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Comparative Evaluation of Performance of Traditional Method and Commercially Available Pedal Operated Paddy Thresher with the Developed Machine

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Traditional method of threshing of the Paddy crop is categorized as very laborious, low output, high damage per cent, costly etc. The present study was conducted to design and develop a power operated paddy drum thresher cum winnower to increase the mechanization in paddy crop

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threshing process, reduce drudgery, and increase production and to make it cost effective etc. Different components of the power operated paddy drum thresher cum winnower were designed and developed at Department of Farm Machinery and Power Engineering, SVCAET and RS, FAE, IGKV RAIPUR. It consisted of threshing drum, blower, reciprocating sieve, lower sieve and upper sieve etc.The data were analyzed and optimized by Response Surface Method (RSM) using Design Expert 13.0 software. The optimum values of the independent variables of threshingunit viz., feed rate 275kg/h, peripheral speed 11 m/s and moisture 14.5% (db) the corresponding values of dependent parameters of threshing unit viz., threshing efficiency 98.7%, threshing capacity 210 kg/h, cleaning efficiency 90.1%and total grain loss percent1.96 were recorded. The total cost of operation was observed to be Rs. 1.04 per kg with breakeven point and payback period of 124.13hours per year and 2 years respectively.

Keywords: Threshing efficiency; threshing capacity; breakeven point; feed rate and total grain loss.

1. INTRODUCTION

India is the world's largest producer and accounting for 22% of the world’s rice production after China. Again it accounted for over 1.8 trillion Indian rupees in the Indian economy in fiscal year 2018 [1]. India is one of the largest exporters of rice to the world, exporting nearly 10 million metric tons every year [2]. Chhattisgarh, known as the “Rice bowl of central India” and accounts for 3.88 Mha area with the production of 5.74 MT and productivity of 1.48 t/ha [3].

The total population of the state is around 2.55 Crore, of which about 70% population is engaged in Agriculture. There are around 37.46 Lakh farm families in the state, with about 80% farmers falling under Small & Marginal category. Paddy, Soybean, Urd&Arhar are the major Kharif Crops while Rabi season is mainly led by Chickpea and Lathyrus. The total area of paddy cultivation is 38.76, 39.03, 38.99 lakh ha and productivity is 3002, 3438, 3212 kg/ha during the year 2019-20, 2020-21 and 2021-22, respectively [4].

Chhattisgarh became second largest contributor of paddy during kharif season in India. In financial year 2021, rice production across the northern state of Chhattisgarh in India amounted to over seven million metric tons. In Chhattisgarh, rice occupies average of 3.6 million ha with the productivity of the state ranging between 1.2 to 1.6 t/ha depending upon the rainfall. Near about 36% of India's total rice production is from these 3 states. West Bengal contributed 13.62% of the total rice produced in India. Uttar Pradesh contributed 12.81% of the total rice produced in India. Punjab accounted for 9.96% of the total rice produced in India.

In Chhattisgarh paddy is most important crop. High yielding varieties of paddy have improved the yield and with their early maturity have significantly reduced the vegetative period of crop, greater crop identification and double cropping system. Threshing is recognized to be a very labour intensive operation and involves considerable human drudgery [5]. Further delay in threshing operation, results in delayed sowing of next crop and hence the reduced yield [6,7].

Paddy cultivation holds a pivotal place in India's agricultural landscape, serving as a cornerstone of both the economy and food security. As the world's second-largest producer of rice, India cultivates paddy across a diverse range of agro-climatic zones, from the fertile plains of Punjab and Haryana to the deltaic regions of West Bengal and Odisha. The crop, predominantly grown during the Kharif season (June to November), benefits from the monsoon rains, which are crucial for its growth. In addition to feeding a substantial portion of the population, rice cultivation provides employment to millions of farmers and laborers, underpinning rural livelihoods and socio-economic structures.

