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Performance Evaluation of Power Operated Chaff Cutter

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ABSTRACT

India is an agrarian country where livestock plays a crucial role in rural livelihoods. Efficient fodder processing is essential to ensure optimal feed utilization and minimize wastage. Traditionally, fodder is chopped using manual tools such as sickles and axes, which are labour-intensive, time-consuming, and result in non-uniform cutting. To overcome these limitations, the present study evaluated the performance of a power-operated chaff cutter powered by a 2 hp electric motor (1425 rpm, 230 V) for selected green and dry fodders, namely paddy straw, wheat straw, green grass and maize fodder. The results showed that fodder properties significantly influenced output capacity and chaffing efficiency. The output capacity was 142.5 kg/h for paddy straw, 140.7 kg/h for wheat straw, 174.05 kg/h for grass, and 326 kg/h for maize straw. The efficiency was 88.72% for paddy straw, 82.08% for wheat straw, 89.27% for grass, and 92.67% for maize fodder. The average length of cut pieces was 7.2 mm, 6.69 mm, 9.8 mm, and 8.4 mm for paddy straw, wheat straw, green grass, and maize, respectively. The operational cost was estimated at ₹71.8 per hour, making the machine economically viable for small and medium-scale farmers. The study concluded that the power-operated chaff cutter reduces labour, ensures uniform fodder size, and improves fodder utilization efficiency compared to manual methods.

Introduction

Animal husbandry plays a vital role in the rural economy of India, where livestock such as cattle and draft animals are widely owned by farming households. India possesses the largest livestock population in the world, with over 536 million animals, including a significant number of bovines (20th Indian Livestock Census, 2019). In Chhattisgarh, the livestock population is approximately 11.84 million, mainly comprising bovines (20th Indian Livestock Census, 2019) and livestock contributes substantially to rural livelihoods. During dry seasons, shortage of fodder is a major problem, making efficient utilization of available feed essential. Proper feeding practices, particularly chopping fodder into smaller pieces, improve feed utilization and digestion efficiency. Chaff cutting reduces fodder wastage and enhances palatability for livestock. Traditionally, fodder cutting is done manually, which is labor-intensive and causes drudgery to farmers. Power-operated chaff cutters provide uniform cutting with reduced labor and time requirements. The performance of these machines depends on machine parameters and fodder properties. Therefore, evaluating the performance of power-operated chaff cutters for green and dry fodder is essential to improve fodder management and reduce labor constraints.

Materials and Methods

Physical and Engineering Properties of Selected Green and Dry Fodder

Size (mm)

In this study, selected fodder samples were measured using a scale to obtain precise dimensions in millimeters.

Weight (g)

Fodder samples were weighed using a digital weighing balance with an accuracy of 0.01 g to determine their individual and bulk weights.

True Density (kg/m³)

A known weight of the sample was placed in a container filled with sand, and the volume of sand displaced by the sample was recorded. The displaced volume was determined by subtracting the initial sand volume from the final sand volume after adding the sample. (Nimesh and Sharanagat, 2016).

The true density was then calculated using the formula:
True density = Weight of sample (kg) / Volume displaced (m^3)

Bulk Density (kg/m³)

Bulk density refers to the mass of fodder per unit volume including the void spaces between particles or stalks. This property is especially significant when designing the feed hopper and conveyor system of the chaff cutter. (Nimesh and Sharanagat, 2016).

Bulk Density=

$$\frac{\text{Weight of fodder (kg)}}{\text{Volume of container (m3)}}$$

Moisture Content (%)

The moisture content on wet basis was calculated using the recorded initial and final weights of the samples. (Nimesh and Sharanagat, 2016).

$$M = \frac{100(W1 - W2)}{(W1 - W)} \quad \text{---------1}$$

Where,

M = Moisture content in percent (wet basis)
W = Mass of the empty dish, (g)
W1 = Mass of the material before drying, (g)
W2 = Mass of the dried material, (g)

Performance test of power operated chaff cutters

Initial and Final fodder length (mm)

To evaluate the cutting efficiency of the chaff cutter, both the initial and final lengths of the fodder were recorded by using digital vernier calliper.

Feed rate of fodder (kg/h)

The feed rate, expressed as the amount of fodder cut per hour, was then calculated using a specific formula based on the total weight of the fodder processed over the time of operation.

$$\text{Feed rate} = \frac{60 \times F}{T}$$

Where,

F=Weight of fodder fed (kg)
T=Time taken(h)

Capacity of Chaff Cutter

The capacity of the chaff cutter was determined by measuring the weight of chaff produced per hour for different fodder crops. The output capacity of the power-operated chaff cutter varied depending on the type of fodder.

Theoretical capacity of machine

$- - - (1)$

Theoretical capacity of machine was calculated using the following formula

$$C = W \times H \times L \times N \times n \times D \quad \text{----------4}$$

Where,

C = Theoretical capacity of chaff cutter, kg/h
W = Throat width, m
H = Throat height, m
L = Length of cut, m

N = rpm of cutting unit
n = Number of blades
D = Density of chaff, kg/m3

Efficiency (%)

The efficiency of the chaff cutter was determined by comparing the actual capacity of the machine with its theoretical capacity. It serves as an important performance indicator that reflects how effectively the machine performs the chopping operation under practical working conditions.

The efficiency was calculated using the following expression

$$\text{Cutting Efficiency (\%)} = \frac{\text{Actual capacity (kg/h)}}{\text{Theoretical capacity (kg/h)}} \times 100 \quad ---(5)$$

Fig.1 View of the power operated chaff cutter while in operation

To Work Out Cost Economics of The Chaff Cutting Operation

Fixed cost

Fixed costs are those expenses that remain constant even when the machine is not in operation.

