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Research Article

Performance Evaluation of Engine Operated Faba Bean Threshing Machine

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Abstract

People all over the world use faba beans, a highly valued legume crop with a high protein content, as a source of protein. Despite being a traditional process, threshing is a crop that provides food and feed and has numerous economic benefits for the farming people in Ethiopia's highlands. Even though Ethiopia produces a lot of faba beans, threshing is still done by hand or using traditional methods. The traditional threshing technique for faba beans is time-consuming, tedious, and vulnerable to contamination, waste, and grain or seed damage. The Faba bean thresher was evaluated and tested in terms of threshing capacity, threshing efficiency, cleaning efficiency, and mechanical damage. A diesel engine-powered faba bean threshing thresher was created, built, tested, and assessed in order to address these issues. Conducted at three different concave clearances (25, 30, and 35mm), feed rates (8, 12, and 16kg/min), and cylinder speeds (400, 450, and 500rpm). The factorial, split-split-plot design was the experimental setup used. With a cylinder speed of 500rpm, concave clearance of 35mm, and a feeding rate of 16kg/min, the maximum threshing capacity of 625.54kg/h was achieved. Concave clearing had a greater influence on the threshing efficiency and the proportion of un-threshed grain than other variables. A maximum threshing efficiency of 96.67% was attained with a concave clearance of 25mm and a cylinder speed of 400rpm. A cylinder speed of 500rpm and a concave clearance of 25mm produced the highest cleaning efficiency of 95.00%. At a feeding rate of 16kg/min, a concave clearance of 25mm, and a cylinder speed of 500rpm, the maximum mechanical damage of 6.13% was observed.

Keywords

Faba Bean, Threshing, Testing, Performance Evaluation

1. _Toc117208980Background and Justification

Humans around the world eat the Faba bean (Vicia Faba L.), a highly prized legume crop with a high protein content (33%), as a source of protein [4]. Ethiopia, Central Asia, and East Asia are among the nine distinct agroecological areas that comprise the majority of the world's faba bean growing area, according to [6]. Ethiopia is the world's fourth-largest exporter of faba beans and ranks second in output, after China [5]. The Tigray, Amhara, Oromia, and SNNP are the primary producers of it. Of all the pulses cultivated in Ethiopia, the faba bean occupies the most area (466,698 hectares) and produces the most (100,6751.83 metric tons) [3].

The process of separating grains or seeds from crop heads or pods is known as threshing. Using sticks to beat the grains out was the first threshing technique. Traditionally, threshing involves laying the collected produce on a concrete or mud floor and pounding it with a stick or flail. Other techniques include removing the seeds with a mortar and pestle. However, because the output is so low, occasionally contaminated, la-

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bor-intensive, and time-consuming, these threshing techniques are not convenient enough. The mechanical approach to threshing offers the benefits of time and labor savings, as well as improved production quality [11].

There are two methods for threshing: mechanical and manual [1]. Both threshing techniques result in numerous seed breaks. The dried crop is spread out on the floor and threshed by hand with a stick or with a pestle and mortar [8]. Time wastage, threshing losses, and excessive drudgery are its defining characteristics [10]. Before threshing, a tarpaulin or comparable material is spread to lessen the likelihood of stones. Winnowing is then used to separate the seeds. Using an engine or electric motor to power a machine for grain threshing is known as mechanical threshing.

Even though Ethiopia produces a lot of faba beans, threshing is still done by hand or using traditional methods. They use draught animals for threshing and wind or a natural breeze for cleaning. These methods take a lot of work, and spills, incorrect grain removal from heads, grain damage, and contamination from mud, sand, and stones all result in losses during threshing. The wind or natural breeze is erratic, location-specific, and sporadic.

Additionally, two to three sunny days and cold nights are needed to finish the threshing process. Rain can sometimes halt the threshing process and wet the grain-straw mixture, making it heavy and challenging to clean. Grain losses and drudgery are the outcomes of all these processes. And this results in faba bean grain losses after harvest. There might be an attempt to import various thresher kinds, but these machines might not be very adaptable to the farming system, be difficult to maintain, have few spare parts, or be out of the price range of farmers. Additionally, they are expensive and inconvenient for feeding units.

Because the person feeding the crop into the thresher cylinder stands dangerously close to the entrance chute, where a slight imbalance may throw him into the threshing drum, the imported thresher's manual feeding technique has led to countless deadly tragedies. The Bako Agriculture Engineering Research Center developed a faba bean threshing machine to address the challenges of threshing and cleaning faba bean grain because there isn't any threshing equipment designed exclusively for this Ethiopian crop. This will lessen the massive quantity of faba bean grain that is wasted following harvest because of conventional threshing and cleaning techniques. Therefore, the objective of this paper was to evaluate the performance of the diesel engine-operated Faba bean threshing thresher.

