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Development and Evaluation of a Motor-Operated Winnower for Small and Medium-Scale Paddy Farmers

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Abstract

Winnowing is the process of separating grain from chaff and other impurities using a natural breeze or a mechanical air flow. In the present study, an existing tractor-operated winnower was modified into a motor-operated unit. A 1-HP AC motor was installed to drive the winnower, with its rotational speed regulated through a motor speed controller and the existing transmission system. The performance of the modified winnower was evaluated as per standard testing procedures to assess its feasibility and efficiency. Key performance parameters examined included cleaning efficiency, output capacity, blown grain percentage, and cost of operation. The results indicated that the air velocity of both tractor- and motor-operated winnowers was approximately three times higher than that of manual winnowing at the optimal dropping height of 121 cm from the ground and 60 cm from the fan center. Grain moisture content was found to have a significant influence on winnowing efficiency, which increased as the moisture content of the grain and chaff decreased. The motor-operated winnower achieved a cleaning efficiency of 97%, an output capacity of 95 kg/h, and a blown grain loss of 9%. The operational costs were calculated as ₹300 for the tractor-operated winnower and ₹88 for the motor-operated unit. Overall, the study demonstrates that the motor-operated winnower is a cost-effective, energy-efficient, and practical alternative to both manual and tractor-operated systems.

Keywords: Winnowing; Tractor-operated winnower; Motor-operated Winnower; Cleaning efficiency; Output capacity; Air velocity; Feed rate; Cost economics.

Introduction

Wind winnowing is one of the oldest agricultural practices developed by ancient civilizations for separating grains from chaff. It has also been used for other purposes such as removing hay, chaff, or pests from stored grain. During the industrial revolution, the process was mechanized with the invention of fanning mills and other winnowing machines (Chambers, 1885). At present, in India, a large number of threshers are used for paddy threshing, which may be of the hold-on type or throw-in type, operated either manually or by power. In these machines, harvested paddy stalks are tied into bundles and fed into a rotating drum equipped with loops on its periphery, which detach grains from the ear heads to achieve threshing. However, such operations are often labor-intensive, drudgery-prone, and have low output efficiency. Cleaning is usually performed manually after threshing. Following threshing, winnowing becomes necessary to separate straw and husk from paddy. Traditionally, this operation is performed using natural wind drafts from elevated platforms, which is uncomfortable and entirely dependent on wind availability. In some villages, small electric fans are used, but these too require proper positioning and manual handling, making them inconvenient. In contrast, small motor-operated paddy winnowers are easier to handle and can efficiently separate the chaff from the grain mixture.

Several researchers have developed power-operated air-screen grain cleaners (Kachru and Sahay, 1990) and centrifugal-type winnowers (Tabak et al., 2004). Studies have also evaluated the performance of tractor-operated winnowers and various straw conveyors (Mohite and Rajguru, 2009; Goel et al., 2009; Kumari et al., 2020). In light of these advancements, there is a pressing need to develop and evaluate simple, low-cost, motor-operated winnowers with high capacity and good cleaning efficiency to reduce drudgery. Accordingly, the present study was undertaken to assess the performance of both tractor-operated and motor-operated winnowers and to determine the operational cost of the modified winnower.

Materials and Methods

Location of Experimental Site

Development and testing of motor-operated winnower was conducted at Department of Farm Machinery and Power Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. As per the design of tractor-operated winnower was developed into a motor-operated winnower. A winnower was attached to the power source which was operated by a 35 hp Tractor. Two mesh in square shape having dimension 130 × 70 cm were fixed in the side of the rotating fan to avoid accidents. Four rectangular fan blades of size 42 x 14 cm having a thickness of 0.08 1 cm were used. The fan (tan blades and flange) was enclosed within frame covered with sieve in side of the frame in order to prevent the accident.

For winnowing operation, 500 rpm or above rpm is required this can be achieved by a motor having 1000 rpm or above. So, 1hp single phase motor, 1440 rpm, 220V was selected for winnowing operation. The power-operated paddy winnower consists of an Electric motor, V-belt, Pulleys, and Controller. The propellers are operated by a belt and pulley through the motor. The machine is operated by a 1hp single phase electric motor. The details of specifications of power operated winnower.

