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Research/Technical Note

Development and Performance Evaluation of a Pedal Operated Paddy Rice Winnower for Small Scale Rural Farmers in Nigeria

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Abstract: A pedal operated paddy rice winnower for small scale rural farmers was developed to work under the condition of Bauchi state. It was locally fabricated in center for industrial studies (CIS), Abubakar Tafawa Balewa University Bauchi. The whole machine was constructed from steel, angle iron, sheets, bearing, chain and sprockets, shaft, bolts, nuts, and bicycle frame, while design parameters calculated includes shaft diameter (15mm), torsional moment (0.68Nm) and gear ratio (2.66) respectively. The cleaning effect of the winnower is achieved through the cranking of the prime mover (Bicycle) which drives the fan. The machine was developed to be driven by human muscle power through the pedal on the bicycle. The threshed grain with a moisture content of 13.28% (wb) was fed into the hopper manually and the final cleaned grain was collected under the sieve on a collecting pan. From the test carried out on the machine, it indicates that only one person is needed to operate, while it needs the sum of #73,100.00 as an investment cost. On the other hand, the performance test indicates a cleaning capacity of 90 – 100kg/hr of threshed paddy rice, with a cleaning efficiency of 84.04% and a loss of not more than 13.82%. The machine has a great potential in helping to reduce cleaning time and save cost.

Keywords: Paddy Rice, Collecting Pan, Cleaning Efficiency, Prime Mover, Threshed Grains

1. Introduction

Rice (Oryza sativa) production is extending to areas which traditionally are not producers of the crops [1]. The crops are the first cultural grasses belonging to the poaceae family. Cleaning and winnowing is one of the important processes done in preparing rice as food. It involves the removal of chaff and other debris from the grain. There are a number of factors that affects the performance in terms of cleanliness and grain loss during winnowing operation, such factors includes air velocity, feed rates, shaker frequency, dimension of sieve opening, sieve tilt angle, crop variety and moisture content ([2], [3], [4], [5] and [6]. Historical evidence has shown that winnowing is an ancient agricultural method developed by ancient cultures for separating grains from chaffs [7].

A good winnowing machine should remove all chaff straw and plant debris with little grain loss. In Nigerian, and north in particular, rice winnowing is part of women's contribution in rice processing. The time take to winnow a batch of 1kg of unclean seeds ranges between 7 – 12 minutes, depending on the winnower's skill, the required cleanliness, grain/non grain ratio, amount and stability of natural air current and other environmental factors [8]. The poor acceptance of local rice in Nigeria has to do with its processing which introduces stone particles and pebbles [9]. Winnowing removes unwanted materials like straws, chaffs, weeds, soil particles and rubbish from grains. It improves grain storability, reduces dockage during milling, gives good quality milled rice and improves the milling output. It also reduces insects, pests and disease infestation [10].

2. Material and Methods

2.1. Design Considerations

i The machine should fulfill its basic task of cleaning the grain.
ii It should be economical.
iii There should not be a need for repeat of the process
iv The machine should be portable to ease transportation.
v The design should be optimized to reduce fatigue of farmers.
vi The attachments should employ low cost materials, methods and standard parts that are locally available.

2.2. Description of Machine Layout

The winnowing machine consists mainly of hopper, the fan, the sieve, the bicycle frame and the supporting frame (Figure 1). The hopper has a trapezoidal shape which is made from metal sheet (18mm gauges) with sides slanted inwards to form a small outlet located above the sieve. The fan and blade are enclosed in a casing whose outlet was positioned to supply air current over the sieve. The sieve is situated and vibrates close to the grain outlet. The fan shaft consists of a sprocket at its rearmost end which is coupled via a chain drive with another sprocket (driven) placed on the extended drive from the pedal axle of the bicycle. A bicycle frame was mounted on the supporting frame as prime mover to power the fan and crank mechanism through a chain and sprocket drive. The supporting frame was constructed using angle iron.