Chhattisgarh, often referred to as the "Rice Bowl of India," plays a significant role in the country's paddy production. This central Indian state is characterized by its favorable agro-climatic conditions, including abundant rainfall and rich alluvial soil, which create an ideal environment for paddy cultivation. The state's diverse topography, encompassing plains, plateaus, and forested areas, supports a variety of paddy varieties suited to different ecological niches [8].

Agriculture in Chhattisgarh is predominantly rain-fed, with paddy being the main crop cultivated during the Kharif season. The state's farming practices are deeply rooted in traditional knowledge and local customs, yet they are increasingly incorporating modern techniques and technologies to enhance productivity and sustainability. Innovations in water management, improved seed varieties, and mechanized farming methods are being adopted to address challenges such as water scarcity, labor shortages, and climate variability [9,10,11].

The socio-economic impact of paddy cultivation in Chhattisgarh extends beyond mere crop production. It influences the cultural fabric, dietary patterns, and economic activities of the region. Festivals, rituals, and community gatherings often revolve around the rice cultivation cycle, underscoring its significance in the daily lives of the people.

The developed power-operated paddy drum thresher-cum-winnower machine offers significant advantages over traditional threshing methods, particularly in terms of labor savings, time efficiency, and grain quality [12,13,14,15]. While the traditional method is still viable for small-scale or resource-limited settings, the mechanized approach is more suitable for modern agricultural practices, especially in larger-scale operations.

1.1 Climatic Conditions and Agricultural Practices

The monsoon season of 2023-2024 brought adequate rainfall to most parts of Chhattisgarh, providing favorable conditions for paddy cultivation. However, some areas experienced irregular rainfall patterns and minor flooding, which impacted local yields. Farmers utilized a combination of traditional knowledge and modern agricultural techniques to optimize production. The use of high-yielding, drought-resistant paddy varieties, coupled with mechanized farming methods, played a significant role in achieving better productivity [16,17].

1.2 Government Support and Initiatives

The state government implemented several initiatives to support paddy farmers. These included subsidies on seeds and fertilizers, financial assistance, and investments in irrigation infrastructure. The promotion of sustainable farming practices, such as the System of Rice Intensification (SRI) and organic farming, contributed to increased yields and environmental sustainability.

1.3 Production Data

Based on preliminary estimates, Chhattisgarh's paddy production for the 2023-2024 agricultural year is projected to be around 8 million metric tons. The production figures for key districts are as follows:Raipur: 1.2 million metric tons, Bilaspur: 1.1 million metric tons, Durg: 1.0 million metric tons, Surguja: 900,000 metric tons, Bastar: 850,000 metric tons and other districts: 3.0 million metric tons

1.4 Acreage

The total area under paddy cultivation in Chhattisgarh for 2023-2024 is approximately 3.6 million hectares. The average yield per hectare has been recorded at around 2.2 metric tons, which is a slight improvement compared to the previous year, reflecting the effectiveness of improved farming practices and government interventions [18,19].

1.5 Market Dynamics and Economic Impact

The paddy market in Chhattisgarh has been influenced by both domestic and international factors. The Minimum Support Price (MSP) set by the government has provided a safety net for farmers, ensuring fair compensation for their produce. Additionally, the state's efforts to enhance storage and processing facilities have added value to the rice supply chain, benefiting farmers and contributing to the local economy.

1.6 Challenges and Future Outlook

Despite the positive trends, paddy farmers in Chhattisgarh face challenges such as water management issues, pest infestations, and market volatility. Climate change continues to pose a significant threat, necessitating ongoing adaptation and resilience-building measures.

The future outlook for paddy production in Chhattisgarh hinges on sustained government support, innovation in agricultural practices, and effective resource management. Continued investments in irrigation infrastructure, promotion of sustainable farming techniques, and improvement of market access will be crucial for ensuring the resilience and growth of the state's paddy sector [20].

In conclusion, the 2023-2024 period has demonstrated Chhattisgarh's capability to sustain robust paddy production despite various challenges. With favorable climatic conditions, effective government interventions, and the resilience of farmers, the state continues to be a pivotal player in India's rice production landscape.

