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Design, Fabrication and Performance Evaluation of a Cassava Peeling Machine

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Abstract

The design and fabrication of a cassava peeling machine is aimed at providing a base for the processing of cassava, using locally available materials. The need and importance of this research study are eminent because of the increase in the production of cassava tubers, as farmers deserve a drudgery-free cassava processing operation. The cassava peeling machine is powered by a variable-speed GX390 multipurpose gasoline engine (±1,600 rpm) with a maximum power output of 8.2 kW and a rated power of 8.0 kW. Power is transmitted through the belt from the engine pulley (driving pulley) to the gearbox pulley (driven pulley). The gearbox translates the radial motion of the driven pulley shaft to the axial motion of the machine peeling disc, which is assembled at the base of the stationary peeling drum. Tubers of cassava are loaded into the peeling drum, which is abraded (inner surface). As the peeling disc rotates, it causes relative motion on the cassava tubers. The cassava tubers constantly rub and tumble against the abrasive surface of the peeling drum, which results in peeling. Water is sprinkled while the machine is in operation to wash off peels from the tubers. Before loading, the engine has to be in operation and run for at least 2 minutes to avoid stalling or jamming. The average peeling efficiency of the machine is found to be 88.1% with a throughput of 280 kg/hr. Key components of the machine include the prime mover, peeling drum, an abrasive peeling surface, machine stand, and a transmission system (gearbox). The research centre is at the College of Agriculture, Science, and Technology, Lafia, Nasarawa State, in the Department of Agricultural and Bio-Environmental Engineering Technology. The total cost estimate of the research is One Million, Four Hundred and Fifty-Two Thousand, One Hundred and Twenty-Six Naira Only (N1,452,126).

Keywords: Design, Construction, Cassava, Peeling Machine, Testing.

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1.0 INTRODUCTION

Cassava (Manihot esculenta) is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. Cassava originated from tropical America and was first introduced into Africa in the Congo basin by the Portuguese around 1558. Cassava is rich in carbohydrates, calcium, and vitamins B and C. However, nutrient composition differs according to the variety and age of the harvested crops and soil conditions, climate, and other environmental factors during cultivation. Cassava cultivars have been classified biochemically using cyanogenic glucoside content as bitter and sweet. The bitter cultivars are characterised by their high cyanogenic content, whereas those cultivars with very low cyanogenic content are termed 'sweet varieties'. (Advances in Genetic Analysis and Breeding of Cassava, 2023). Cassava is the third largest source of food carbohydrates in the tropics after rice and maize, and Nigeria is the world's largest producer of cassava, with a production level estimated at 62 million tonnes in 2023 (BusinessDay Nigeria, 2025). Until recently, cassava was primarily produced for food, as it is consumed on a daily basis in different forms and oftentimes more than once a day. Its importance as a major cheap source of calorie intake for both humans and livestock in many tropical countries has been widely acknowledged. It is mostly processed traditionally into garri, fufu, alibo and abacha in Nigeria, and kokonte and agbelima in Ghana. More recently, cassava is a beneficial source of starch and ethanol. The peel can also serve as feed for animals; the leaves have medicinal properties (Ibrahim et al., 2023). The processing of cassava tubers for industrial or human use involves different operations, of which peeling is a major bottleneck.

The cassava peel has two layers called the periderm and the cortex, the inner layer.

i. **Periderm** – This is the outermost layer, which is brown in colour.

ii. Cortex – lies below the periderm, thick and white in colour. In cassava peeling operations, both the periderm and the cortex are removed.

Adetan et al. 2005 stated that the two sections of a cassava tuber include the general section and the transverse section. The most commonly used instrument for peeling cassava tubers is the household knife, which is time-consuming and can be stressful to use. This is why the design of a machine has been proposed. Also, the problems encountered in peeling cassava root tubers stem from the fact that cassava roots exhibit appreciable differences in weight, size and shape. There are also differences in the properties of cassava peel, which varies in thickness and texture. As a result, most of the fabricated machines experienced issues such as flesh loss, breakage, and low processing capacity. With the mass production of the crop, farmers prefer to cultivate and sell it due to inadequate technology for processing it. Agricultural engineers are challenged to develop cassava processing machines, which can reduce the drudgery encountered during processing.

1.0 Aim and Objectives of the Study

1.1 Aim

The primary aim of this research is to design and fabricate a cassava peeling machine that operates on the principle of mechanical abrasion. In this process, the cassava tubers are subjected to controlled frictional forces as they tumble or rub against an abrasive surface within a rotating drum. The design seeks to mechanise the peeling process, thereby minimising manual labour, reducing processing time, and ensuring uniform peeling with minimal loss of edible material.