2. Materials and Methods

2.1. Experimental Site Description

The manufacturing and performance evaluation of the machine was done at the Bako Agricultural Engineering Research Center (BAERC), which lies between 90 06’58” to 90 07’0’’N latitudes and 370 03’28” to 370 03’32” E longitudes.

2.2. Description of the Thresher Components

The parts of the prototype faba bean thresher included: -feeding conveyor, cylinder, concave, fan, sieve, frame, diesel engine CHANGFA 7HP, engine seat, pulleys, belts, and grain outlet (Figure 1).

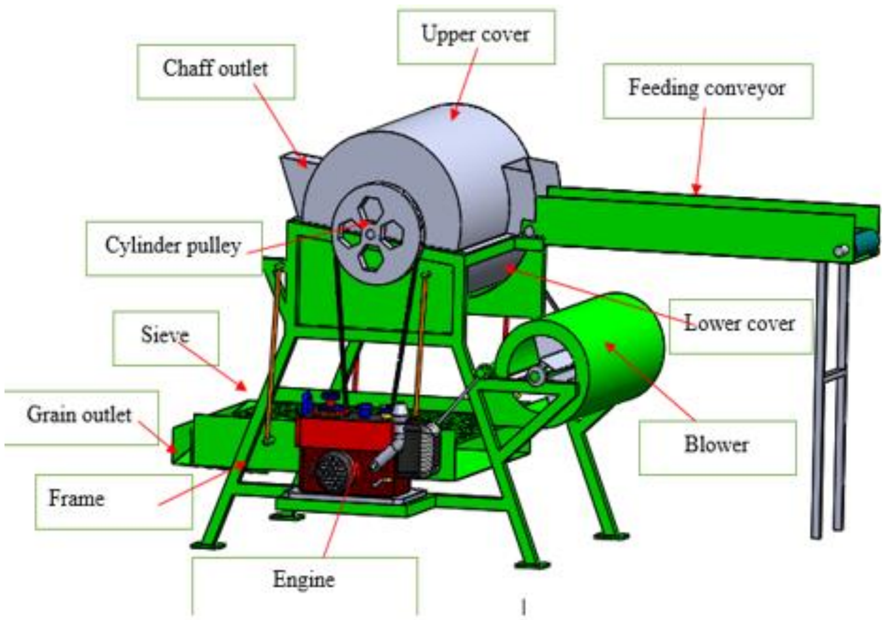

Figure 1. *Pictorial drawing of a faba bean threshing machine.*

2.3. Performance Evaluation of Threshing Machine

The Faba bean thresher was evaluated and tested in terms of threshing capacity, threshing efficiency, cleaning efficiency, and mechanical damage.

2.3.1. Throughput Capacity

Maximum threshing capacity is calculated using [9] Eqn. (1).

$$T = \frac{Q}{T} \quad (1)$$

Where: T = threshing capacity (kg/h), Q = quantity of material that passes through the grain collector (kg), and T = time (h).

2.3.2. Threshing Efficiency

According to [12], threshing efficiency is the ratio of the mass of un-threshed grains received from all the outlets to total grain output and expressed as a percentage (Eqn. (2)).

$$Te = 100 - \left(\frac{Qu}{Qt} \times 100\right) \quad (2)$$

Where: T_e = threshing efficiency (%); Qt = total quantity of grains (kg); Q_u = quantity of un-threshed grain sample (kg).

2.3.3. Cleaning Efficiency

The cleaning efficiency was determined using Eqn. (3) [2].

$$C_e = \left(\frac{wc}{wm}\right) \times 100 \quad (3)$$

Where: C_e cleaning efficiency (%), wc = weight of cleaned grain in the sample from the grain outlet (kg), wm = weight of whole material collected in the sample from the grain outlet (kg).

2.3.4. Mechanical Grain Damage

Mechanical damage was calculated using [9] Eqn. (4).

$$M_d = \frac{Q_b}{Q_t} * 100 \quad (4)$$

Where: Md = percentage of mechanical damage (%); Qb = quantity of broken grains in the sample (kg); Qt = total quantity of grains (kg).

2.4. Experimental Design

For data analysis, a split-split-plot experimental design was used. In this context, the main plots' cylinder speeds, the sub-plots' concave clearance, and the sub-sub-plots' feeding rates employ three replications each block.