Performance Evaluation of Winnower

The number of parameters like feed rate, cleaning efficiency, output capacity, corrected output capacity, and energy consumption of winnower were determined. During the test, the sample of grain, straw from main outlet, straw outlet was taken to determine various parameters during 10 min test. The trails to be done from each outlet at 6 intervals i.e., 500, 600, 700, 800, 900, 1000 rpm of test. The collected samples were divided in to number of fractions as per Power thresher for cereals test code. The samples were analysed and following parameters were determined. The grain ratio is calculated by dividing weight of the straw.

$$\text{Grain ratio} = \frac{\text{Weight of grain in sample}}{\text{Weight of straw in sample}} \times 100 \quad (1)$$

Cleaning efficiency = I/J X 100

where,

I = Weight of whole grain per unit time at main grain outlet, kg.

J = Weight of whole material per unit time at the main outlet, kg.

$$Wc = \frac{(100-M) \times Rs \times w}{(100-Ms) \times R} \quad ..(2)$$

Where,

Wc = Corrected output capacity, kg/hr.

W = Output capacity obtained, kg/hr

M = Observed moisture content of grain, %.

Ms = Standard moisture content of grain (13%).

R = Observed grain ratio.

Rs = Standard grain ratio.

$$\text{Moisture content (\%)} = \frac{\text{Initial weight} - \text{Dried weight}}{\text{Dried weight}} \text{X100} \quad (3)$$

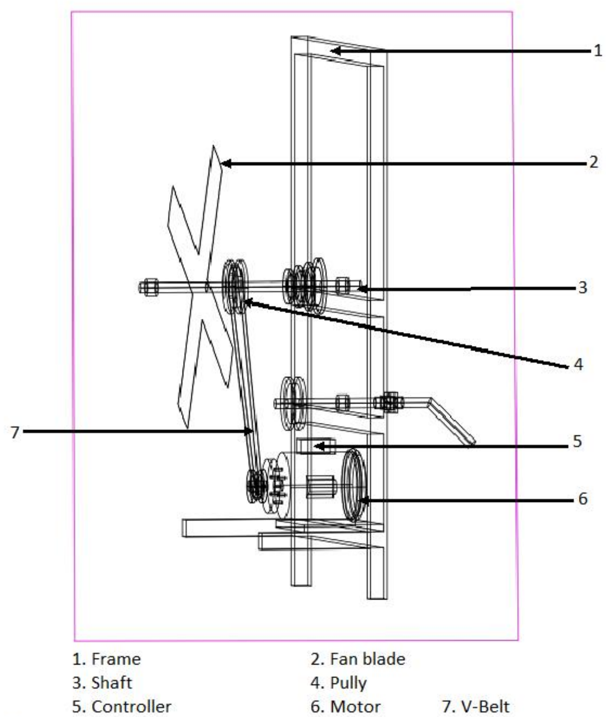

Fig. 1 Schematic diagram of motor operated winnower

To know air velocity of tractor operated winnower at three speeds the winnower was operated at respective blower speeds. An Anemometer as held 30cm away from the outlet at three positions and air velocity at three positions was noted. Then average air velocity was calculated. The same procedure was replaced for remaining speeds. The area of blower opening was noted and from this air discharge was calculated. The performance evaluation of tractor operated and power operated winnower were carried out by following method given in RNAM Test code.

Cost Economics of Winnowing

Understanding the cost economics of winnowing is crucial for assessing the financial feasibility and operational efficiency of such machines, particularly for small and medium-scale farmers. These costs help in determining the cost per hour or cost per kilogram of grain cleaned, thereby aiding in economic decision-making and comparative evaluation of different winnowing systems. The fixed cost represents those expenses that do not vary with the extent of machine use. These are incurred even if the winnower operates for fewer hours in a year. The major components of fixed cost include the following: Depreciation accounts for the reduction in machine value over time due to wear and tear. It is calculated using the straight-line method:

Depreciation=$Depreciation = (C - S) \times (L \times H)$ (4)

where, S is the salvage value, L is the total life of the machine in years, and H is the annual operating hours, C is the cost of the machine.

Interest represents the cost of capital tied up in purchasing the machine. It is calculated as:

$Interest, I = \left(C + S/_{2}\right) \times \frac{1}{H}$ (5)

where, I is the annual interest rate expressed as a decimal.

Insurance and Taxes (₹/hr) cover insurance premiums and government taxes on machinery, generally estimated as 2% of the initial cost of the machine. Housing or Shelter Cost (₹/hr) includes the expenses for storage, protection, and maintenance space for the machine, taken as 1.5% of the initial cost.

Total Fixed Cost (₹/hr) = Depreciation + Interest + Insurance and Taxes + Housing

The variable cost represents expenses that depend directly on the number of operational hours. These costs increase with higher machine usage and are incurred only during active operation. These cost include Electricity Cost, Operator’s Cost, Repair and Maintenance (10% of the initial cost).