1.2 Objectives

In order to achieve the stated aim, the following specific objectives were formulated:
To design and construct a functional cassava peeling machine using locally sourced materials, thereby promoting cost-effectiveness and ease of maintenance.
To evaluate the performance of the constructed machine based on the following operational parameters:

Peeling Efficiency – the proportion of peel removed relative to the total peel present on the cassava tubers.

Flesh Loss – the percentage of edible cassava flesh removed along with the peel during operation.

Throughput Capacity (kg/hr) – the quantity of cassava tubers processed per unit time, indicating the productivity of the machine.

2.0 MATERIALS AND METHOD

2.1 Source of Materials

All materials and components used in the fabrication of the cassava peeling machine were procured locally from metal fabrication workshops and mechanical stores within Lafia and Akwanga, both in Nasarawa State, Nigeria. This local sourcing approach was intentional to enhance affordability, accessibility of spare parts, and sustainability of production in a rural or small-scale industrial context.

2.2 Sample Preparation

Freshly harvested cassava roots were obtained from local farms within the Lafia Local Government Area, Nasarawa State. The cassava varieties selected for testing were those commonly cultivated in the region. The roots were sorted, washed, and trimmed to uniform lengths before being used for the machine performance evaluation.

2.3 Design Components and Assembly

The cassava peeling machine was designed as a compact and integrated system comprising several key components. These components are arranged to ensure efficient transfer of motion, effective peeling action, and easy discharge of peeled cassava and waste materials. The major parts include:

Peeling Chamber: The main compartment where the peeling operation occurs. It houses the abrasive drum and facilitates the mechanical abrasion of cassava tubers.

Peeling Drum: A cylindrical stainless-steel drum with an abrasive inner surface that ensures effective removal of cassava skin.

Peeling Disc and Shaft: These components transfer motion from the gearbox to the peeling drum, ensuring uniform rotation and abrasion.

Gearbox and Transmission System: A reduction gearbox transmits torque from the gasoline engine to the peeling drum at a controlled speed.

Pulley and Belt Drive: These serve as the power transmission mechanism between the gasoline engine and the gearbox.

Chute and Chute Cover: The chute allows for easy loading of cassava tubers and the discharge of peeled products, while the cover prevents spillage during operation.

Machine Stand: Provides firm support and stability during operation.

Peel and Water Outlet: Facilitates the drainage of peel residues and wash water during the peeling process.