2.5. Statistical Analysis

The data collected were subjected to analysis of variance using the statistical procedure as described by [7]. The analysis was made using R statistical software. When the effects of the treatment were found significant, an LSD test was performed to assess the difference among the treatments at 5% level of significance.

3. Results and Discussions

3.1. Threshing Capacity

The mean threshing capability and analysis of variance are shown in Table 1. According to the statistical study, ANOVA, the threshing capacity of the thresher was significantly ($P < 0.05$) impacted by cylinder speed, concave clearance, and feeding rate. The effects of concave clearance and feed rate, as well as cylinder speed and concave clearance, were significant; however, the cross-effect of the three parameters was not significant at $p < 0.05$. When the concave clearance was 35mm and the feeding rate was 16kg/min, a maximum threshing capacity of 625.54kg/h was recorded at a drum speed of 500rpm. At 400rpm, the minimum threshing capacity was 309.47kg/hr, recorded when the concave clearance was 25mm and the feed rate was 8kg/min.

Table 1. *The interaction effect of drum speed and the feeding of the machine on the threshing capacity.*

Treatments		**Feeding Rate (Kg.min^{-1})**			
Speed	**concave clearance**	**8**	**12**	**16**	**Means**
	25	309.47^{s}	395.62 ^{lm}	535.36 ^{no}	413.48
400	30	332.53 ^{r}	442.77^{mno}	542.0^{ij}	439.10
	35	348.44^{pq}	489.51^{lm}	582.47^{hi}	473.47
450	25	422.54^{op}	546.60^{kl}	596.72 ^{h}	521.95

Treatments		Feeding Rate (Kg.min^{-1})			
Speed	**concave clearance**	**8**	**12**	**16**	**Means**
	30	448.37^{mn}	562.11^{hi}	610.38^{ef}	540.28
	35	468.59^{jk}	588.94^{fg}	605.76^{cd}	554.43
	25	469.67^{lm}	602.52^{gh}	613.38^{de}	561.85
500	30	486.54^{ij}	609.25^{cd}	623.30^{b}	573.03
	35	529.40^{cd}	622.13^{cd}	625.54^{a}.	592.36
Means		423.95	539.35	601.70	518.88
MSE		30.16			
LSD		86.09			
CV (%)		2.1			

Standard errors of variances of means, MSE, CV stands for coefficient of variation, and LSD for least significant difference.

3.2. Threshing Efficiency

Analysis of variance revealed that cylinder speed and concave clearance had a significant ($p < 0.05$) effect on threshing efficiency. Table 2 shows that the cylinder's maximum threshing efficiency of 96.67% was achieved when it was operated at 400.00rpm, with a concave clearance of 25mm and a feed rate of 12kg/min. In contrast, the cylinder's minimum threshing efficiency of 70.24% was achieved at 500rpm, with a concave clearance of 35mm and a feed rate of 16.00kg/min. Threshing efficiency rose as feed rate increased and fell as cylinder speeds and concave clearances increased. As the concave clearance decreased, the threshing efficiency rose. At all cylinder speeds, the concave clearance of 35.00mm produced the lowest threshing efficiency.

The threshing efficiency increased with increasing feed rate, and decreased with an increase in concave clearances and cylinder speeds. The threshing efficiency increased by decreasing the concave clearance. The concave clearance of 35.00mm resulted in minimum threshing efficiency at all cylinder speeds.

Table 2*. The interaction effect of speeds, concave clearances, and feed rates on threshing efficiency.*

Treatments	Concave	Feed Rate (Kg.min^{-1})			
Speed (rpm)		**8**	**12**	**16**	**Means**
	25	88.89^{cde}	87.78^{cdef}	93.16^{ab}	89.94
400	30	83.82^{ghi}	87.41^{cdef}	85.65^{efgh}	85.63
	35	87.78^{cdef}	86.67^{defg}	82.28^{hij}	85.58
	25	96.54^{a}	96.67^{a}	75.82^{m}	89.68
450	30	90.87^{bc}	88.12^{cdef}	87.36^{def}	88.78
	35	81.27^{ij}	76.94^{lm}	77.91^{klm}	78.52
	25	93.54^{ab}	89.01^{cde}	84.24^{fghi}	88.93
500	30	80.45^{ijkl}	81.82^{ijk}	78.58^{jklm}	80.28
	35	76.50^{m}	77.22^{lm}	70.24^{n}	74.44
Means		86.59	85.74	81.69	
MSE				1.354	

