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Design Optimization of Linseed Thresher for Higher Efficiency

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Abstract

Linseed, a valuable rabi crop grown for both grain and fiber, has seen rising demand across industries, boosting interest in optimizing its production processes. Recognizing this, Swami Vivekanand College of Agricultural Engineering & Technology and Research Station (SVCAET & RS) at Indira Gandhi Krishi Vishwavidyalaya (IGKV) Raipur conducted a study focused on improving the design and efficiency of linseed threshing technology. The research aimed to develop an optimized head-cut type linseed thresher, addressing both design and performance factors. Three distinct prototypes were designed, varying in concave and threshing drum specifications. Design optimization was conducted across various parameters to enhance the performance of each unit. Specifically, the study examined three peripheral speeds (10.5, 12.5, and 14.5 m/s), three types of threshing cylinders (peg, canvas, and a hybrid of peg and canvas), and three concave opening sizes (3, 4, and 5 mm) to determine the ideal configuration. This approach sought to maximize threshing effectiveness while maintaining grain quality and minimizing fiber damage. The findings of this research provide crucial insights for increasing the efficiency and durability of linseed threshers, making them more viable for widespread agricultural use.

Keywords: Linseed thresher, threshing efficiency, optimization, design parameters and peripheral speed

INTRODUCTION

Linseed is a rabi crop cultivated for both seed and fiber purposes. It is cultivated in various ecosystems, including utera (relay cropping), rain-fed, and irrigated systems [1]. It was sown from October 15 to late November [2]. Linseed crops are harvested by sickle or by plucking the whole crop with roots when the leaves are dried, capsules become shiny, stems turn golden yellow, and seeds become brown [3].

Linseed threshing separates the linseed (flaxseed) from the rest of the plant. This involves loosening and removing the seeds from the stalks and seed pods, which is a crucial step in the post-harvest process of linseed cultivation [4]. The main steps in the linseed threshing process include (1) drying, (2) threshing, and (3) cleaning. The flax plants were sun-dried for a few days after the harvest. This drying period helps reduce the moisture content and makes the threshing process more efficient [5]. The dried plants were threshed to separate the seeds. Conventional techniques include treading dried plants with bullocks or striking them with rods. Modern methods employ mechanical threshers that

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use impact and rubbing actions to separate seeds from the plant materials. To ensure that the seeds are fresh and ready for storage or extra processing, they are cleaned after threshing to remove any remaining chaff or debris. Threshing is a vital process in linseed farming because it directly affects the quality and yield of the seeds obtained. Traditional linseed threshing is labor-intensive and time-consuming. Linseed, a valuable oilseed crop [6], presents unique challenges during threshing owing to its small seed size and delicate structure. The optimization of the threshing unit for linseed is essential for improving efficiency, reducing seed loss, and maintaining seed quality [7]. The creation and improvement of a linseed thresher are the main subjects of this study [8]. By integrating advanced mechanical principles and leveraging insights from existing threshing technologies, the goal is to enhance the overall performance of the linseed threshing process, thereby making it more effective and economical [9].

MATERIALS AND METHOD

According to the literature, the cylinder speed, type of threshing cylinder, and size of the concave affect the thresher performance. Maintaining these parameters is important to achieve good threshing [10]. The choice of speed is essential for striking a balance between threshing efficiency and grain retention, as a low cylinder speed might result in more un-threshed grains [11]. An unwanted conclusion could be grain breakage if the speed is too high. However, a slow speed could prevent the crop from being properly threshed [12]. To achieve balance and ensure effective threshing without sacrificing grain quality, the ideal threshing drum speed must be chosen [13]. The concave clearance of the threshing drum fluctuated between 10 m/s and 16 m/s. varied from 10 to 15 mm and a moisture content of 8–14% [14].

Study on Design Parameters of the Threshing Drum

To investigate the effects of various design parameters on the threshing efficiency and breakage percentage of the grains, a threshing drum was constructed. Three different threshing cylinders, i.e., peg type (Figure 1) [15], canvas belt type, a combination of peg and canvas belt type (Figure 2), and three different concaves size (Gap between two axial slits of concave), i.e., 3 mm, 4 mm, 5 mm were fabricated, and experiments were conducted with different peripheral 10.5, 12.5, and 14.5 m/s, for example [16]. Table 1 provides specific information on the independent and dependent parameters of this study. Three replications of the observed data for each independent parameter were performed, and the results were documented appropriately. A three-factor randomized block design (FRBD) was used to statistically analyze the experimental results [17].

