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Adaptation and Performance Evaluation of Engine Driven Faba bean Thresher to PTO Driven Faba Bean Thresher

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ABSTRACT

One of Ethiopia's first domesticated cool-season food legumes is the faba bean. Ethiopia primarily uses traditional methods for threshing faba beans, which are labor-intensive, lead to worker fatigue, yield little, and lower seed quality. Thus, the purpose of this study is to modify and assess the performance of a PTO-driven faba bean thresher. The mainframe, feeding table, threshing unit, grain, chaff, and straw, dust outlets, three-point linkage, and power transmission system make up the modified thresher. Three factors three drum speed (rpm) levels and three feed rate (kg/hr) levels with three replications were included in the fully randomized experimental design. At predetermined drum speed and feed rates, the main and interaction effects of machine operating parameters on threshing capacity, threshing efficiency, cleaning efficiency, percentage of grain breakage, and percentage of grain loss were investigated. When the machine operated at a feeding rate of 840 kg/hr and a drum speed of 450 rpm, the optimal result was achieved. For the faba bean crop, these operating parameters yielded a threshing capacity of 416 kg/hr, a threshing efficiency of 99.24%, a cleaning efficiency of 97.38%, a grain breakage percentage of 0.56%, and a grain loss of 1.49%. These results generally indicate that the threshing machine is easy to use, has a straightforward design, and is appropriate for small and medium-sized farmers.

INTRODUCTION

Legumes play a significant role in many agricultural systems around the world. One of Ethiopia's first domesticated cool-season food legumes is the faba bean. After China, Ethiopia is the world's second-largest producer of faba beans (Teklay *et al.*, 2014). One of Ethiopia's most significant cool-season grain legumes in terms of hectares, total production, foreign exchange earnings, and soil improvement is the faba bean (*Vicia faba* L.). There are several ways that faba beans support smallholder livelihoods. As an inexpensive source of protein and other vital nutrients, it can significantly contribute to the improvement of smallholders' food security (Elsheikh & Ahmed, 2000).

A valuable legume crop with a high protein content (33%), the faba bean (*Vicia faba* L.) is consumed by people all over the world as a source of protein and nutrients (Elsheikh & Ahmed, 2000). It is an important crop because it is inexpensive and high in carbohydrates (Rasul, 2018). Additionally, when they are immature they are called "horse beans," "broad beans," "tick beans," or "faba beans" (Robinson *et al.*, 2019).

With a share of 1.5 million metric tons in 2013, Ethiopia is Africa's top producer of faba beans (FAOSTAT, 2016). Compared to the national average yield of 1.8 t/ha, the

productivity of improved varieties is extremely high at 3.5 t/ha. Faba beans were grown on approximately 511,908.4 ha of land across the country each year, with 3,682,512 smallholder farmers involved (CSA, 2021).

The productivity of faba beans is about 2.1 tons ha⁻¹, which is extremely low when compared to the average yield of 3.7 t ha⁻¹ in major producer countries, despite their enormous importance and area coverage (CSA, 2021). However, a number of factors, including the absence of post-harvest technologies like threshing operations, have an impact on the overall productivity of faba beans. A crucial step in agricultural processing is threshing, which entails removing the grain or seeds from plants as well as the plant stalk. It can be achieved by rubbing, squeezing, striking a fast-moving object with the heads, or using a combination of these techniques. The process of threshing involves applying mechanical force that combines impact, shear, and/or compression to separate grain from other plant material (Bill & Bernard, 1999). Ethiopia primarily uses traditional methods for threshing faba beans, which are labor-intensive, lead to worker fatigue, produce little, and lower the quality of the seed. The most popular techniques are animal trampling and stick beating, which can leave up to 30% of the crop on the ground. Urine and excrement from animal trampling

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contaminate the remaining area, potentially lowering its market value. According to Gelgelo Kibi *et al.* (2018), all of these conventional faba bean threshing techniques are extremely time-consuming, labor-intensive, inefficient, and result in significant losses.

The Bako Agricultural Engineering Research Center (BAERC) modified and assessed an engine-driven soya bean thresher for Faba beans with a maximum threshing capacity of 410.07 kg/hr at 500 rpm drum speed for grain straw ratio of 0.63:1 in order to address the aforementioned issues and enhance the working conditions of the farmers. The percentage of mechanical damage and loss at this operation is 0.21 and 8.40%, respectively (Gelgelo Kibi *et al.*, 2018).