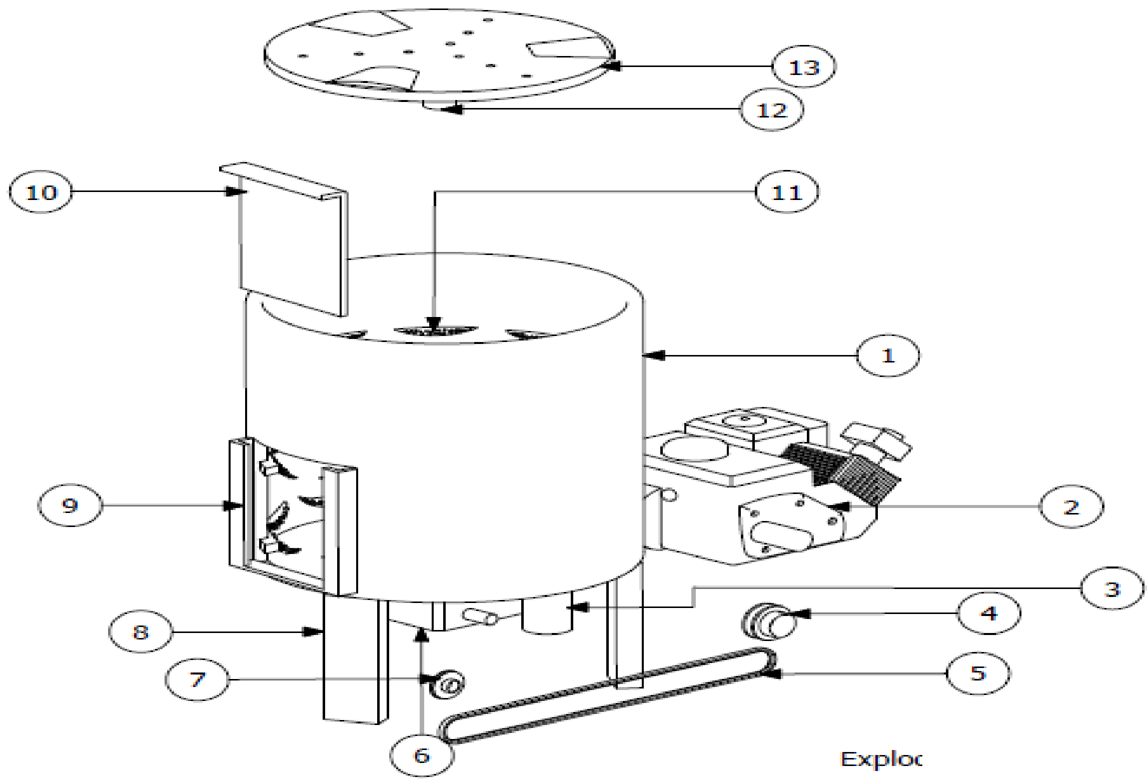

Figure 1: Exploded view of Cassava Peeling Machine

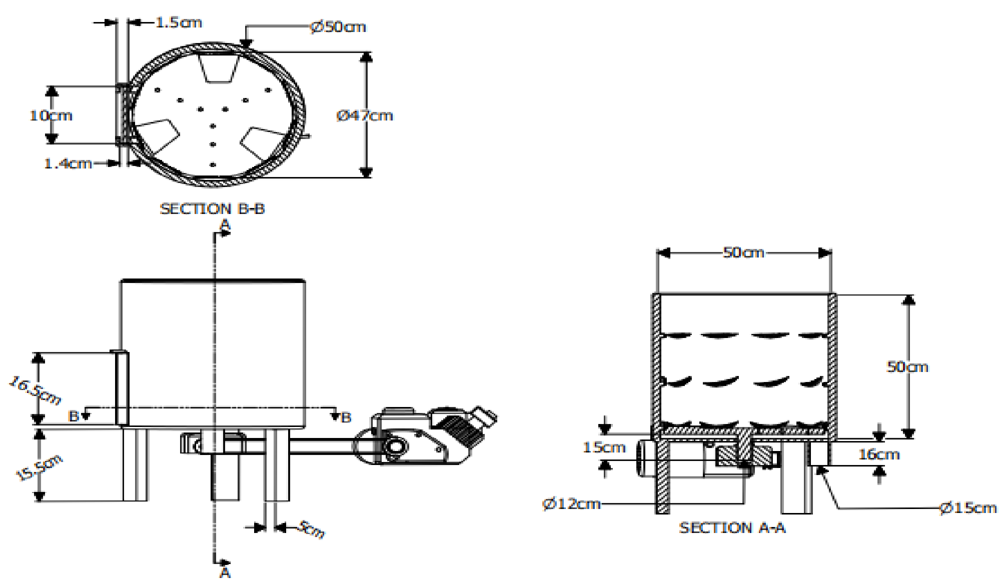

Figure 2: Machine Sectional view (complete)

Table 1: Fabricated Peeling Cassava Machine components

S/N	DESCRIPTION	QTY	DIMENSION	MATERIAL
1.	Peeling drum	1	Ø50 cm × 50 cm	Stainless steel
2.	GX390 Multipurpose Gasoline Engine	1		Cast iron
3.	Peel/water outlet	1	16 cm × Ø15 cm	Mild steel
4.	Engine Pulley	1	Ø9.5 × Ø6 cm	Cast iron
5.	Engine Belt	1	AA42	Rubber
6.	Transmission system (Gearbox)	1		Cast iron
7.	Gearbox pulley	1	Ø9 cm × Ø5.4 cm	Cast iron
8.	Machine stand	1	Ø15.5 cm × Ø5 cm	Mild steel
9.	Chute	1	16.5 cm × 10 cm	
10.	Chute cover	1	16.5 cm × 10 cm	Stainless steel
11.	Abrasive metal	20		Stainless steel
12.	Peeling disc shaft	1	Ø12 cm × 15 cm	Mild steel
13.	Peeling disc	1	Ø47 cm	Stainless steel

2.1 Design considerations and calculations

To make the machine efficient and reliable, the following key points were taken into account:

- ❖ It needed to peel different cassava varieties, shapes, and sizes, the peeling chamber was lined with a stainless steel plate that has regular indentations for better peeling.
- ❖ All parts of the machine were made from materials sourced locally.
- ❖ The machine had to be affordable for small and medium-scale cassava processors handling 1–10 tonnes of cassava per day. Locally sourced engineering materials

Assuming machine operational capacity to be 1200 kg/hr
The bulk density of fresh cassava roots is approximately 500 kg/m^3 (Hundekari & Swami, 2022), the volume of cassava was determined from equation one (1)

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} \qquad (1)$$

2.2 Design Power requirement

Total power P_{total} required = P_{shaft} + $P_{peeling}$ .... (2)

Note that the bevel gearbox translates horizontal motion (from the prime mover i.e. gasoline engine) to vertical motion.
But the peeling disc is welded together with vertical shaft which takes power from the bevel gearbox.