Calculation of Dependent Parameters

The dependent parameters are the threshing efficiency and broken grain percentage [18]. It was calculated using the following formula (Table 1).

Figure 1. Peg-type threshing cylinder.

Figure 2. Combination peg and canvas-type threshing cylinder.

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

S.N.	Independent parameters		Dependent parameters
	Variables	***Levels***	
1	Peripheral speed	10.5 m/s 12.5 m/s 14.5 m/s	Threshing efficiency, % Broken grain, %
2	Type of threshing cylinder	Peg type Canvas belt Peg and canvas combination	
3	Size of concave	3 mm 4 mm 5 mm	

Threshing Efficiency

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

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

Where,

μ_T = thresholding efficiency, %
w_{ut} = Weight of un-threshed grains, kg; and
w_{tp} = Weight of total panicles feed per unit time, kg

Broken Grain

The damaged seeds that were visible by open eyes were separated by hand and weighed, and visible seed damage (%) was estimated as a percentage of total seed mass as follows:

$$\text{Broken grain (\%)} = \frac{W_d}{W_m} \times 100 \tag{2}$$

Where,

W_d = Mass of damaged seeds visible to the open eye (g); and
W_m = Total seed mass (100 g).

RESULTS AND DISCUSSIONS

An experiment was conducted to optimize the design parameters. The effects of these parameters are discussed in the following subsections.

Effect of Type of Cylinder and Peripheral Speed on Threshing Efficiency

Figure 3 shows how threshing efficiency is affected by the type and peripheral speed of the threshing cylinder. Research has shown that threshing efficiency is strongly affected by speed. The threshing efficiency increases with an increase in peripheral speed from 10.5 m/s to 12.5 m/s but after 12.5 m/s it starts decreasing. Because a faster peripheral speed causes a stronger acceleration and impact force on the capsule, threshing efficiency increases as drum speed increases for finger millet thresher [11]. The highest threshing efficiency of 98.06% was observed at 12.5 m/s, and the lowest value of 96.34% was observed at 10.5 a speed. Kamble et al. (2003) and Sudajan et al. (2002) also reported similar results for pearl wheat threshers and sunflower threshers [5, 14]. The type of threshing cylinder also significantly affects threshing efficiency. It was discovered that the peg-type and canvas-type threshing cylinders had the best threshing efficiency (98.22%), while the canvas-type threshing cylinder had the lowest (96.54%). The interactive effect of peripheral speed and type of threshing cylinder on the threshing efficiency was also found to be significantly different. The highest threshing efficiency of 98.56% was observed at 12.5 peripheral speed for the peg-type and canvas-type threshing cylinders. This may be due to both the impact and frictional action of the cylinder. Grain ears are impacted by high-speed threshing of teeth with the additional actions of compression, rubbing, and combing [6, 8, 9, 16, 17]. Similar results were reported by Vejasit and Salokhe (2004) and Bhawatharani et al. (2013) [2, 15].

Effect of Type of Cylinder and Concave Size on Threshing Efficiency

The results of the effect of the type of threshing cylinder and the size of the concave on threshing efficiency are shown in Figure 4. The data revealed that the type of threshing cylinder and the size of the concave significantly affected the threshing efficiency (α = 0.05). The highest threshing efficiency of 98.24% was found for the combined (peg and canvas) threshing cylinder, and the lowest (96.34%) was observed for the canvas-type threshing cylinder. The size of the concave also significantly affects threshing efficiency at the 5% level of significance. As shown in Figure 4, the threshing efficiency increased while increasing the gap between the two axial slits of the concave bar from 3 mm to 4 mm. Further increasing the size of the concave bar decreases the threshing efficiency because an increase in the gap reduces the threshing time, and the linseed capsule may easily pass through a large concave gap. The small gap increases the threshing efficiency by separating grains from the stalks, potentially capturing more grains and leading to a higher overall threshing efficiency (Figure 5).