Treatments	Concave	Feed Rate (Kg.min^{-1})			
Speed (rpm)		8	12	16	Means
LSD				3.858	
CV (%)				2.4	

3.3. Cleaning Efficiency

ANOVA showed that cylinder speed, concave clearance, and feed rate all had a significant ($p < 0.05$) effect on the thresher's cleaning efficiency. The maximum cleaning efficiency of 95.00% was obtained when the cylinder was operated at 500rpm, with a concave clearance of 25.00mm and a feed rate of 8.00kg/min. The lowest cleaning efficiency of 92.70% was obtained when the cylinder was operated at 400.00rpm, 35.00mm concave clearance, and 16.00kg/min feed rate (Table 3). According to Table 3, cleaning effectiveness generally increased with cylinder speed but declined with concave clearance and feed rates.

Table 3. The interaction effect of speeds, concave clearances, and feed rates on cleaning efficiency.

Speed (rpm)	Concave Clearance (mm)	Feed Rate (Kg.min^{-1})			
		8	12	16	Means
	25	94.16^{ef}	94.03^{e}	93.99^{ef}	94.06
400	30	93.13^{fgij}	93.16^{fgij}	93.07^{gijk}	93.12
	35	92.94^{ijk}	92.70^{k}	92.67^{k}	93.10
	25	94.45^{bcd}	94.29^{cde}	94.20^{de}	94.31
450	30	94.56^{fg}	93.40	93.35^{ghi}	93.77
	35	94.52^{g}	93.32^{ghi}	93.36^{gh}	93.73
	25	95.00^{a}	94.86^{ab}	94.66^{abc}	94.84
500	30	94.48^{bcd}	94.30^{cde}	94.20^{de}	94.32
	35	94.33^{cde}	94.15^{de}	94.16^{de}	94..21
Means		93.95	93.80	93.74	
MSE	0.231				
LSD	0.163				
CV (%)	1.00				

3.4. Mechanical Damage

Table 4 displays the data demonstrating how cylinder speed, concave clearance, and feed rate affect grain damage during faba bean threshing. At a cylinder speed of 500rpm, concave clearance of 25.00mm, and feed rate of 16.00kg/min, the maximum grain damage of 6.13% was seen; at a cylinder speed of 450rpm, concave clearance of 25.00mm, and feed rate of 16.00kg/min, the lowest damage of 2.56% was noted. At feed rates of 8.00, 12.00, and 16.00kg/min, the average grain damage was 3.80, 4.08, and 4.65%, respectively. Table 4 shows that the grain damage decreased as concave clearance increased and increased with cylinder speed and feed rate.

***Table 4**. The interaction effect of speeds, concave clearances, and feed rates on mechanical damage.*

Treatments	Feeding Rate ($Kg.min^{-1}$)				
Speed (rpm)	**Concave clearance (mm)**	**8**	**12**	**16**	**Means**
	25	4.45^{gh}	4.77^{efg}	4.87^{c}	4.70
400	30	3.38^{jk}	3.79^{hi}	3.59^{def}	3.92
	35	2.75^{m}	3.19^{kl}	3.89^{h}	3.3
	25	4.28^{fg}	4.57^{cde}	5.73^{b}	4.83
450	30	3.88^{h}	4.40^{gh}	4.49^{ef}	4.12
	35	3.29^{jk}	3.26^{jk}	3.72^{hi}	3.42
	25	5.66^{b}	5.76^{b}	6.13^{a}	5.89
500	30	3.89^{h}	4.16^{efg}	4.79^{cd}	4.31
	35	2.56^{m}	2.86^{lm}	3.49^{ij}	2.97
Means		3.8	4.08	4.65	
MSE				0.12	
LSD				0.33	
CV (%)				6.9	

3.5. Fuel Consumption

The prototype Faba bean thresher's average fuel usage at different feed rates, concave clearances, and cylinder speeds is displayed in Table 5. The analysis of variance on the fuel consumption of the prototype threshing machine revealed that the cylinder speeds, feed rates, and concave clearances of the threshed all had highly significant ($p < 0.01$) effects. Energy costs would likely grow as work and feed rates grew, as evidenced by the fact that the threshing machine's fuel consumption normally increased as cylinder speeds and feed rates climbed. It appears to diminish as concave clearance rises, though, indicating how concave clearance affects the energy required for threshing.

