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Studies on Performance Parameters for Development of Finger Millet Thresher

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To study about the design parameters and optimizations of the performance parameters for the finger millet thresher development.
Study Design: Development of prototype to test the design parameters and optimization through experiments.
Place and Duration of Study: Department of Farm Machinery and Power Engineering, Swami Vivekanand College of Agricultural Engineering and Technology and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raipur, between September 2021 to April 2022.
Methodology: A prototype was developed which consisted of threshing drum, concave unit and reciprocating sieve unit. A study was conducted by taking four feed rate (120, 150, 180 and 210kg/h), four types of threshing cylinder (peg type, canvas type, combination of peg and canvas type and flail type) along with three types of concave (bar type, perforated sheet and combination of both) to find out the optimized threshing parameters for finger millet. The statistical analysis was

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carried out by three factor randomised block design with the three replications. The various performance parameters were also calculated.

Results: The result showed that the maximum threshing efficiency (97.25%), cleaning efficiency (99.25%), total broken percentage (2.08%) and threshing capacity (121.5kg/h) were observed with 180 kg feed rate, combination of peg and canvas type of threshing cylinder, combination of bar and perforated sheet type concave.

Conclusion: It was concluded that combination of peg and canvas type threshing cylinder works better compared to other and gives a combination of impact and rubbing action. This impact and rubbing action can be used to develop a thresher for such crop which needs impact with rubbing such as finger millet.

Keywords: Finger millet; peg; canvas; feed rate; threshing efficiency; thresher; cleaning efficiency; bar; perforated sheet, Impact, rubbing.

1. INTRODUCTION

Finger millet (*Eleusine caracona*) is produced on about 40 lakh acres throughout the world and is a staple food for millions of people in the arid plains of East and Central Africa, as well as Southern India. Finger millet is the third most significant millet in the country, behind pearl millet and sorghum, in terms of area (10.05 lakh hectares) and output (17.6 lakh tons). In Chhattisgarh, finger millet is cultivated on 0.06 lakh hectares with a production of 0.02 lakh tonnes, and the average productivity of the state's finger millet crop was 253 kg/ha in 2019-20 [1]. Baster, Nararayanpur, Bijapur, Sarguja, Rajnandgaon, and Koriya are among the major finger millet producing areas in Chattisgarh.

Rice is being major crop of the region on the other hand minor millets i.e. *Kodo*, *Kutki, Sawan, Ragi*, proso and foxtail millets are also being grown in Bastar plateau, northern hills and some other tribal area of Chhattisgarh [2].The tribal tribes of Chhattisgarh's Bastar region rely heavily on finger millets as a food source. A large part of finger millet's appeal stems from its high nutritional and therapeutic value, including its high fibre content (which promotes slow digestion), which is well-liked by diabetic patients, its calcium content, which strengthens bones and is beneficial for treating anaemia, and its anti-aging properties, which help to slow the ageing process of the skin.

It also contains nutritional sources for amino acids, calcium, iron, sulphur, and fibers, which suppresses appetite, aids in weight management by avoiding excessive calorie intake, creates a feeling of fullness that discourages overeating, strengthens bones, lowers cholesterol by removing excess liver fat, and maintains blood pressure. Thus they are very useful to diabetic, cardiovascular, osteoporosis, obese and duodenal ulcer patients [3,4,5].Threshing of crop can be defined as the removal of grains from the crops or plant by application of different forces such as impact, shearing, rubbing etc. The process of removal of upper husk from the threshed finger millet grains is termed as the pearling process. The detail about the threshing and pearling process of finger millet grains from the panicles is shown in Fig. 1. The threshing and pearling of the crop is very much affected by the moisture content of the crop [6]. Firstly, Firstly, the matured finger millet crop is sundried to reduce the moisture level up to 15 to 20 %. Then the finger millet grains were separated from the panicles by applying some impact force to the crop. After the threshing of crop the grains are pearled by application of some rubbing or friction force. Then the grains are mostly winnowed with the help of winnowing fans. Earlier various researchers have developed mechanical thresher machine for the threshing of the crop. The threshing elements used for the threshing of crop used were peg type beating element with canvas belt for rubbing action. The combination of the such threshing cylinder configuration were not studied till date and in the present study an attempt has been made to study the effect of different machine parameters on the threshing and cleaning performance for the development of the finger millet thresher.