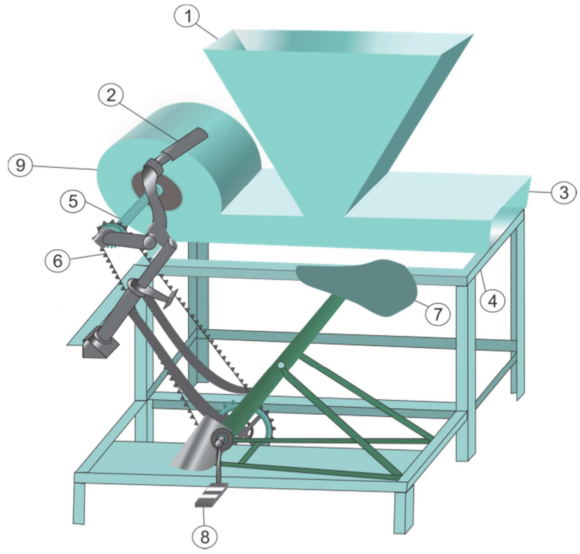

Figure 1. *Isometric drawing of Pedal-Operated Rice Winnower.*

Hopper (1), Handle (2), outlet (3), frame (4), Shaft (5), Chain (6), Seat (7), pedal (8), Blower Casing (9), Drive Sprocket (10), Driven Sprocket (11).