***Table 5**. The interaction effect of speeds, concave clearances, and feed rates on fuel consumption.*

Treatments	Feeding Rate ($Kg.min^{-1}$)				
Speed (rpm)	**Concave clearance (mm)**	**8**	**12**	**16**	**Means**
	25	7.54^{lm}	7.97^{j}	8.27^{i}	7.93
400	30	7.27^{no}	7.67^{kl}	8.05^{j}	7.66
	35	7.12^{o}	7.46^{lmn}	8.84^{jk}	7.8
	25	7.89^{j}	8.84^{f}	9.69^{c}	8.81
450	30	7.65^{klm}	8.59^{gh}	9.38^{d}	8.54
	35	7.45^{mn}	8.36^{i}	9.13^{e}	8.31
	25	8.75^{fg}	9.84^{c}	10.69^{a}	9.76
500	30	8.72^{fg}	9.65^{c}	10.58^{a}	9.65
	35	8.45^{hi}	9.36^{d}	10.31^{b}	9.37

Treatments	Feeding Rate ($Kg.min^{-1}$)				
Speed (rpm)	Concave clearance (mm)	8	12	16	Means
Means		7.87	8.47	9.33	
MSE				0.07	
LSD				0.21	
CV (%)				4.7	

4. Conclusions and Recommendations

4.1. Conclusions

People all over the world use faba beans, a highly valued legume crop with a high protein content, as a source of protein. Despite being a traditional process, threshing is a crop that provides food and feed and has numerous economic benefits for the farming people in Ethiopia's highlands. The traditional threshing technique for faba beans is time-consuming, tedious, and vulnerable to contamination, waste, and grain or seed damage. In light of the problems with threshing the crop, an effort was made at Bako Agricultural Engineering Research Center to create a diesel engine CHANG-FA-driven faba bean threshing machine, test it, and evaluate its performance.

In accordance with statistical procedures, field tests were conducted. Computer software was used to collect and evaluate the data. The investigation involved evaluation of the effects of cylinder speed, concave clearance, and feed rate on threshing capacity, threshing efficiency, cleaning efficiency, grain damage, and fuel consumption. Three-cylinder speeds (V_1 = 400.00, V_2 = 450.00, and V_3 = 500.00rpm), three concave clearances (C_1 = 25.00, C_2 = 30.00, and C_3 = 35.00mm), and three feed rates (F_1 = 8.00, F_2 = 12.00, and F_3 = 16.00kg/min) were taken into consideration as independent variables during the testing and performance evaluation of the prototype faba bean threshing machine.

The prototype thresher's threshing capacity generally rose as the concave clearance and feeding rate increased. At a cylinder speed of 500.00rpm, concave clearance of 35.00mm, and feed rate of 16.00kg/min, the maximum threshing capacity of 625.54kg/h was achieved.

The threshing efficiency was almost consistent at all cylinder speeds, rising with increasing feed rate and falling with increasing concave clearances. The maximum threshing efficiency of 96.67% was recorded with a cylinder speed of 450.00rpm and a concave clearance of 25.00mm. Fuel usage rose as operating speed and feeding rate increased, while it fell as concave clearance grew. Consequently, the following deductions were drawn:

The highest threshing capacity of 625.54kg/h was attained at a feed rate of 16.00kg/min, a concave clearance of 35.00mm, and a cylinder speed of 500.00rpm. In general, as the concave clearance and feeding rate increased, so did the prototype thresher's threshing capability.

At all cylinder speeds, the threshing efficiency was nearly constant, increasing as the feed rate increased and decreasing as the concave clearance increased. With a concave clearance of 25.00mm and a cylinder speed of 450.00rpm, the highest threshing efficiency of 96.67% was observed. The fuel consumption of the operation increased with the feeding rate and speed, and dropped as the concave clearance increased. Consequently, the following deductions were drawn:

4.2. Recommendations

When operating at a cylinder speed of 450.00rpm, concave clearance of 25.00mm, and a feed rate of 12.00kg/min,

1) The prototype thresher designed for use with the local faba bean variety seems to be effective.
2) However, it is advised that the thresher be reassessed at a larger range of concave clearances, feed rates, and cylinder speeds.
3) To generate high-quality faba bean seeds that will command a premium price, conduct methodical, organized, and unrelenting efforts to make the thresher affordable or jointly owned.
4) It is necessary to assess the thresher for more crops.
5) Provide ground wheels to facilitate the thresher's mobility during transit.

Abbreviations

BAERC	Bako Agricultural Engineering Research Center
CSA	Central Statistical Agency
CV	Coefficient of Variation
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
LSD	Least Significant Difference
MSE	Standard Errors of Variances Of Means

Conflicts of Interest

The authors have no competing interests to declare.

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