$P_{total} = P_{peeling\ disc}$

$$P_{peeling\ disc} = T_{peeling\ disc} \times V_{peeling\ disc} \qquad (3)$$

$$V_{peeling\ disc} = \frac{2\pi N}{60}\ \text{rad/s} \qquad (4)$$

Where:
$T_{peeling\ disc}$ = Torque of the peeling disc, Nm
$V_{peeling\ disc}$ = Angular velocity of the peeling disc, rad/s
N = number of revolutions per minute of peeling disc (rpm)
$r_{peeling\ disc}$ = Radius of rotating disc, m
The number of Revolutions of the peeling disc was computed to be 1,400 rpm
Hence, GX390 gasoline multipurpose engine with speed of >1,400 rpm and rated power of about 9.4 hp was selected for the design.

2.3 Belt Design Assessment

The tension on the belt can be computed thus:

$$\text{Power} = (T_1 - T_2) \qquad (5)$$

Where T_1 and T_2 are tensions on the tight and slack side respectively (N).

$$\left(\frac{T_1}{T_2}\right) = e^{f\theta}\ \text{(belt tension ratio)} \qquad (6)$$

Where:
f = coefficient of friction between belt and sheave
θ = the angle of wrap (rad)
The angle of wrap for an open belt is given as (Khurmi and Gupta, 2005):

$$\theta = (180 - 2\alpha)\left(\frac{\pi}{180}\right) \qquad (7)$$

$$\text{But } \sin\alpha = \frac{r_1 - r_2}{C} \qquad (8)$$

Where r_1 and r_2 are radii of both pulleys
C = centre to centre distance between the pulleys (mm)

2.4 Evaluation of Driving and Driven Pulley Mechanics

Diameter of driving pulley selected, D1
If the outside diameter of the driven pulley is five times that of the driving pulley,
Using the ratio (Khurmi and Gupta, 2005):

$$N_1D_1 = N_2D_2 \qquad (9)$$

Where N_1D_1 and N_2D_2 are the number of revolution for driving and driven pulley respectively

To find the operating speeds of the driver and driven pulleys:

$V_1 = \frac{\pi D_1 N_1}{60}$ the speed of driving pulley was computed to be 9.16 m/s

And

$V_2 = \frac{\pi D_2 N_2}{60}$ is the speed of the driven pulley and was computed to be 8.91 m/s

2.5 Determination of belt tensions. Khurmi and Gupta (2005):

$P = (T_1 – T_2) V$ ……………………………………… (10)

2.6 Shaft design:

This is based on permissible angle of twist. The amount of twist permissible depends on application. Machine shaft's angle of twist is about 0.3deg/m (Khurmi and Gupta, 2005).

Substituting equation (3) and (4) into equation (2) gives;

$d = \frac{2\delta L}{G\theta}$ …………………………………………….… (11)

Where

θ= angle of twist of the shaft = 0.3deg/m

δ= permissible torsional stress, MPa

L= length, m

G = Modulus of rigidity of the material = 80 Gpa for the material.

Shaft of 20 mm diameter was used

2.7 Design of bearing

The rating/service life of ball or roller bearing is given as follows:

$L = \left(\frac{C}{W}\right)^k \times 10^6$ revolutions or $C = W\left(\frac{L}{10^2}\right)^{1/k}$ (Khurmi and Gupta, 2005) ……………………………………… (12)

Where L = Rating life (dimensionless)

C = Basic dynamic load rating, N

W = Equivalent dynamic load, N

K = 3 for ball bearings

The total life expected for the bearing is 20 x 10^6 revolutions at 95% reliability. According to (Rober, 2001), the relation between the bearing life and reliability is as:

$\log_e\left(\frac{1}{R}\right) = \left(\frac{L}{a}\right)^b$ or $\frac{L}{a} = \left[\log_e\left(\frac{1}{R}\right)\right]^{1/b}$ ……………………. (13)

Where

L is the life of the bearing corresponding to the desired reliability R a and b are constants whose values are a = 6.84 and b = 1.17 if L_{90} is the life of a bearing corresponding to a reliability of 90% (i.e. R_{90})

then,

$\frac{L}{L90} = \left[\log_e\left(\frac{1}{R90}\right)\right]^{1/b}$ ……………………..………. (14)

A four flanged bolt ball bearing of 20 mm was used

2.8 Machine operation mode

The cassava peeling machine is powered by a variable-speed GX390 multipurpose gasoline engine (±1,400 rpm) with a maximum power output of 8.2 kW and a rated power of 8.0 kW. Power is transmitted through the belt from the engine pulley (driving pulley) to the gearbox pulley (driven pulley). The gearbox translates the radial motion of the driven pulley shaft to the axial motion of the machine peeling disc, which is assembled at the base of the stationary peeling drum. Tubers of cassava are loaded into the peeling drum, which is abraded (inner surface). As the peeling disc rotates, it causes relative motion on the cassava tubers. The cassava tubers constantly rub and tumble against the abrasive surface of the peeling drum, which results in peeling. Water is sprinkled while the machine is in operation in order to wash off peels from the tubers. Before loading, the engine has to be in operation and run for at least 2 minutes to avoid stalling or jamming. Key components of the machine include the prime mover, a peeling drum, an abrasive peeling surface, a machine stand, and a transmission system (gearbox).