Depreciation cost (straight line method)

This method helps in estimating the annual cost of owning and operating the machine, which is important in farm machinery cost analysis and economic evaluations. It is calculated as

$$D = \frac{C - S}{L \times H} \qquad \text{------6}$$

Where,

D= Depreciation per hour;
C = Capital investment;
S = Salvage value, 10% of capital;
H = Number of working hours per year; and
L= Life of machine in year.

Interest

Interest is calculated on the average investment of the machine by considering its value at the beginning and end of its useful life.

$$I = \frac{C - S}{2} \times \frac{i}{H} \qquad \text{-------7}$$

Where,

I = Interest per hour; and
i = % rate of interest per year.

Variable cost

Repair and maintenance

The cost of repair and maintenance was considered as 10% of the initial cost of the machine per year.

Power consumption and its cost

Power cost refers to the operating expense incurred due to the electrical energy consumed during machine operation. It was calculated using the following formula: Power cost = Power rating (kW) × Time (h) × Cost of power per unit (₹)

Labor cost

Labor cost refers to the expense incurred for paying wages to the workers engaged in operating and managing the machine (Akram et al., 2024).

It was calculated using the formula:

Labor cost = Salary of one worker (Rs/h) × Number of workers

Result and Discussion

Performance Test of Power Operated Chaff Cutters

The summarized results of the performance tests, including detailed measurements and analysis, are presented in Tables 1 and 2.

The performance of the 2 hp electric motor-powered chaff cutter was evaluated based on fodder length, feed rate, power consumption, output capacity, and cutting efficiency.

The feed rate of the machine varied with fodder type, recorded as 148.5 kg/h for paddy straw, 148 kg/h for wheat straw, 337 kg/h for maize straw, and 180 kg/h for green grass, reflecting the machine's processing capability. The average length of chopped fodder pieces after operation was found to be 7.2 mm for paddy straw, 6.6 mm for wheat straw, 9.8 mm for grass, and 8.4 mm for maize straw, indicating uniform cutting and consistent machine performance. Power consumption during operation was measured at 1.5 kWh, which helps estimate the energy cost for chaff cutting. The output capacity of the chaff cutter also varied among fodder types: 142.5 kg/h for paddy straw, 140.7 kg/h for wheat straw, 174.05 kg/h for green grass, and 326 kg/h for maize straw. This variation indicates that the machine performs better with coarse or bulky fodders like maize. The cutting efficiency was high for all tested fodders, with 88.72% for paddy straw, 82.08% for wheat straw, 89.27% for grass, and 92.67% for maize straw, demonstrating effective chopping and minimal wastage. Overall, the results suggest that the chaff cutter is capable of processing both green and dry fodders efficiently, with consistent output and energy consumption, making it suitable for small- to medium-scale farm operations.

Cost of operation

The operational cost of the power-operated chaff cutter was calculated by including both fixed and variable costs.

Table 1 Performance observations of chaff cutter for dry fodder crops

Sr. No.	Particulars	Test Values	
		For dry fodder crop	
		Paddy straw	Wheat straw
1.	Place of test	SVCAET & RS	**SVCAET & RS**
2.	Avg. feed rate, (kg/h)	148.5	**148**
3.	Average length of each cut pieces, (mm)	7.2	**6.6**
4.	Avg. speed of cutting unit (rpm)	311	**310**
5.	Avg. power required at load, (kW/h)	1.5	**1.5**
6.	Labors required, (man-h)	One	**One**
7.	**Efficiency of chaff cutter, (%)**	**88.72**	**82.08**

Table.2 Performance observations of chaff cutter for green fodder crop

Sr. No.	Particulars	Test Values	
		For green fodder crop	
		Green grass	Maize
1.	Place of test	SVCAET & RS	**SVCAET & RS**
2.	Avg. Feed rate, (kg/h)	180	**337**
3.	Average length of each cut pieces, (mm)	9.8	**8.4**
4.	Avg. speed of cutting unit (rpm)	306	**337**
5.	Avg. power required at load, (kW/h)	1.5	**1.5**
6.	Labors required, (man-h)	One	**One**
7.	**Efficiency of chaff cutter, (%)**	**89.27**	**92.67**

Table.3 Cost of operation of machine

Sl. No.	Particulars	Amount
1	Capital cost, Rs	25400
2	Life, year	10
3	Life, h /year	200
4	Fixed cost	
	a. Depreciation at 10% salvage value, Rs/h	11.3
	b. Interest 10% per annum, Rs/h	6.35
	c. Insurance, Rs/h	1.2
	d. Total fixed cost, Rs/h	18.98
5	Variable cost	
	a. Repair and maintenance Rs/h	6.35
	b. Labour required	1
	c. Labour cost, Rs/h	37.5
	d. Power consumed kWh	1.5
	e. Power cost Rs/h	9
	f. Total variable cost, Rs/h	46.5
6	Cost of operation, Rs/h	71.83
7	Breakeven point, h/year	94
8	Payback period, year	3.14

In conclusion, the study showed that the physical and engineering properties of green (maize, grass) and dry (paddy, wheat) fodders significantly affected chaffing performance. Green fodders, with higher moisture content and bulk density, were less brittle, while dry fodders were more brittle, influencing cutting efficiency and length of chopped pieces. The 2 hp electric chaff cutter performed efficiently for all fodders, producing uniform pieces with output capacities ranging from 142.5 to 326 kg/h and cutting efficiency between 82% and 92.67%. Economic analysis indicated that the machine cost Rs 25,400, with an operating cost of Rs 71.8/h, making it a cost-effective and time-saving option for small-scale farmers with 2–5 livestock.

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Data availability

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

Author contributions

Kedar: Investigation, analysis, writing original draft, Surendra Jogdand: Methodology, investigation, R. K. Naik: Conceptualization, methodology, writing.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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