2. MATERIALS AND METHODS

The experimental setup consisted of a threshing drum of 350 mm diameter and 650 mm length. The threshing cylinder was developed with different types of threshing element viz. peg type, canvas belt type, combination of peg and canvas belt type (Fig. 2) and flail type. to conduct study the different design parameters of the machine. The prototype was fabricated in the workshop of SVCAET & RS, IGKV, Raipur. It consisted of threshing drum, concave unit and reciprocating sieve unit. The parameters such as moisture content of crop and peripheral speed of the threshing drum was kept fixed at 14 % and 8.5 m/s [6].

2.1 Study on Design Parameters of the Threshing Drum

The threshing drum was fabricated to study the different design parameters on the threshing efficiency, threshing capacity and broken percentage of the grains. Four different types of the threshing cylinder i.e. peg type, canvas belt type, combination of peg and canvas belt type and flail type and three different concave type i.e. bar type, perforated sheet type and combination of bar and perforated sheet were developed and experiments were conducted at four different feed rates varied between 120 kg/h to 210 kg/h. The parameters such as moisture content of crop and peripheral speed of threshing cylinder was fixed and kept as 14 % and 8.5 m/s, respectively. The observed data for the different independent parameters were replicated three times and data were recorded accordingly. The data observed by the experiment were analysed statistically using factorial RBD (Randomised Block Design).

The details about the independent parameters and dependent parameters for the study was presented in [Table 1].

2.2 Study on the Design Parameters of the Cleaning Unit (Reciprocating Sieve)

Similarly, an experiment was conducted to study the design parameters for the performance of the cleaning unit of the machine. The cleaning unit consisted of reciprocating sieves (upper and lower) driven from the eccentric unit. The independent parameters for the study were three inclination angle of the reciprocating sieve from horizontal i.e. 2, 4 and 6^{o} and three different sieve size (upper sieve) i.e. 2, 3 and 4 mm at four different feed rates of 120, 150, 180 and 210 kg/h. The dependent parameters considered for the study were cleaning efficiency and total loss in percentage. The data observed were also analysed statistically using three factor randomised block design. The details of the independent and dependent parameters with different level for the cleaning unit are presented in [Table 2].

Fig. 1. Finger millet threshing and pearling process

Table 1. Different independent and dependent parameters for the study on design parameters for the threshing drum

S. No.	Independent Parameters		Dependent Parameters
	Variables	Levels	
1.	Feed rate , kg/h	a) 120, b) 150, c) 180, d) 210	a) Threshing Efficiency, % b) Broken grain, %
2.	Type of threshing cylinder	a) Canvas belt, b) Peg and canvas combination, c) Flail type, d) Peg type	
3.	Type of concave	a) Square bar, b) Perforated sheet, c) Bar and perforated sheet combination	