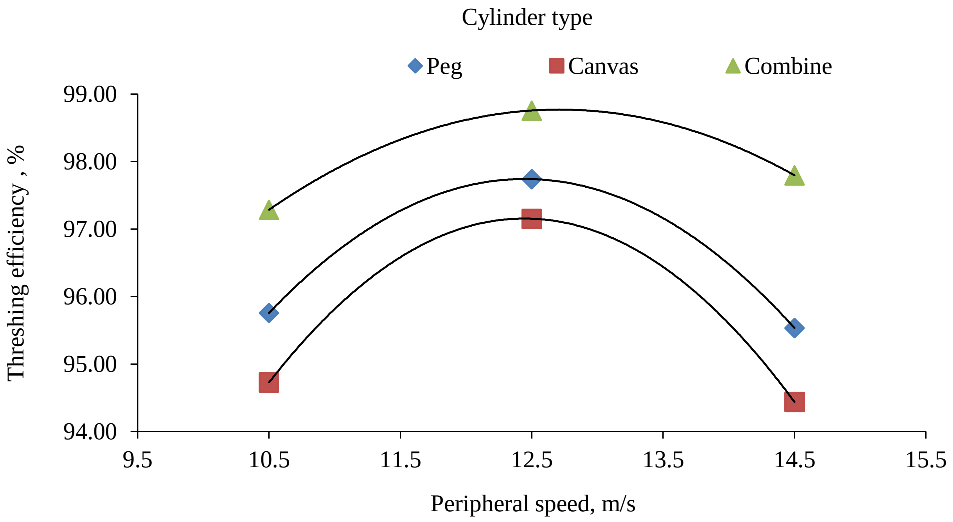

Figure 3. Effect of cylinder type and peripheral speed on threshing efficiency.

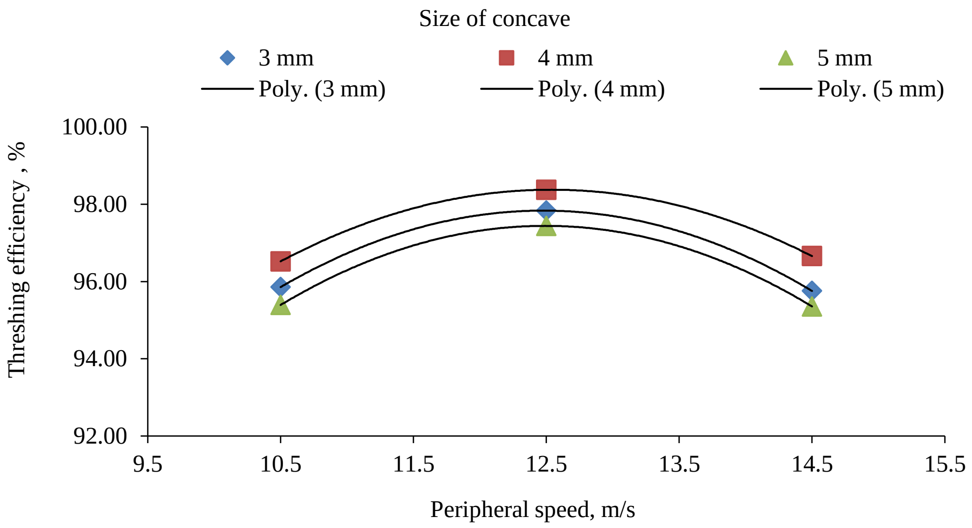

Figure 4. Effect of size of concave and peripheral speed on threshing efficiency.

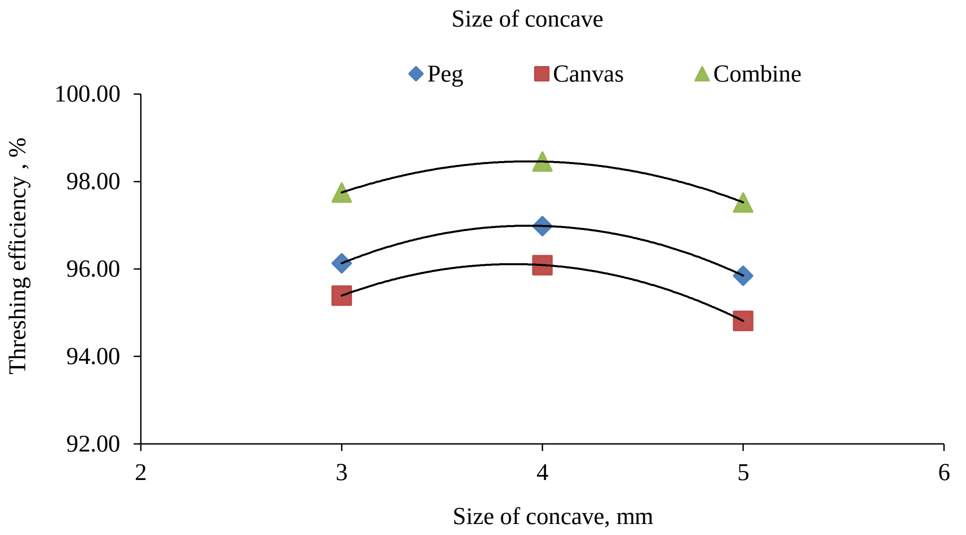

Figure 5. Effect of cylinder type and size of concave on threshing efficiency.