2.9 Machine Budget

The cost of production of the cassava peeling machine is estimated in table 2 below

Table 2: Summary of the machine detailed budget or cost evaluation cost

S/N	Materials/Items	Quantity	Total cost (₦)
1	2.0mm stainless sheet (gauge 14)	2 sheets	317,000
2	50 x50 x5 angle bar	2 length	140,620
3	Gearbox pulley	1	20,375
4	Bearings	2	45,312
5	Bushing	3	30,562
6	GX390 Multipurpose Gasoline Engine	1	375,422
7	Gearbox	1	200,270
8	3.00 mm mild steel shaft	1	45,000
9	Electrodes	3 pks	20,000
10	Oil paint	2 gal	50, 000
11	Reams of A4 papers	3 reams	15, 000
12	Miscellaneous		150,000
13	Sub-total cost of research		1,344,561
14	Labour cost = 8 % of the total cost of research work		107,564.9
15	Grand total cost of research		1,452,126

3.0 Performance Evaluation of the machine

The Peeling parameters of the machine such as the Peeling efficiency (%), Mechanical damage (%), Peel retention (%) and Throughput capacity (kg/h) are obtained using the following equations from *Adegoke* et al.*, 2020*:

Peeling efficiency (%), $\mu = \frac{W_{pr}}{W_{pr}+W_{prh}}$ ………………… (15)

Mechanical damage (%), $\lambda = \frac{W_{trp}}{W_{trp}+W_{tc}}$ …………… (16)

Peel retention (%), $P = \frac{W_{prh}}{W_{prh}+W_{pr}}$ ………………………… (17)

Throughput capacity (kg/h), $\eta = \frac{W_{pr}+W_{prh}+W_{trp}+W_{tc}}{t}$ ………………………………………………… (19)

Where:
W_{pr} = Weight of peel removed by machine
W_{prh} = Weight of peel removed by hand post machine peeling
W_{trp} = Weight of tuber flesh removed along with peel
W_{tc} = Weight of tuber flesh completely peeled
t = peeling time

Table 3: Peeling Operation Variables of Machine

S/N	Speed of Prime Mover (rpm)	Wt of tuber (kg)	Wt of peeled tuber (kg)	Wt of peel (kg)	% Wt of peel (kg)	% Peeling loss (kg)	Wt of peel removed by hand (kg)	Peeling Efficiency (%)	Throughput capacity (kg/hr)
1	1600	10	8.29	1.32	13.16	6.80	0.17	88.56	120
2	1600	20	16.86	3.14	15.71	5.45	0.65	82.97	240
3	1600	40	34.66	5.34	13.35	3.00	0.66	89.00	480
4	2000	10	8.14	1.86	18.60	5.00	0.14	93.00	120
5	2000	20	16.4	3.60	18.00	4.98	0.4	90.00	240
6	2000	40	35.21	4.79	11.97	1.30	0.53	90.03	480
7	2800	10	7.24	2.86	28.60	17.30	0.17	94.39	120
8	2800	20	14.73	5.27	26.37	17.30	0.59	89.94	240
9	2800	40	34.74	7.76	19.40	7.40	2.5	75.63	480
10	3600	10	7.34	2.88	28.80	18.00	0.34	89.44	120
11	3600	20	14.65	5.35	26.75	17.40	0.53	90.99	240
12	3600	40	32.89	8.92	22.30	12.78	2.8	76.11	480

4.0 Results and Discussion

From table 3, the average peeling efficiency of the machine was found to be 88.1 % with Throughput of 280 kg/hr. This result indicate that very great amount of the cassava peels were removed from tubers and minimal loss due to mostly tuber size. The graph below (Figure 3) clearly shows that Peeled tuber weight (kg) is positively related to total peel weight (kg) and also, larger sizes of tuber tend to peel more effectively than smaller ones. This is because the collected surface area for a number of small tubers put together an equivalent of larger tubers (in weight) is greater, and the chance of every portion of their surface area to have contact with the abrasive surface for peeling to take place is low.