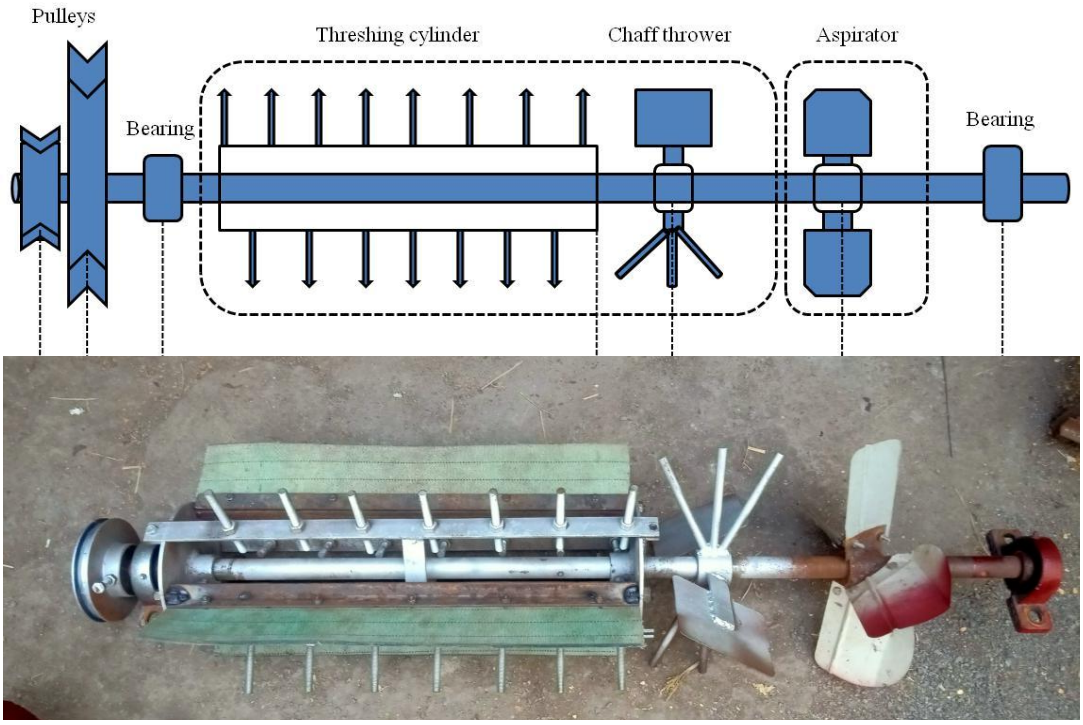

Fig. 2. Developed prototype of threshing cylinder (Peg and canvas combination type)

Table 2. Different independent and dependent parameters for the study on design parameters for the reciprocating unit

S. No.	Independent parameters		Dependent parameters
	Variables	Levels	
1.	Feed rate , kg/h	a) 120 b) 150 c) 180 d) 210	a) Cleaning efficiency, % b) Total loss, %
2.	Inclination angle, degree	a) 2 b) 4 c) 6	
3.	Sieve size, mm	a) 2 b) 3 c) 4	

2.3 Calculation of Dependent Parameters

The different dependent parameters were determined during the experiment by following the standard formula given by IS: 6284-1985. The detailed description of the different parameter was discussed below.

2.3.1 Threshing efficiency

Threshing efficiency is the percentage of threshed grain received from all outlets with respect to total grain input by mass. The threshing efficiency was calculated by using the formula and expressed in percentage (IS: 6284-1985, 1986).

$$\mu_T = \left(1 - \frac{w_{ut}}{w_{tp}}\right)$$

Where,

μ_T = Threshing efficiency, %;
w_{ut} = Weight of unthreshed grains, g ;and
w_{tp} = Weight of total panicles feed per unit time, g

2.3.2 Cleaning efficiency

The percentage of clean grain received at the main grain outlet to the total grain mix received at the main grain outlet is known as cleaning efficiency. The cleaning efficiency was calculated by using the formula and expressed as percentage (IS: 6284-1985, 1986)

$$\mathrm{CE} = \frac{\mathrm{Q_{CG}}}{\mathrm{Q_T}} \times 100$$

Where,

CE = Cleaning efficiency, %;
Q_{CG}= Quantity of clean grain obtained from the sample taken at main grain outlets, kg; and
Q_T = Total quantity of the sample taken at main grain outlets, kg.

2.3.3 Total loss

The total loss was calculated by summing up the different loss such as spilled grains loss, total broken grain percentage, total blown grains percentage and percentage of unthreshed grains.

2.3.4 Spilled grain loss (L_{sg})

The ratio of total quantity of spilled grains from the cleaning sieve to the total quantity of grain in main grain outlet is termed as spilled grain loss.

2.3.5 Percentage of broken grain (L_{bg})

The broken grains from main outlets with respect to the total grain mixture received at main grain outlet expressed as percentage by mass.

2.3.6 Percentage of blown grains (L_{bl})

The clean grains lost along the chaffed straw with respect to total grain input expressed as percentage by mass in termed as blown grain percentage.

2.3.7 Percentage of un-threshed grains (L_{uth})

The unthreshed grain from all outlets with respect to total grain input expressed as percentage by mass is termed as un-threshed grain percentage.

2.3.8 Total loss (L_t)

The sum of the above all loss expressed as percentage by mass is termed as total loss and calculated as follows

$$\text{Total loss } (\mathrm{L_t}), \% = \mathrm{L_{sg}} + \mathrm{L_{bg}} + \mathrm{L_{bl}} + \mathrm{L_{uth}}$$

Where,
L_t= Total loss in per cent by mass, %;
L_{sg}= Spilled grain loss in per cent by mass, %;
L_{bg}= Broken grain in per cent by mass, %;
L_{bl}= Blown grain in per cent by mass, %; and
L_{uth}= Un-threshed grain in per cent by mass, %.

3. RESULTS AND DISCUSSION

The result obtained through the experiments were presented and discussed in details in the following section. The effects of various independent parameters on the performance parameters of the thresher were also discussed.