Results and Discussion

The study involved the modification of a tractor-operated winnower and a comparative performance evaluation with a motor-operated winnower. The modification aimed to enhance efficiency, safety, and ease of operation. Key changes in the tractor-operated winnower included the redesign of the feeding mechanism for uniform material flow, improved air duct geometry for better separation, adjustable fan speed and sieve inclination for different crops, and the inclusion of safety guards and vibration dampers. Performance evaluation of both winnowers was carried out under similar operating conditions to assess their efficiency on the basis of feed rate, output capacity, cleaning efficiency, power consumption, and cost economics.

Performance Evaluation of Modified Winnower

The performance testing of both the motor-operated and tractor-operated winnowers was conducted using the BPT-5204 paddy variety. Key performance parameters such as cleaning efficiency, feed rate, air velocity, and output capacity were measured under controlled operating conditions. The air velocity from both winnowers was recorded at a distance of 20 cm from the fan outlet, and an average air velocity of 5.03 m/s was observed, indicating uniform airflow distribution across the cleaning chamber.

The feed rate for the motor-operated and tractor-operated winnowers was found to be 219 kg/hr and 300 kg/hr, respectively, demonstrating higher throughput in the tractor-operated model due to its higher power input and suction efficiency. The cleaning efficiency of the winnowers varied across different operating conditions and was recorded as 86.0%, 88%, 91%, 93%, 95%, and 97.0%, respectively, depending on the fan speed and feed rate combinations. As far as output capacity is concerned, the average clean grain output was found to be 97 kg/hr under the tested conditions, which reflects satisfactory performance for medium-scale paddy cleaning operations. The summarized results are presented in Table 1, illustrating the comparative performance of motor-operated and tractor-operated winnowers in terms of operational efficiency, throughput, and grain quality improvement. The clean grains are collected at the outlet. The output capacity was determined by measuring the weight of clean grains converted on an hourly basis. The hopper is opening at 25, 50, 75, 100 % (Fig. 2). And the output capacity is obtained at different opening of hopper 76, 82, 89, 96 (kg/hr). The testing of the motor-operated winnower was carried out with paddy grain and the fan speed was measured and found to be 500, 600, 700, 800, 900, 1000 rpm and the airflow rate was 6.2 and 6.8 m/s, respectively. The moisture content levels of paddy were 12-15%. The performance was carried out winnower fan speed, which is 500 to 1000 rpm, respectively. Cleaning efficiency was found to be 86, 88, 91, 93, 95, 97%, respectively (Fig. 3). The performance of the winnower was found cleaning satisfactory as far as cleaning efficient power consumption is concerned. The testing of the motor-operated winnower was carried out with paddy grain and the fan speed was measured and found to be 500, 600, 700, 800,900, 1000 rpm. The performance was carried out winnower fan speed, which is 500 to 1000 rpm, respectively, the blown grains was found to be 2, 3, 4, 6, 8 ,9%, respectively (Fig. 4).

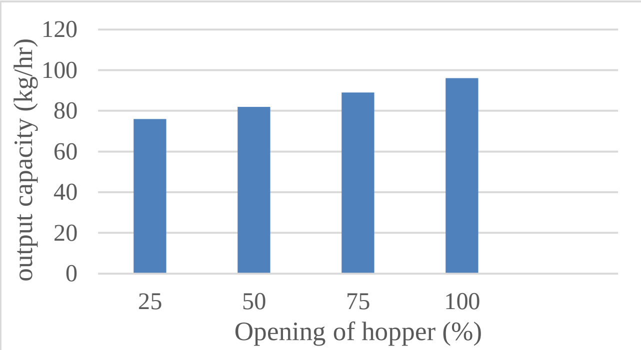

Fig. 2 Output capacity at opening of hopper

Table 1 Performance evaluation of motor-operated winnower

S.No.	Particular	Observations
1	Speed, (RPM)	500
2	Speed of PTO, (RPM)	-
3	Speed of winnowing fan, (RPM)	750
4	Weight of sample before winnowing, (kg)	50
5	Weight of grain after winnowing, (kg)	47.12
6	Weight of chaff/impurity after winnowing, (kg)	1.89
7	Weight of grain present in chaff, (kg)	0.6
8	Weight of impurity present in grain, (kg)	0.1
9	Grain moisture content, (w.b)	12-15%
10	Air velocity, (m/s)	6.2
11	Time required for winnowing (min)	13.20
12	Feed rate (kg/hr)	219
13	Opening of hopper, (cm)	1.5
14	Height of dropping grain, (cm)	121
15	Clean grain distance (cm)	58
16	Grain ratio	0.94
17	Recovery	0.99
18	Purity	0.96
19	Output capacity at outlet, kg/hr	97
20	Cleaning efficiency %	94
21	Power consumption, kWh	0.08