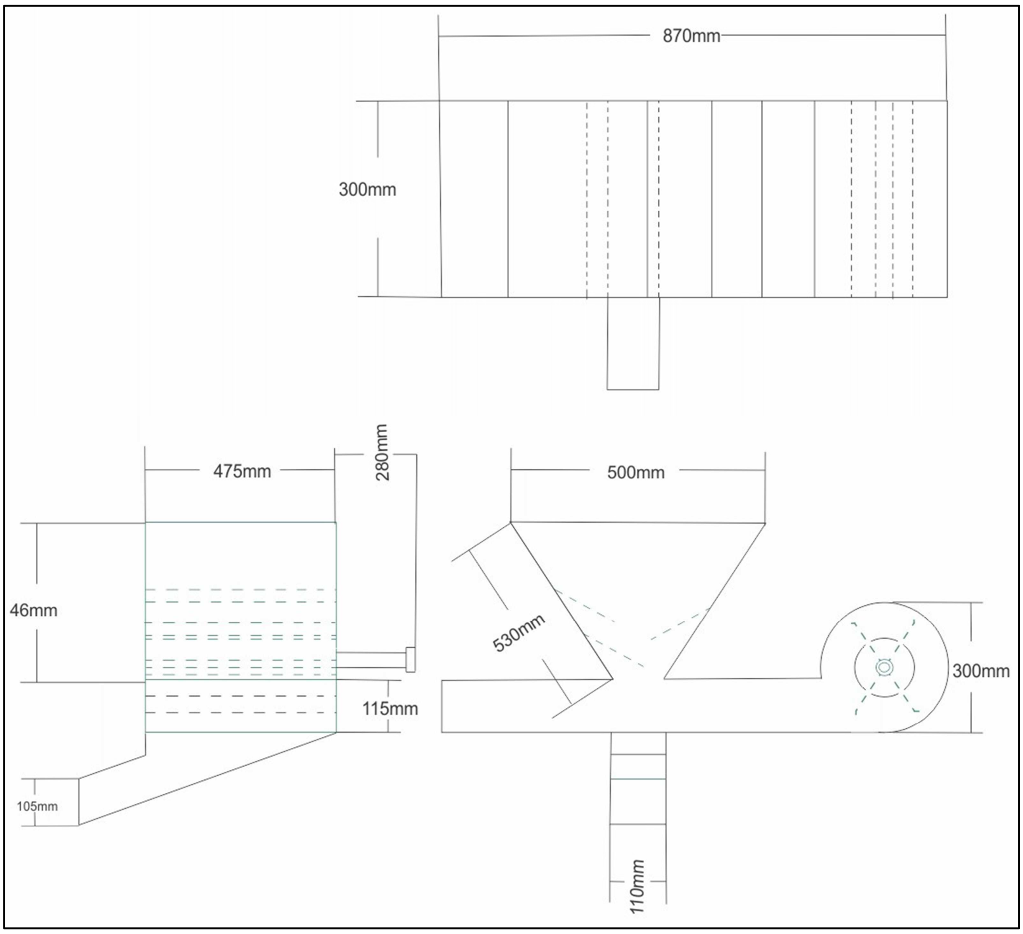

Figure 2. *Orthographic Drawings of the Machine.*

Table 1. *Description and Specification of Machine Parts.*

S/No.	Description and Specifications	Qty	Material
1	Prime Mover (Bicycle Unit)	1	-
2	Bearing (Φ 50mm)	1	M. S
3	Driven Sprocket (Φ 150mm)	1	M. S
4	Driver Sprocket (Φ 150mm)	1	M. S
5	Chain (Φ 1730 mm)	1	M. S
6	Fan Shaft (Φ 15mm x 700mm)	1	M. S (Rod)
7	Bolt (Φ 10 mm)	4	M. S
8	Bolt (Φ 13 mm)	4	M. S
9	Grain Outlet (110 x 105 x)	1	M. S Sheet (gauge 18)
10	Non Grain outlet ()	1	M. S Sheet (gauge 18)
11	Hopper ()	1	M. S Sheet (gauge 18)
12	Fan Blade	4	M. S Sheet (gauge 18)
13	Fan Casing (Φ 300 x 115)	1	M. S Sheet (gauge 18)
14	Frame (0.06 mm)	1	M. S Angle iron
15	Machine Height (1400 mm)	1	-

2.3. Working Operation

The winnower machine is operated through the cranking of the prime mover which drives the fan. An amount of the threshed grains is fed into the winnower through the hopper. It flows down by gravity and pass through the hopper outlet and drops across the fan air stream unto the sieve. The non – grain materials being lighter than the grains are blown out of the machine through the out end of the machine. The clean grain material passes through the sieve on to the grain collecting pan and subsequently, flows down still by gravity towards the grain outlet were it is collected.

2.4. Design Calculations

2.4.1. Shaft Diameter

The machine consists of two shafts, the fan shaft and the pedal axle shaft. Power is transmitted by a chain and sprocket drive. The following equation was used to determine the shafts diameter.

$$D^3 = \frac{16}{\pi Ss}\sqrt{(KbMb)2} + \sqrt{(KtMt)2} \qquad (1)$$

Where:
M_t = Torsional moment, Nm
$M_{b=}$ Bending moment, Nm
K_b = Combined shock and fatigue factor applied to bending moment.
K_t = Combined shock and fatigue factor applied to torsional moment
S_s = Factor of safety
D = Shaft diameter (m)

2.4.2. Fan Blade

The number of blades depends on size and purpose of the fan. A 450 vane angle was selected for this fan blower. The number of blades was calculated as [11].

$$Z = \frac{8.5\,SIN\,B}{1-W/L} \qquad (2)$$

Where:
B = Vane angle
W = Width of blade
L = Length of blade

2.4.3. Volume of Hopper

The volume of hopper was obtain by using the equation for calculating the volume of a trapezium, hence,

$$V = \frac{1}{3}\left\{Lb + La + \sqrt{LbLa}\right\} \qquad (3)$$

Where,
V = Volume of Hopper (m^3)
La = Area of top (mm)
Lb = Area of base (mm)

2.4.4. Gear Ratio

The gear ratio for the prime mover was calculated as [12]

$$G_o = \frac{Gp}{Gf} \qquad (4)$$

Where, Gp is the gear teeth on pedal axle (mm)
G_f is gear teeth on fan shaft (mm)

2.5. Performance Evaluation

The performance evaluation involves collecting samples from the grain outlet and the non grain or unwanted outlet. The weight of grains and other materials in each sample were recorded. The procedure was replicated for each throughput. The following equations were used to determine the percentage cleaning efficiency and percentage grain loss. [8].

$$E_c = \frac{Wg}{Wtg} \times 100 \qquad (5)$$

$$G_L = \frac{Wgn}{Wg+Wgn} \times 100 \qquad (6)$$

Where,
Ec = Percentage Cleaning Efficiency (%)
G_L = Percentage Grain Loss (%)
W_g = Weight of Grain Material in Clean Grain Sample (Kg)
W_{tg} = Weight of Total Material in Clean Grain Sample (Kg)
W_{gn} = Weight of Grain Material in Non Grain Sample (Kg)

3. Results and Discussion

3.1. Design Parameters

Table 2. *Calculated Data of Design Parameters.*

S/No.	Parameter	Unit	Mean Value
1	Shaft Diameter	mm	15
2	Torsional Moment	Nm	0.68
3	Shaft Revolution	rpm	409.8
4	Wind Velocity	m/s	2.36
5	Volume of Hopper	m^3	0.0406
6	Feed Rate	kg/min	3.04
7	Angle of Repose	o	23
8	Moisture Content	%	13.82
9	Gear ratio	-	2.66
10	Fan Blade	-	4
11	Percentage Loss	%	13.82
12	Cleaning Efficiency	%	86.04