Thus, the machine was brought to AAERC as pre-extension demonstration and on-farm evaluation were conducted and 306.31Kg/hr, 0.02, 95.2%, and 8% threshing capacity, percentage of mechanical damage, threshing efficiency, and seed breakage were obtained respectively.

Despite the machine has promising results, the current price of engine in the market is very expensive which makes farmers not to adopt the machine. However, the government of Ethiopia distributes many tractors to the farmers in order to enhance agricultural mechanization and to increase the mechanized farming in the country. Therefore, this research project is aimed to adapt and evaluate the performance of PTO driven faba bean Thresher.

MATERIAL AND METHOD

Material and Instruments

The material used for prototype construction were: angle iron, bolt and nuts, bearings (205 and 206), Square pipe, Sheet metal, Steel shaft, electrodes, round bars, flat iron, single and double line pulleys and perforated sheet metals (for sieve).

The Instruments used for evaluating/testing and data collection of PTO driven thresher were:

- Threshing machine
- PTO : used to transfer power from tractor to thresher
- Testing and performance evaluation were conducted using the faba bean crop.
- A stop watch is used to measure how long threshing takes.
- A tachometer is used to measure the speed of rotating parts such as the threshing drum.
- Weighing with an electric balance
- The grain moisture content is measured using a grain moisture meter.
- The straw moisture content is measured using a straw moisture meter.
- Graduated cylinder: used to determine fuel consumption

Methods

Description of the thresher components

The feeding table, threshing unit, cleaning unit, grain outlet unit, straw and chaff outlet unit, and power transmission unit were the parts of the prototype faba-bean thresher. The threshing drum is composed of flat, strait To enable straw motion and biting, iron, sheet metal, and a steel shaft with a spike tooth and peg type welded in the center are welded to the threshing drum in the appropriate configuration. Power is transferred from the tractor to the thresher via PTO thanks to its power transmission mechanisms.

Working principles of the thresher

To minimize vibration while using tractor power through the PTO, the thresher needs to be placed on flat ground. The thresher receives power from the tractor engine through the PTO, and when the PTO is operating, the harvested faba bean crop that is placed on the feeding table is forced into the drum's entry. The crop material is threshed by the drum that rotates in the concave and is powered by the PTO. During the threshing process, grain is sent to the grain outlet and straw to the straw outlet. The grain was released outside the machine after passing through an oscillating top sieve and landing in a concave fall on the grain collector. With the aid of the air pressure produced by the blower and the systems applied to the drum because of the peg and chopper arrangements, the straw, chaff, and undesired materials are transferred to the straw outlet.

The modified parts of the machines

The adapted machine parts such as: - Side plates, threshing drum, drum concave, fan unit, and grain outlet were modified

Selection of power transmission and drive system

Selection of pulley diameters

Cast iron pulleys of the groove type were utilized in the drive system. Based on the requirement to lower the PTO speed to the necessary level, pulley diameters were chosen. Pulley diameters are calculated using the following formula.

$$\frac{N2}{N1} = \frac{D1}{D2} \quad 1$$

Where, N1 and N2 represent the driving and driven pulleys' respective rpms. The diameters of the driving and driven pulleys are D1 and D2.

The values of D1, D2, and N1 were 1750mm, 900 mm, and 400 rpm and the maximum determined value of N2 was equal to 778 rpm.

Selection of the belt

In this work, the power needed by the threshing machine was transmitted using traditional V-belt and groove-type

pulley arrangements. The V-belt drive was used primarily due to its low maintenance costs, simplicity, and flexibility. Furthermore, the v-belt can absorb shocks, which lessens the impact of vibratory forces (Khurmi and Gupta, 2005).

