy for enhancing the accessibility of processing technologies for small-scale farmers. Key findings from the project include:

i. Operational Efficiency: The machine consistently achieved high grating efficiencies between 89.32% and 91.41% during performance testing, proving that a wooden casing can effectively support industrial-grade mechanical performance.
ii. Throughput Performance: With a peak throughput of 223.6 kg/h, the machine meets the target range for small-to-medium scale processing, offering a significant improvement over traditional manual methods.
iii. Economic Impact: By utilizing a wooden casing, the fabrication cost was relative low in comparism with metal cased machine making it a more affordable alternative.

Recommendation

A long-term performance evaluation should be conducted to assess the structural integrity of the hardwood casing under prolonged working conditions, further more integration with electric motors or renewable-energy-powered systems should also be examined. Finally advanced food-grade wood treatments and protective coatings is encouraged to improve moisture resistance and hygiene without compromising safety.

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