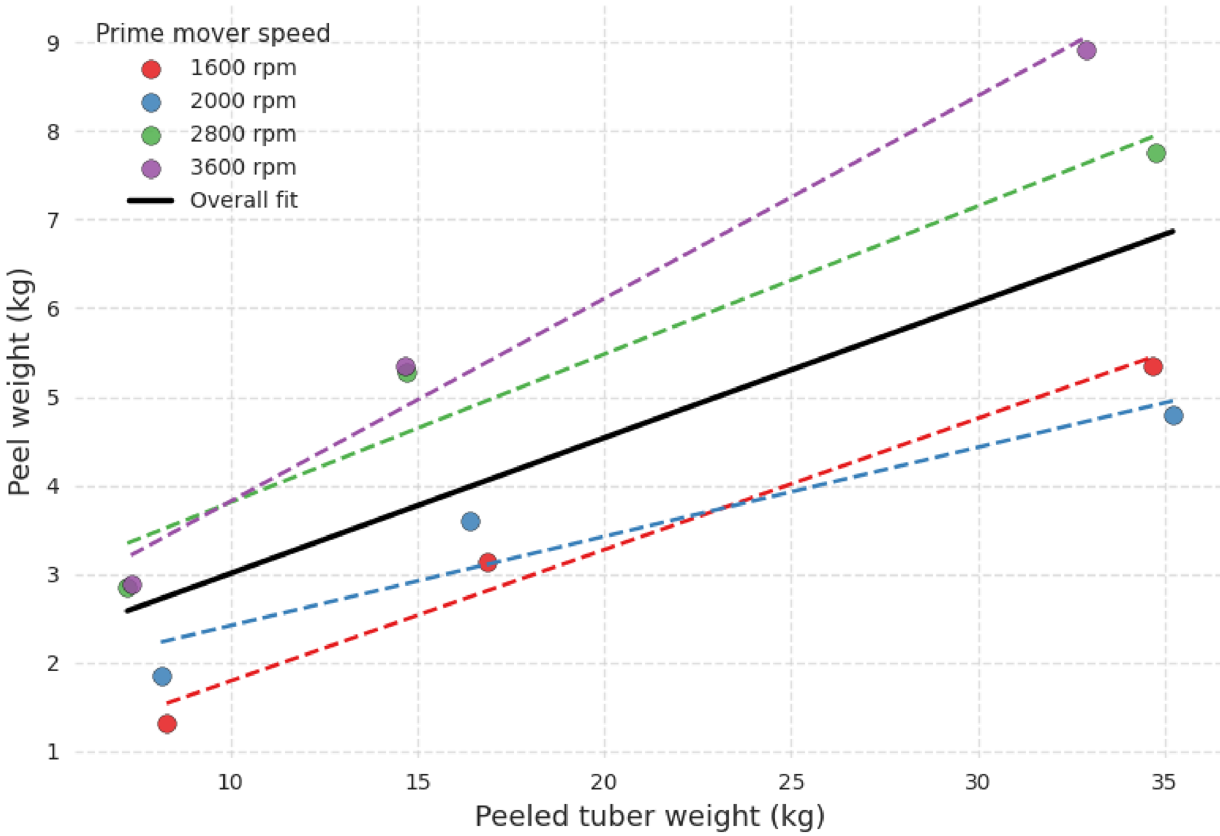

Figure 3: Relationship between peeled tuber weight and peel weight at different prime mover speeds.

Table 4: Peeling Performance Indicators of Cassava at Different Speeds

speed (rpm)	N	mean peeled (kg)	mean peel (kg)	Pearson r	slope (peel vs peeled)	R^2
1600	3	19.937	3.267	0.9895	0.1481	**0.9792**
2000	3	19.917	3.417	0.9463	0.1005	**0.8954**
2800	3	18.903	5.297	0.9695	0.1671	**0.9399**
3600	3	18.293	5.717	0.9906	0.2286	**0.9812**

Within each speed group the correlation between peeled tuber weight and peel weight is forceful (Pearson r ≈ 0.95–0.99), and linear fits explain most of the variance (R^2 ≈ 0.90–0.98).

The peeling efficiency varies with the speed of the machine.

4.1 Effect of Speed on Peeling Efficiency

The analysis revealed that peeling efficiency varied with the speed of the prime mover. Efficiency was calculated as the ratio of the weight of peel removed by machine to the total tuber peel weight (weight of peel removed by machine + weight of peel removed by hand post-machine peeling). Results showed that mean peeling efficiency generally increased with speed up to an optimal point, after which it plateaued or declined slightly. At lower speeds, efficiency was reduced, likely due to insufficient mechanical force to remove the peel effectively. Conversely, very high speeds may have caused excessive material loss, reducing overall efficiency. The observed trend indicates that prime mover speed is a critical parameter influencing peeling performance, and selecting an optimal speed is essential for maximising yield while minimising tuber loss.