Determination of belt contact angle

The following formula provides the belt contact angle (Khurmi and Gupta, 2005).

$$\phi = \sin^{-1} \left[\frac{R-r}{c} \right] \tag{2}$$

The following formula determines the angles of wrap for the larger and smaller pulleys:

$$\alpha_1 = 180 - 2 \sin^{-1} \left[\frac{R-r}{c} \right] \tag{3}$$

$$\alpha_2 = 180 + 2 \sin^{-1} \left[\frac{R-r}{c} \right] \tag{4}$$

Where: α_1 = angle of wrap for the engine pulley, deg; R = radius of a larger pulley, mm; r = radius of a smaller pulley, mm; Deg C is the center distance between the two center pulleys, and α_2 is the angle of wrap for the drum shaft pulley. Consequently, the values of Φ , α_1 , and α_2 were found to be 0.5830 using the aforementioned equations, 178.750, and 181.240 whereas, that of the drum pulley and fan pulley connector were 0.6340, 178.630, and 181.370

Determination of belt length

The following formula was used to determine the belt's suitable length for driving the system (Shigley and Mischke, 2001).

$$L = 2c + \frac{\pi}{2} (D_2 + D_1) + \frac{(D_2 - D_1)^2}{4c} \tag{5}$$

$$L = 2 * 0.47 + \frac{3.14}{2} (0.175 + 0.09) + \frac{(0.09 - 0.175)^2}{4 * 0.47} = 1.364m$$

The fan pulley and drum pulley of the belt were chosen from the standard table based on their closest standard length, which came out to be 1364 mm. The belt's exact length is 1415 mm because it is a B type V-belt, which was added to the inside length of 43. The following equation was then used to calculate the precise center distance. Gupta and Khurmi (2005)

$$C = \frac{K + \sqrt{K^2 - 32(D_2 - D_1)^2}}{16} \tag{6}$$

Where: L = belt length, m; C = pulley center distance, m; D2 = driven pulley pitch diameter, m; D1 = Driver pulley pitch diameter, m K=4L-6.28 (D₂+D₁)

The precise center distance is also accurate because the computed length of the V belt is equal to the nearest standard belt. As a result, the center distances for the drum-PTO connector pulley and the fan-drum pulley were 470 mm and 670 mm, respectively. The following formula, provided by Khurmi and Gupta (2005), was used to determine the belt's speed.

$$V = \frac{\pi D_2 N_2}{60} \tag{7}$$

$$V = \frac{3.14 * 0.175 * 400 rpm}{60} = 3.66m/s$$

When it came to conducting performance evaluations,

this value was the highest.

Determination of belt tensions

The following formulas were used to calculate the tensions on the belt's tight and slack sides Gupta and Khurmi, 2005).

$$T_1 = T - T_c \tag{8}$$

$$T = \sigma_{max} \alpha \tag{9}$$

$$T_c = mv^2 \tag{10}$$

Where T_c and T represent the belts' centrifugal and maximum tension (N);

Tension in the tight and slack sides (N) is represented by T1 and T2. The maximum safe normal stress (N/mm²) is represented by max. α = is the belt's cross-sectional area (mm²); m = mass per unit length of belt (kg/m); and v = is the belt's speed (m/s).

The formula provided by Khurmi and Gupta (2005) was used to estimate the tensions on the belt's tight and slack sides:

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu \alpha_1 \cos \phi} \tag{11}$$

$$\mu = 0.54 - \frac{42.6}{152.6 + N_2}$$

The coefficient of friction between a belt and a pulley is equal to 0.25. 66 = groove angle in degrees. The angle of wrap on a small pulley in rad is equal to 400 from the design book.

Khurmi and Gupta (2005) state that the following formula was used to calculate the torsional moment (Tr) caused by single and double belt tensions.

$$T_r = (T_1 - T_2) \frac{D_2}{2} \tag{12}$$

T1 is the tension on a belt's tight side (N), T2 is the tension on a belt's slack side (N), and D2 is the driven pulley's diameter (m).