3.1 Effect of Feed Rate, Type of Cylinder and Type of Concave on Threshing Efficiency (%)

The effect of feed rate, type of cylinder and type of concave on threshing efficiency were presented in [Table 3]. It was observed that the threshing efficiency decreased with increase in feed rate. The threshing efficiency was found to be significantly different. The highest threshing efficiency was found to be 99.47 per cent when feed rate was 120 kg/h, type of threshing cylinder was peg-canvas type and type of concave was bar-perforated sheet type (combine). The lowest threshing efficiency was found to be 92.53 per cent at higher feed rate of 210 kg/h and for canvas type threshing cylinder with bar type concave configuration.In lower feed rate the threshing efficiency was observed to be higher, it may be due to higher opportunity time incurred by the crop inside the threshing cylinder whereas, at higher feed rate some of the grains were come outside with the straw due to heavy load. Another reason for lowest threshing efficiency may be due to less opportunity time to being threshed by the cylinder due to higher intensification of crop at higher feed rate. Similar types of finding were also observed by [7,8,9].

3.2 Effect of Feed Rate, Type of Cylinder and Type of Concave on Broken Grain Percentage (%)

The result on the interactive effect of feed rate, type of threshing cylinder and type of concave on broken grain percentage are shown in [Table-3]. The broken percentage of grains was found to be highest for the peg type threshing cylinder for all the feed rates. The highest broken percent was found to be 4.60 per cent when feed rate, type of threshing cylinder and type of concave were 180 kg/h, peg type cylinder and bar type concave respectively. The high broken percentage at low feed rate may be due to repetitive impact of grains by the threshing cylinder pegs. The lowest broken per cent of 1.11% was observed at 180 kg/h feed rate for peg + canvas combination type threshing cylinder and bar + perforated sheet type concave. The lowest broken percentage may be due to combine effect of impact and rubbing of grains in case of peg + canvas type cylinder. This combined peg and canvas type threshing element reduces the number of pegs in the threshing cylinder which ultimately leads to lesser repetitive impact force to the grains inside the cylinder and reduces the broken percentage. Similar findings are also reported by [10,11].

3.3 Effect of Feed Rate, Inclination Angle and Sieve Size on Cleaning Efficiency (%)

The results on the interactive effect of feed rate, inclination angle and sieve size on cleaning efficiency are shown in [Table-4]. It was found that the cleaning efficiency increased with decrease in feed rate. The highest cleaning efficiency was found to be 99.40% when feed rate, inclination angle and sieve size was 120 kg/h, 4^{o} and 3 mm, respectively. The highest cleaning efficiency was found at lower feed rate may be due to less foreign material at the reciprocating sieve. However, it was also found that the cleaning efficiency was at par for the different feed rate for 3 mm sieve size only. It was observed that 3 mm sieve seize is suitable for better cleaning efficiency in finger millet. It may be due to larger inclination angle is not able to clean the grain properly. More crop residue mixer will flow to the grain outlet. It was also observed that at lager inclination angle the overflow was also in higher side, which increases the total loss subsequently, decreases the cleaning efficiency. Similar types of observation were also noted by [12, 13, and14].

3.4 Effect of Feed Rate, Inclination Angle and Sieve Size on Total Loss Percentage (%)

The result obtained on interactive effect of feed rate, inclination angle and sieve size on the total loss per cent is presented in [Table-4]. The data revealed that there is significance difference in loss percentage between the independent variables. It was also observed that the highest total loss percent (4.67%) was found in case of210 kg/h feed rate, 6 degree inclination angle and 4 mm sieve size whereas, the lowest percent of total loss i.e. 1.28 per cent was observed in case of 180 kg/h feed rate, 4 degree inclination angle and 3 mm sieve size. It may be due to increase in the broken percentage at lower feed

Table 3. Effect of feed rate, type of cylinder and type of concave on threshing efficiency (%) and broken grain percentage (%)