This clear difference of over threefold indicates that the motor-operated system is more economically efficient for regular or small-scale operations (Fig. 5). The reduced cost can be attributed to its lower power requirement, electric energy use instead of diesel, and reduced fixed and maintenance costs. In contrast, the tractor-operated winnower, though suitable for large-scale or field-level operations, exhibits higher running costs due to diesel consumption, engine wear, and operator dependency. Hence, from a cost economics standpoint, the motor-operated winnower is more economical and sustainable for continuous use, while the tractor-operated unit may only be justified when high mobility and large throughput are required.

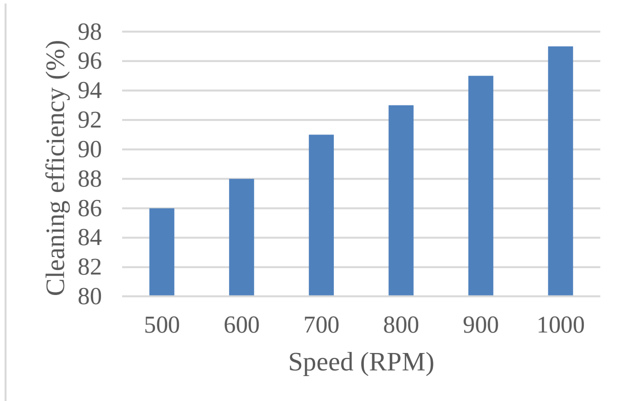

Fig. 3 Cleaning efficiency at different speeds

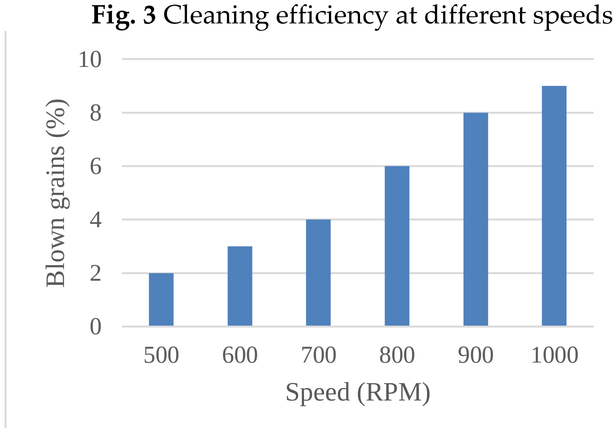

Fig. 4 Blown grains at different speeds

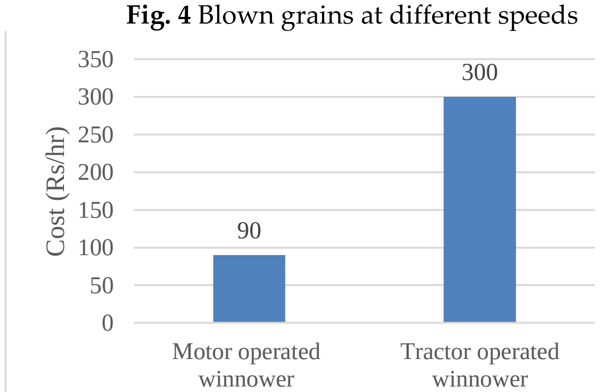

Fig. 5 Cost Economics for motor- and tractor-operated winnower.

Conclusions

Winnowing is the process of separating grain from husk and chaff using natural wind or an artificial air blast. Traditionally, farmers perform manual winnowing, which is time-consuming, labor-intensive, and highly dependent on favorable weather and labor availability. To overcome these limitations, the conventional tractor-operated winnower was modified into a motor-operated winnower, providing a more efficient and cost-effective alternative for small and medium-scale farmers. The performance of both winnowers was evaluated using the BPT-5204 paddy variety, and fan speeds were measured with a tachometer at 500, 600, 700, 800, 900, and 1000 rpm. The cleaning efficiency of the motor-operated winnower increased from 86% at 500 rpm to 97% at 1000 rpm, while its output capacity was 97 kg/hr. Air velocity ranged from 1.7 m/s at 220 cm to a maximum of 7.3 m/s at 60 cm from the fan axis, indicating the optimum position for the hopper. For the tractor-operated winnower, the best performance was observed at 750 rpm, providing high cleaning efficiency. However, the cost of operation was significantly higher as ₹300/hr for the tractor-operated winnower compared to only ₹88/hr for the motor-operated model, demonstrating the latter's superior economic and energy efficiency.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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