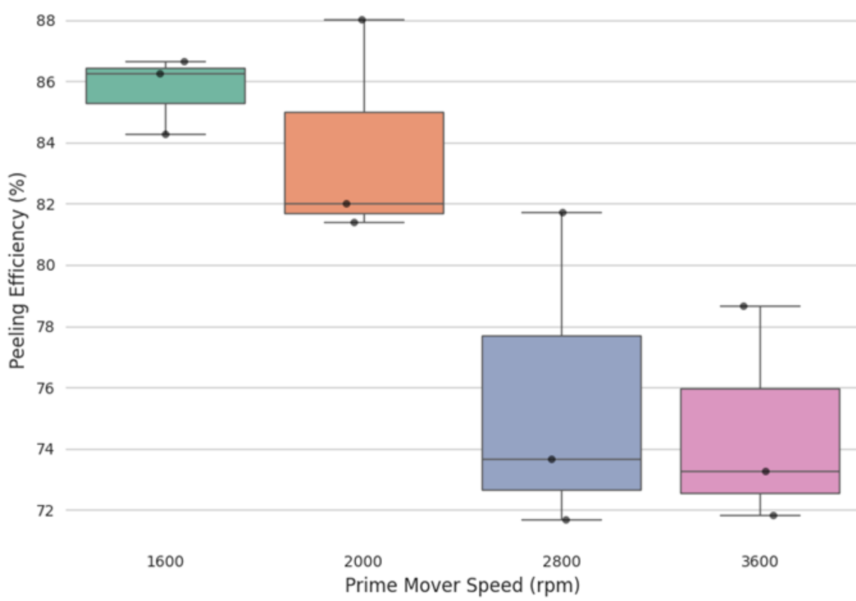

Figure 4: Effect of Prime Mover Speed on Peeling Efficiency (ANOVA & Tukey HSD)

Statistical analysis confirmed that prime mover speed had a significant effect on peeling efficiency ($p < 0.05$). Tukey's HSD post-hoc test revealed that lower speeds (1600–2000 rpm) achieved significantly higher peeling efficiencies compared to higher speeds (2800–3600 rpm). The decline in efficiency at elevated speeds may be attributed to excessive mechanical action, which increases edible tuber loss along with the peel. These findings suggest that optimal operation lies within the lower-to-mid speed range, ensuring maximum yield and minimal losses.

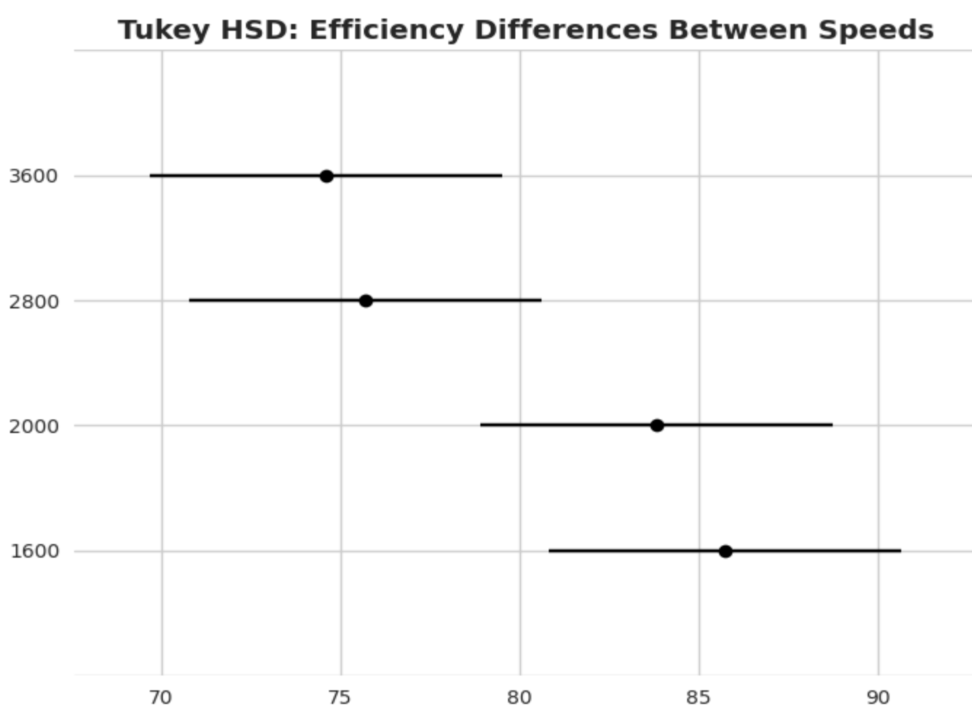

Figure 5: Tukey HSD: Efficiency Differences between Speeds

4.2 Efficiency Distribution by Prime Mover Speed

The efficiency distributions demonstrate that peeling performance is strongly influenced by prime mover speed. At 1600 rpm, efficiency is consistently high with minimal variation, while 2000 rpm also maintains relatively high efficiency but with greater variability. In contrast, higher speeds (2800–3600 rpm) show reduced efficiency and broader distributions, indicating unstable performance. These results confirm that lower prime mover speeds provide both higher and more reliable peeling efficiency.