In summary, paddy cultivation in India, and particularly in Chhattisgarh, is a multifaceted sector that not only contributes to the nation's food security but also shapes the economic and cultural landscape of its regions. The continued evolution and adaptation of paddy farming practices are essential to meet the growing demands and challenges of the 21st century.

Paddy production in Chhattisgarh for the agricultural year 2023-2024 has demonstrated notable performance despite various challenges. The state's commitment to maintaining its position as a major rice producer in India is reflected in the substantial output recorded during this period.

2. MATERIALS AND METHODS

2.1 Comparison of Performance of the Developed Power Operated Paddy Drum Thresher cum Winnower with Traditional Method of Threshing of Paddy Crop

The performance of the developed machine was compared with the traditional method (Fig. 2) and the commercially available pedal operated paddy drum thresher (Fig. 1). The performance parameters taken for the comparison study were threshing efficiency, threshing capacity, cleaning efficiency, total grain loss percentage and total cost of operation for the different methods of threshing and winnowing.

The traditional method of threshing of paddy crop operation was hand beaten by a wooden/ bamboo stick for threshing and winnowing operation was done by the natural air.

Pedal operated paddy drum thresher was also tested for the parameters stated above. The independent variable for the testing such as moisture content of crop, peripheral speed and feed rate was taken as per the recommended by the manufacturer. The testing of the developed machine was done at the optimum values of the independent variables obtained through the performance evaluation of the machine i.e. 275 kg/h feed rate, 14.5 % moisture content and 11 m/s peripheral speed of the cylinder.

2.2 Cost Analysis of Power Operated Paddy Drum Thresher Cum Winnower

Cost of threshing and winnowing operation was worked out on the basis of the prevailing market price of threshing and winnowing machine, labour charges, repair and maintenance. Cost of threshing and winnowing operation was calculated on the basis of Rs/h. For calculation of cost of machine assistance was drawn from IS: 9164-1979. The procedure for calculation of cost of operation of Threshing and winnowing is given below.

Fig. 1. Use of hand stick for separation of grains from paddy crop

Fig. 2. Winnowing operation by manually

Fig. 3. Pedal operated thresher

Fig. 4. Power operated paddy drum thresher cum winnower (developed machine)

2.2.1 Fixed cost of machine

The fixed cost of the machine includes the depreciation cost, interest on investment and housing cost of the machine. These costs were required throughout the life of the machine whether the machine is in use or not.

2.2.1.1 Depreciation

This cost reflects the reduction in value of a machine with use (wear) and time (obsolescence). It is the loss of value of a machine with the passing of time and calculated by the formula (IS 9164: 1979).

$$D = \frac{C - S}{L \times H} \quad (1)$$

Where,

D = Depreciation per hour;
C = Initial cost of implement, Rs;
S = Salvage value @ 10 % of C, Rs;
L = Working life of machine in years; and
H = Number of working hours per year.

2.2.1.2 Interest of investment

Interest was calculated on the average investment of the machine, taking into consideration the value of the machine in first and last year (IS 9164: 1979).

$$I = \frac{C + S}{2} \times \frac{i}{H} \quad (2)$$

Where,

I = Interest per hour; and
i = 10% per year;

2.2.1.3 Shelter/ housing cost

Housing cost was calculated on the basis of the prevailing rate of the locality and generally taken

as 1% of the initial cost of the machine per year. (IS 9164: 1979)
Therefore,
Total fixed cost = Depreciation +Interest + Housing

2.2.2 Variable cost

The variable cost includes electricity charge, repair and maintenance cost and labour wages for operating the machine.

2.2.2.1 Electricity cost

Electricity consumed (kWh/h) × Electricity charges (Rs/kWh)

2.2.2.2 Repair and maintenance cost

Cost of repair and maintenance varies between 5 to 10% of the initial cost of the machine per year. (IS 9164: 1979)

2.2.2.3 Labour wages

Wages of labour was calculated on the basis of actual wages of the worker in present time. (IS 9164: 1979).