***Table 3.** Results of Performance Evaluation Test for Paddy.*

	Feed Rate (kg/min)	Fan Speed (rpm)	Mass Out (kg)	Mass Out (kg)	% Loss	% Clean
1.	2.0	390	1.8	0.2	10	90
2.	2.5	394	2.2	0.3	12	88
3.	3.0	410	2.6	0.4	13.3	86
4.	3.6	425	3.0	0.6	16.7	83.3
5.	4.1	430	3.4	0.7	17.1	82.9
	3.04	409.8	2.6	0.44	13.82	86.04

3.2. Performance Evaluation

The results for the cleaning efficiency and percentage grain loss for the winnowing machine is shown in Table 3. It indicates that as the feed rate increases, the cleaning efficiency decreases, while the percentage grain loss increases with increased feed rates. The result is similar to [8], which reports that the percentage grain loss for sorghum, soya beans and millet increases either with another increase or decrease in feed rate from the minimum point. He explain the phenomenon as due to the fact that as the feed rate gradually increases, the mass flow across the air current could still allow air to penetrate and flush out unwanted materials up to a point corresponding to minimum grain loss, after which feed rate reached a level that the blanket effect could completely prevent air current penetrating through the material mass flow and consequently, more grains are dragged along the sieve and expelled through unwanted material outlet, which gives rise to increase in grain loss after minimum point [8]. The average cleaning efficiency and percentage grain loss for the winnower were 86.04% and 13.82% respectively, while the average feed rate was 3.04kg/min. However, [10] reported the average percentage cleaned and cleaning loss for finger millet as 81.50% and 18.46% respectively. There results for percentage clean grain (81.50%) was slightly lower, while the percentage grain loss (18.46%) was slightly higher when compared to what was obtain from this study for paddy rice. Figure 3 shows the graphical percentage cleaned and loss of the paddy.

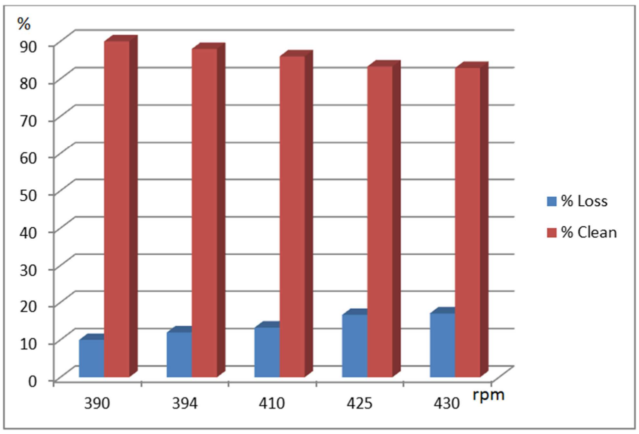

***Figure 3.** Graph of Percentage Cleaned and Los of Paddy Rice.*

3.3. Bill of Engineering Measurements and Evaluation (BEME)

A market survey was done following an initial estimate of the materials required for the fabrication of the machine. The costs provided in Table 4 are indicative of the actual expenses incurred in development of the pedal-operated rice winnower.

***Table 4.** Bill of Engineering Measurements and Evaluation.*

S/No.	Item	Qty	Unit Cost (#)	Amount (#)
1	Angle Iron	3	1,500	4,500.00
2	Bearing	2	500	1,000.00
3	Shaft	1	3,000	3,000.00
4	Metal Sheet	1	7,500	7,500.00
5	Welding Electrode	500	10	5,000.00
6	Bicycle Unit	1	10,000	10,000.00
7	Paint	4 liter	500	2,000.00
8	Blower Fabrication	1	1,000	1,000.00
9	Frame	3	4,700	14,100.00
10	Transportation	-	-	5,000.00
11	Labour	-	-	20,000.00
	TOTAL			73,100.00

4. Conclusions

The results obtain from this research work shows that the time required to clean the rice grain are decreased, while cost is also saved. The materials could be sourced locally, while the machine will be suitable and needful for small and medium class farmers. Although the cleaning efficiency was initially satisfactory, but as the feed rate and fan speed increases, it decreases, hence the need to determine the optimum cleaning efficiency and minimum percentage grain loss. However, with an average feed rate of 3.04kg/s, the average cleaning efficiency (86.04%) and percentage grain loss (13.82%), it indicates that room exist for an improvement.

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