This may be due to the increase in threshing time. Additionally, it increases the grain damage percentage, which is unacceptable. The highest threshing efficiency (98.31%) was obtained in the case of a 4 mm concave size, whereas the lowest threshing efficiency (96.77%) was observed in a 5 mm concave.

Interactive Effect of Peripheral Speed, Type of Cylinder, and Size of Concave on Threshing Efficiency (%)

The results obtained from the experiment conducted on the effects of peripheral speed, type of cylinder, and size of concave on threshing efficiency (%) were analyzed statistically and are shown in Table 2. All three factors peripheral speed, type of cylinder, and size of the concave significantly affected the threshing efficiency (α=0.05%). Based on the statistics, the combination of a peg-type and canvas-type threshing cylinder with a 4 mm concave size and a peripheral speed of 12.5 m/s generated a maximum threshing efficiency of 99.16%. The interplay between peripheral speed, cylinder type, and concave size significantly affects the threshing efficiency. It is concluded that seed damage may be decreased and linseed separation efficiency may be increased by changes in some of the concave design parameters. It was observed to be best threshing efficiency at 12.52 m/s peripheral speed, combined type threshing drum and at 4 mm concave gape.

Table 2. Interactive effect of peripheral speed, type of cylinder, and size of concave on threshing efficiency (%).

	Threshing efficiency, %								
Peripheral speed (PS) →	***10.5 m/s***			***12.5 m/s***			***14.5 m/s***		
Size of concaves(S) ↓	*Type of threshing cylinder (TC)*								
	Peg	Canvas	Combine	Peg	Canvas	Combine	Peg	Canvas	Combine
3 mm	95.72	94.75	97.10	97.47	97.14	98.70	95.21	94.28	97.44
4 mm	96.25	95.24	98.01	98.15	97.82	99.16*	96.56	95.21	98.20
5 mm	95.31	94.12	96.75	97.41	96.51	98.41	94.83	93.82	97.41

Factors	*C.D.*	*SE(d)*	*SE(m)*
Cutting speed (PS)	0.026	0.013	0.009
Type of threshing cylinder (TC)	0.026	0.013	0.009
Size of concaves (S)	0.026	0.013	0.009
PS× TC	0.044	0.022	0.016
PS × TC	0.044	0.022	0.016
TC×S	0.044	0.022	0.016
Interaction (PS × TC × S)	0.077	0.038	0.027

Effect of Peripheral Speed and Type of Cylinder on Broken Grain

The graphical representation of the effect of peripheral speed and type of cylinder on broken grains is shown in Figure 6, which shows that the percentage of broken grains increases with increasing peripheral speed. A high speed provides a high impact force, causing damage to the grain. The type of threshing cylinder also significantly affects the percentage of broken grains. The lowest and highest broken percentages of 1.96% and 3.52% were found in the case of the peg-canvas combination cylinder and only peg-type cylinder, respectively, and the canvas-type threshing cylinders caused less damage to the seed owing to the low rubbing force. The peg-type threshing cylinder significantly damages the seed because of the high impact force.

Effect of Peripheral Speed and Size of Concave on Broken Grain

A graphical representation of the effect of the peripheral speed and type of cylinder on the broken grains is shown in Figure 7. The peripheral speed and size of the concavity significantly affected the percentage of broken grains. The broken grain percentage was observed to be the lowest (1.96%) for the peg-canvas-type threshing cylinder and a 12.5 m/s peripheral speed. The percentage of broken grains increased with increasing peripheral speed beyond the 12.5 m/s. The highest percentage of broken grains was found in the case of a peg-type threshing cylinder (3.52%).