Therefore, Total variable cost = Electricity cost + Repair and maintenance cost + Labour wages

2.2.3 Total cost of operation

The total cost of operation was calculated by adding the total fixed cost and total variable cost using Equation 3.73. (IS 9164: 1979)

$$C_{TC} = FC_T + VC_T \quad (3)$$

Where,

C_{TC} = Total cost of operation, Rs/h;
FC_T = Total fixed cost, Rs/h; and
VC_T = Total variable cost, Rs/h.

2.2.4 Break-even point

The break-even point was calculated by following formula [21].

$$BEP = \frac{FC_a}{C_{CH} - V} \quad (4)$$

Where,

BEP = Break-even point, h/year;
FC_a = Annual fixed cost, Rs/ year;
V = Variable cost, Rs/h; and
C_{CH} = Custom hiring charge, Rs/h.

2.2.5 Payback period

The payback period for the developed thresher was calculated to know the time required to get back the investment. The payback period was estimated by using the following formula [22].

$$PBP = \frac{IC}{ANP} \quad (5)$$

Where,

PBP = Payback period, Year;
IC = Investment, rupees;
ANP = Annual net return, Rs/year;
= (CH-VC) ×AU
and AU = Average annual use, h/year.

3. RESULTS AND DISCUSSION

3.1 Cost Economics of the Developed Power Operated Paddy Drum Thresher Cum Winnower

The total cost of operation, breakeven point and payback period of the developed power operated paddy drum thresher cum winnower was calculated based on the total cost of the machine. The total cost of the machine was estimated as Rs. 53500.00. The cost of operation of developed power operated paddy drum thresher cum winnower was found to be Rs. 156.16 per hour and Rs. 1.034 per kg at 150 kg/h output capacity of the machine. Table 1 represents the detailed description of the cost of operation of machine.

The total cost of operation was found to be Rs. 156.16 per hour and Rs. 1.034 per kg considering the output capacity of machine as 150 kg/h. The breakeven point and payback period was also calculated and found to be 124.13 hour per year and 2 year, respectively.

3.2 Energy Requirement to Operate the Developed Power Operated Paddy Drum Thresher Cum Winnower

The detail energy required to operate the machine during testing was presented in the Table 2 It is revealed from the Table 2 the total energy required to operate the power operated paddy drum thresher cum winnower machine was found to be 680.80 MJ/ha.

Table 1. Cost of operation of developed power operated paddy drum thresher cum winnower

S. No.	Particulars	Amount
1.	Capital cost of machine, Rs.	53500.00
2.	Useful life of machine, year	6.00
3.	Annual working hour, h	300.00
4.	Fixed cost	
	a. Depreciation , Rs./h	26.75
	b. Interest, Rs./h	9.80
	c. Housing, Rs./h	1.78
	d. Total fixed cost, Rs/h	38.33
5.	Variable cost	
	a. Electricity charges, Rs./h	24.00
	b. Repair and maintenance cost, Rs./h	17.83
	c. Labour wages for 2 labours, Rs./h	75.00
	d. Total variable cost, Rs./h	116.83
6.	Total cost of operation, Rs./h	156.16
7.	Total cost of operation @ 180.5 kg/h output, Rs./kg	1.034
8.	Breakeven point, h/y	124.13
9.	Payback period, y	2

Table 2. Energy requirement of developed machine

S.No.	Particulars	Value
1.	Direct energy source	
	Total human energy, MJ/ha	53.13
	Total electricity energy, MJ/ha	324.49
	Total energy from direct energy source, MJ/ha	377.61
2.	Indirect energy source, MJ/ha	
	Total machine energy, MJ/ha	303.18
3.	Total energy, MJ/ha	680.80

Table 3. Detailed comparisons between traditional method, pedal operated paddy drum thresher and developed power operated paddy drum thresher cum winnower