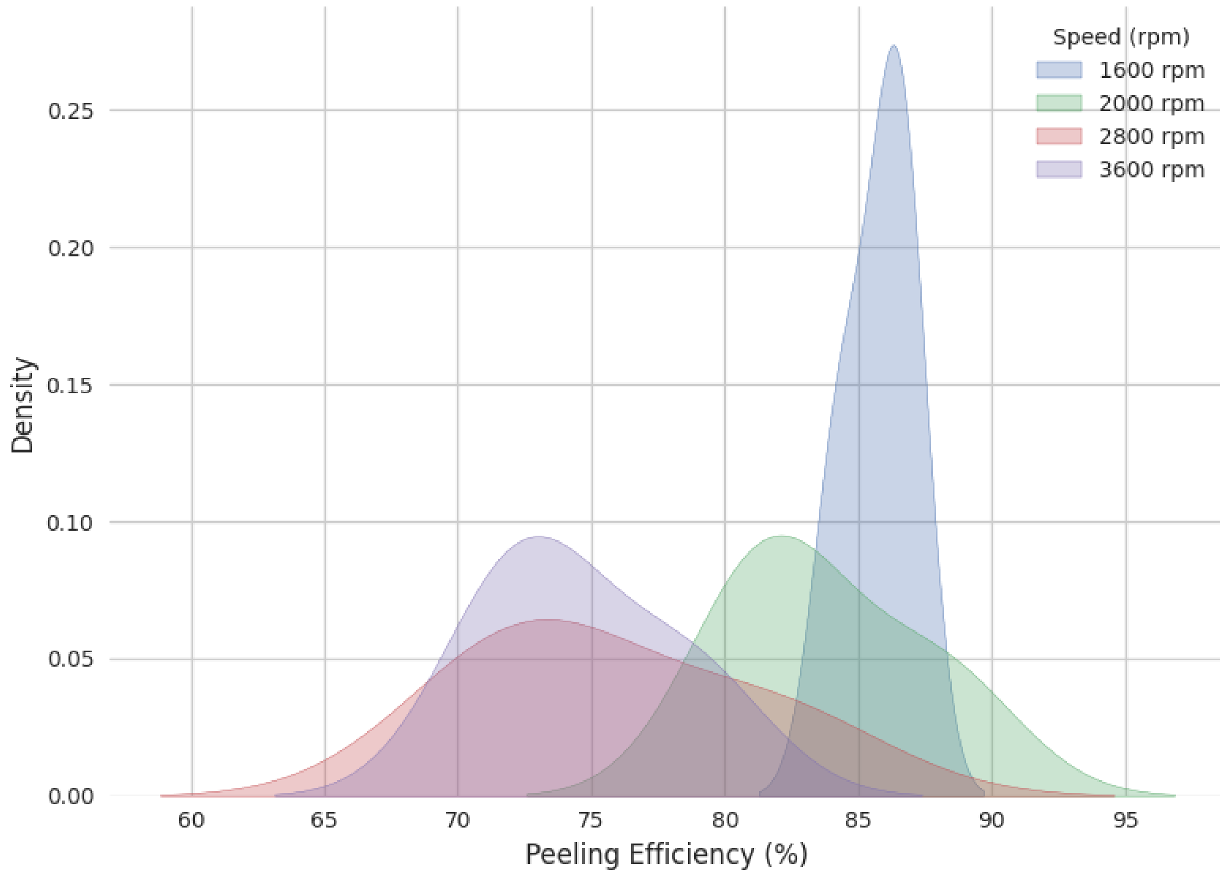

Figure 6: Efficiency Distribution by Prime Mover Speed

5 CONCLUSION AND RECOMMENDATION

At the end of the research, a cassava peeling machine was designed and fabricated, and a performance evaluation was carried out. The following weights were selected for the performance evaluation: 10, 20 and 40 kg with prime mover speeds of 1600, 2000 and 3600 rpm, respectively. The average percentage weight of peel obtained across all aforementioned variables was 20%. This value falls within the range of percentage weight of peel in a cassava tuber. It can be observed from table 3 that at a speed of 2000 rpm, peeling efficiency is at its peak ( ) across all weights of cassava with minimal percentage peeling loss ( ). Therefore, 2000 rpm proves to be the best operational speed of the machine. For a batch operation, the machine can take between 10 and 60 kg of cassava with a throughput capacity of 280 kg/hr. Freshly harvested cassava tubers (between 1 and 2 days of harvest) are recommended for peeling to achieve optimum results. The total cost estimate of the research is One Million, Four Hundred and Fifty-Two Thousand, One Hundred and Twenty-Six Naira Only (N1,452,126).

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