Effect of Type of Cylinder and Size of Concave on Broken Grain Percentage

A graphical representation of the effect of the concave opening size and cylinder type on the broken grain is shown in Figure 8. The percentage of broken grains is significantly influenced by the size of the concave and the type of threshing cylinder. The broken grain percentage was observed to be the lowest (1.96%) for the peg-canvas-type threshing cylinder. The highest percentage of broken grains was found in the case of a peg-type threshing cylinder (3.52%). The repeated impact of the threshing cylinder pegs on the grains may be the cause of the high breakage percentage. A small concave opening size provides a high resident time to thresh the material owing to the repetitive impact force, and the broken grain percentage increases in the case of a type of cylinder 3 mm concave opening size. It was observed from the data that the broken grain percentage was significantly lowest in the case of peg-type and canvas-type threshing cylinders and 4 mm concave openings. Similar findings were reported by Sinha et al. (2009) [9]. This is in line with Zaalouk (2009) assertion that threshing efficiency increased as cylinder speed increased but decreased as feeding rate and concave clearance increased [18]. Concave clearance is crucial for minimizing grain loss and damage, and threshing equipment is reported to have a threshing rotor and wrap-around concave [4].

Interactive Effect of Peripheral Speed, Type of Cylinder, and Size of Concave on Broken Grain (%)

The results obtained from the experiment conducted on the effect of peripheral speed, type of cylinder, and size of concave on broken grains were analyzed statistically and are shown in Table 3. The speed, type of cylinder, and size of the concave significantly affected the broken grains (α=0.05%). The data reveals that the highest broken grain 3.49% was found at 14.5 m/s speed, peg-type threshing cylinder, and 3 mm concave size (the gap between two axial slits of concave).

It was also observed that the lowest broken grain 1.17% was found in the case of a 12.5 m/s peripheral speed, a combination of peg and canvas-type threshing cylinders, and a 4 mm concave size. This is because the effectiveness of threshing depends not only on the performance of the thresher itself but also on the crop–machine parameter combination [7]. The speed of the crop during feeding must be extremely slow to avoid excessive breakage. This is because grain velocity just before impact is one of the major causes of seed damage [15]. Patel et al. (2023) reported similar results for finger millet threshers.

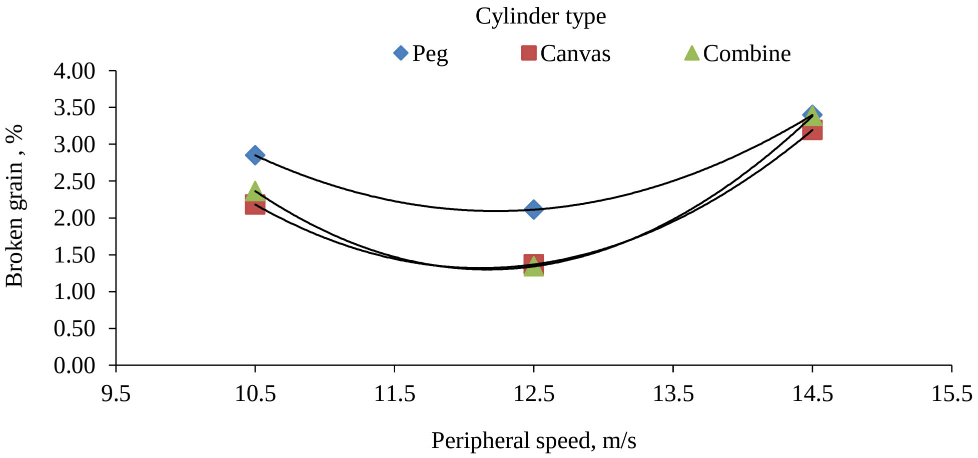

Figure 6. Effect of cylinder type and peripheral speed on broken grain percentage.