S. No.	Parameters	Traditional method (Hand beating)	Pedal operated paddy drum thresher	Developed power operated paddy drum thresher cum winnower
1.	Threshing efficiency, %	89.52	90.40	98.7
2.	Total grain losses, %	3.52	3.14	2.55
3.	Cleaning efficiency, %	-	-	90.1
4.	Threshing capacity, kg/h	25	55.63	150

Table 4. Cost comparison of different threshing methods used for paddy crop

S. No.	Method	Threshing capacity, kg/h	Total cost of operation, Rs./h	Total cost of operation, Rs./kg	Per cent saving in cost from traditional method
1.	Traditional method	25	57	3.2	0.00
2.	Pedal operated paddy drum thresher	55.63	122.38	2.2	31.25
3.	Developed power operated paddy drum thresher cum winnower	150	156.16	1.04	67.5

3.3 Comparative Study of traditional Method and Commercially Available Pedal Operated Paddy Thresher with the Developed Machine

The performance of the developed machine was compared with the traditional method of threshing and cleaning of paddy grain as well as with the performance of the commercially available pedal operated paddy drum thresher. The result on the performance parameters such as threshing efficiency (%), threshing capacity (kg/h), total grain loss percentage (%) and cleaning efficiency (%), for these methods of threshing is shown in Table 3.

The developed power-operated paddy drum thresher cum winnower has the highest threshing efficiency at 98.7%, indicating it is the most effective at separating grains from the stalks. The pedal-operated thresher also shows improved efficiency over the traditional method, though not as high as the power-operated machine. It was revealed from the Table 2 that the threshing efficiency, cleaning efficiency, total grain loss and threshing capacity is highest for the developed prototype as compared to other two methods.

It was found that there is 10.25% increase in threshing efficiency,total grain loss percent was found to be decreased 27.6% the developed machine. In traditional method and pedal operated paddy drum thresher was not cleaning of crop in single operation and cleaning efficiency was found 90.1% in developed machine. 500% increase in threshing capacity of developed prototype when compared to the traditional method of paddy crop threshing and winnowing. Similarly, the percent increase in threshing efficiency 9.18%, total grain loss percent was found to be decreased 18.78%. Threshing capacity was found to be 169.6% increase when compared to pedal operated paddy drum thresher. Similar types of works were also conducted by Kumar et al. [23], Hanumantharaju et al. [24], Chaturvedi et al. [25].

3.4 Comparison of Cost of Operation of Different Threshing Methods

The cost of operation of traditional method (hand beating), pedal operated paddy drum thresher and developed machine was compared and shown in the Table 4.

It is revealed from Table 4 total cost of operation for paddy crop threshing by pedal operated paddy drum thresher and developed power operated paddy drum thresher cum winnower were found 31.25 % and 67.5 % cheaper than the traditional method of threshing done by hand beating through a stick.

4. CONCLUSION

i. The developed power-operated paddy drum thresher cum winnower demonstrated significant improvements in efficiency and cost-effectiveness over traditional and pedal-operated methods. The total cost of operation was calculated to be Rs. 156.16 per hour, with an operational cost of Rs. 1.034 per kg at an output capacity of 180.5 kg/h. The machine's breakeven point was 124.13 hours per year, and the payback period was 2 years.
ii. In terms of energy requirements, the machine consumed a total of 680.80 MJ/ha, with direct energy sources contributing 377.61 MJ/ha and indirect energy sources 303.18 MJ/ha. When compared to traditional hand beating and pedal-operated threshers, the developed machine achieved a threshing efficiency of 98.7%, a cleaning efficiency of 90.1%, and significantly reduced total grain losses to 2.55%.
iii. The cost analysis revealed that the developed machine's total cost of operation per kilogram was Rs. 1.04, resulting in a 67.5% saving compared to the traditional method and a 31.25% saving compared to the pedal-operated thresher. This highlights the developed machine's superior performance and cost benefits, making it a valuable addition to paddy cultivation practices in Chhattisgarh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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