Particulars		**Threshing efficiency, %**			**Broken grain percentage, %**		
Feed rate, kg/h	**Type of cylinder**	**Type of concave**			**Type of concave**		
		Bar	**Sheet**	**Combine**	**Bar**	**Sheet**	**Combine**
120	Canvas	96.30	97.10	98.23	4.10	2.43	2.40
	Combine	98.57	98.97	99.47	2.37	2.30	1.73
	Flail	97.47	97.90	99.10	3.93	2.80	2.30
	Peg	98.13	98.50	98.90	4.30	3.20	3.53
150	Canvas	95.93	97.10	98.13	3.87	2.40	2.03
	Combine	98.30	98.43	99.10	1.97	1.97	1.42
	Flail	97.20	97.40	98.90	4.23	2.63	2.40
	Peg	97.90	98.20	98.67	4.10	2.87	2.90
180	Canvas	94.90	96.33	97.50	4.37	2.67	2.33
	Combine	97.83	98.10	98.53	2.40	1.60	1.11
	Flail	96.90	97.97	98.53	3.47	2.83	2.17
	Peg	97.33	97.90	98.20	4.60	3.00	2.23
210	Canvas	92.53	95.20	96.77	4.87	3.20	2.50
	Combine	96.47	97.27	97.87	2.30	2.53	1.87
	Flail	95.97	96.87	97.43	3.70	2.60	2.33
	Peg	96.57	97.40	97.63	4.47	3.67	3.37
Factors		**C.D.**	**SE(d)**	**SE(m) ±**	**C.D.**	**SE(d)**	**SE(m) ±**
Factor (FR)		0.042	0.021	0.015	0.145	0.073	0.052
Factor (Cy)		0.042	0.021	0.015	0.145	0.073	0.052
Factor (Co)		0.036	0.018	0.013	0.125	0.063	0.045
Interaction (FR × Cy × Co)		0.144	0.073	0.051	0.501	0.252	0.178

Note: FR = Feed rate, kg/h, Cy = Type of cylinder, Co = Type of concave

Table 4. Effect of feed rate, inclination angle and sieve size on cleaning efficiency (%) and total loss percentage (%)

Particulars		Cleaning efficiency, %			Total loss, %		
Feed rate, kg/h	Inclination Angle, degree	Sieve Size, mm			Sieve Size, mm		
		2mm	3mm	4mm	2mm	3mm	4mm
120	2	98.60	99.37	98.47	3.1	2.4	4.4
	4	98.70	99.40	97.67	2.4	2.0	3.5
	6	95.80	99.17	94.40	3.9	2.8	3.6
150	2	95.50	99.27	93.50	3.2	2.2	3.2
	4	95.50	99.15	94.47	2.2	1.8	2.6
	6	95.20	99.13	93.57	3.4	2.1	3.8
180	2	95.47	99.16	93.40	3.1	1.7	2.3
	4	93.80	99.25	94.33	1.6	1.3	2.3
	6	96.93	99.15	93.93	3.1	1.9	3.0
210	2	94.80	98.98	93.90	4.2	1.8	2.4
	4	94.20	98.17	92.60	2.1	1.6	2.9
	6	92.33	98.83	90.83	3.1	2.5	4.7
Factor		**C.D.**	**SE(d)**	**SE(m)**	**C.D.**	**SE(d)**	**SE(m)**
Factor (FR)		0.426	0.205	0.145	0.114	0.057	0.04
Factor (θ)		0.369	0.178	0.126	0.099	0.049	0.035
Factor (Ss)		0.368	0.183	0.129	0.099	0.049	0.035
Interaction (FR × θ × Ss)		1.275	0.634	0.448	0.342	0.171	0.121

Note: FR = Feed rate, kg/h; θ = Inclination angle, degrees; Ss = Sieve size, mm.

rate. Whereas, at higher feed rate with the increase in the unthreshed grain at outlet may increases the total loss percentage. Similar results were reported by [15]. Similar observations were also observed by many other researchers [16,17]. That may be referred to by increasing inclination angle the movement of threshed materials on the sieve increased and there is no chance for threshed residue materials to pass through the aperture with seed. These results were in agreement with [18].

4. CONCLUSION

1. The results on studies on design parameter revealed that the peg and canvas type threshing cylinder was found to be most suitable in terms of threshing efficiency. Similarly the bar and perforated sheet combined concave was found to be optimum for threshing efficiency.
2. The optimum threshing efficiency and broken percentage of grain was found to be for combination of peg and canvas type threshing cylinder and for combination of bar and sheet concave type.
3. The highest cleaning efficiency of 99.4 % was observed at 4 degree sieve inclination, 120 kg/h feed rate and 3 mm sieve size.

Hence, it can be concluded that for the development of thresher for the finger millet crop the recommended feed rate could be 180 kg/h. The type of threshing cylinder and concave could be combination of peg and canvas type and combination of bar and sheet concave type respectively for better performance results of the machine. It can be suggested that to develop a thresher for any crop which needs impact with rubbing action the peg with canvas strip combination type threshing cylinder could be used.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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