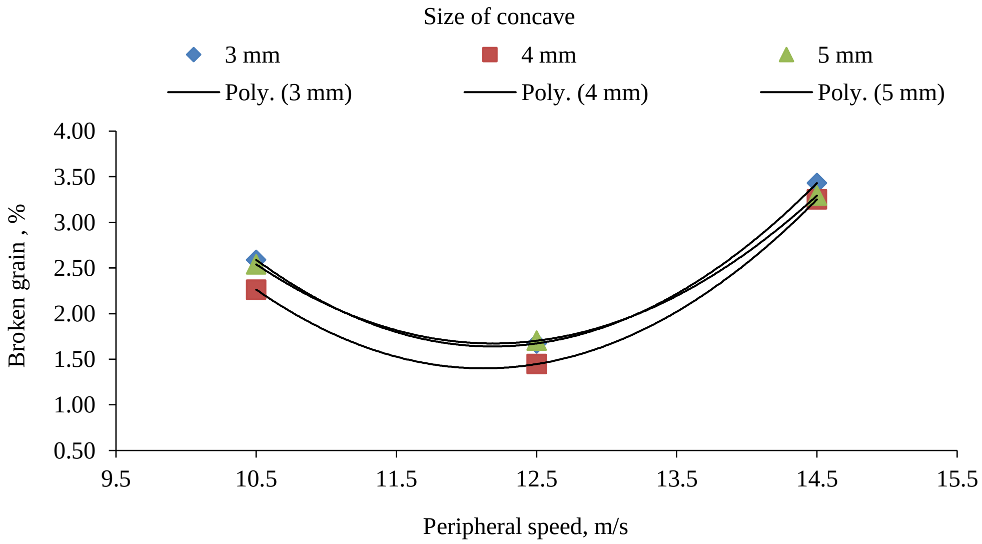

Figure 7. Effect of size of concave and peripheral speed on broken grain percentage.

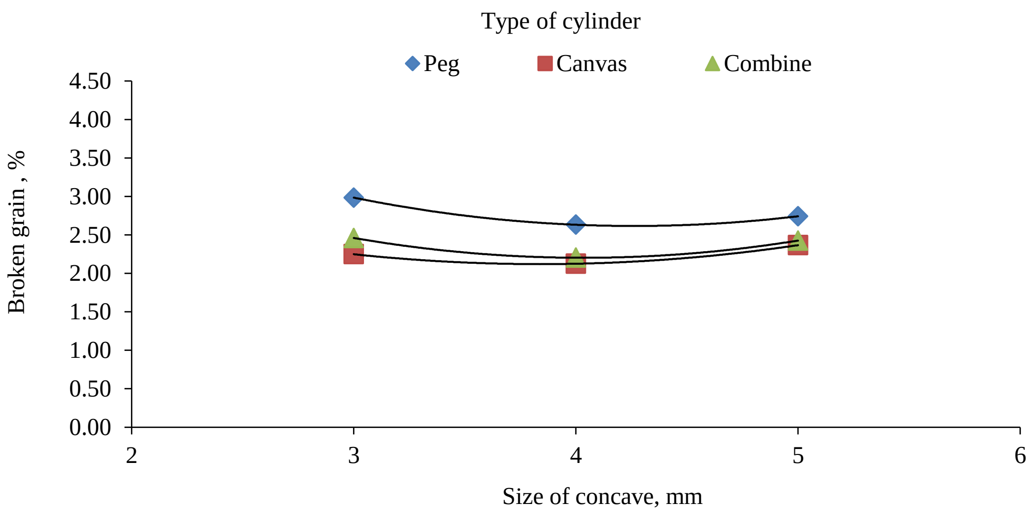

Figure 8. Effect of cylinder type size of concave on broken grain percentage.

Table 3. Interactive effect of peripheral speed, type of cylinder, and size of concave on broken grain (%).

	Broken grain (%)								
Peripheral speed (C) →	***10.5m/s***			***12.5 m/s***			***14.5 m/s***		
Size of concaves(S) ↓	*Type of threshing cylinder (TC)*								
	Peg	Canvas	Combine	Peg	Canvas	Combine	Peg	Canvas	Combine
3 mm	3.15	2.19	2.43	2.14	1.42	1.46	3.66	3.14	3.49
4 mm	2.60	2.00	2.19	1.95	1.22	1.17	3.34	3.16	3.25
5 mm	2.80	2.35	2.47	2.24	1.47	1.40	3.19	3.28	3.41

Factors	*C.D.*	*SE(d)*	*SE(m)*
Peripheral speed (PS)	0.067	0.033	0.024
Type of threshing cylinder (TC)	0.067	0.033	0.024
Size of concaves (S)	0.067	0.033	0.024
PS× TC	0.116	0.058	0.041
PS × TC	0.116	0.058	0.041
TC×S	0.116	0.058	0.041
Interaction (PS × TC × S)	0.201	0.1	0.071

CONCLUSION

The final optimized parameters for the development of a linseed thresher include a peripheral speed of 12.5 m/s, a combination of peg and canvas types for the threshing cylinder, and a concave size of 4 mm. These parameters ensure higher threshing efficiency and lower broken grain percentage, indicating minimal damage during the threshing process. The specified peripheral speed balances effective threshing with gentle grain handling, whereas the chosen cylinder type and concave size, provide efficient separation with reduced grain breakage. These optimized values contribute to an efficient and effective threshing process for linseed.

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