Shaft diameter determination

A shaft is a revolving machine part that transfers power. A tangential force delivers the power to the shaft, and the torque (or twisting moment) that is created inside the shaft allows the power to be distributed to different machines connected to the shaft. Additionally, transfer power from one shaft to another using other parts like gears, pulleys, etc. These components and the loads placed on them cause the shaft to bend, according to Khurmi and Gupta (2005). The fan shaft and threshing drum diameters were computed using the maximum shear stress theory. The following formula was used to calculate the total bending moment.

$$M = \sqrt{M_v^2 + M_H^2} \tag{13}$$

Where: MV is equal to the vertical bending moment (Nm), MH stands for horizontal bending moment (Nm). Armah (2018) states that, the theory of maximum shear stress was used to determine the threshing shaft's diameter.

$$d^3 = \frac{16fs}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t T_r)^2} \tag{14}$$

Where, d is the shaft diameter, S_s is the shaft's permitted shear stress (42N/mm²) according to the design book, and K_b is the shock factor for bending moment (1.5). For torsional moments, K_t = shock factor = 1.3, M_b = maximum bending moment (N. m), T = maximum torque (N. m), and f_s = factor of safety (3) for agricultural equipment. Based on the above equations, the resultant bending moment of 50 Nm was calculated by considering the maximum bending moment of MV and MH. Also, the torque of the shaft was estimated by using Eqn. (14) finding out 38.28 Nm. As a result, the minimum diameter of the shaft was found to be 31.99 mm. Therefore, a 35 mm diameter stainless steel shaft was used for the operation of the threshing unit. Similarly, for the fan shaft, the resultant bending moment and the torque of 27.05 and 10.07 Nm were calculated and from this, the diameter of the fan shaft computed was 24.94 mm. Based on this the fan shaft of 25 mm diameter was used to carry the fan blade and to provide an optimum blowing system.

Bearing selection

The desired maximum lifespan bore size, and maximum resultant force on the bearing can all be used to determine its size. According to Khurmi and Gupta (2005), a UCP bearing of 206 and 205 was chosen for the drum shaft and fan shaft since their respective diameters were found to be 35 and 25 mm.

Performance Evaluation of the Machine

Variables and data collected

During the evaluation, two independent variables drum speed and feeding rate were evaluated. These were the three feed rate levels (10, 12, and 14 kg/min) and the three drum speed levels (400, 450, and 500 rpm). The harvested faba bean crop was weighted separately and pushed into the threshing machine at the selected drum speed after being placed on the feeding table. The faba bean threshing machine's threshing capacity, threshing efficiency, cleaning efficiency, grain breakage, and grain loss were assessed.

Threshing Capacity (kg/hr)

Capacity was calculated using the weight of undamaged and damaged grains that were threshed and received each hour at the main grain outlet. The entire amount of threshed grain was gathered from the main grain outlet at the conclusion of each test. The following formula was used to determine the threshing capacity (TC) (Alsharifi, 2018).

$$T_c = \frac{W_g}{t} \times 60 \text{ min/hr} \quad 15$$

Where, W_g is the weight of threshed grain at a main outlet (kg) and TC is the threshing capacity (kg/hr).
 t = Threshing time recorded (min)

Threshing Efficiency (%)

The ability of the thresher to properly separate the grain from the straw and the stuck is known as threshing

efficiency. The following formula was used to calculate it (Ali *et al.*, 2007).

$$TE (\%) = \frac{T_g - U_n G}{T_g} \times 100 \quad 16$$

T_g stands for total grain input weight per unit of time, expressed in kilograms. $U_n G$ is the weight in kilograms of un-threshed grains per unit of time.

Cleaning Efficiency (%)

The following formula was used to determine the thresher's capacity to separate grain from chaff and straw.

$$CE (\%) = \frac{W}{W_o} \times 100 \quad 17$$

W is the weight in kilograms of the grains from the main output opening after cleaning. W_o = Grain and small chaff weight from the main output opening in kilograms.

Damaged Grain (%)

Every grain that was physically broken or damaged was examined, sorted by hand, and weighed with a digital balance. The weight of the actual damaged kernels divided by the weight of a sample was used to calculate the damage caused by mechanical threshing.

$$GB (\%) = \frac{W_b}{W_s} \times 100 \quad 18$$

Where, W_b is the weight of broken (damaged) grains (g) and W_g is the percentage of broken grain.
 W_s = Sample weight (g)

Grain Loss (%)

For the wheat and barley thresher, the following formula was used to determine the total grain loss percentage (GL), which included un-threshed grain losses (UGL), damage grain losses (DGL), and grain losses in straw (GLS) (Ajmal *et al.*, 2017).

$$GL (\%) = UGL + DGL + GLS \quad 19$$

GL stands for total grain losses in kilograms, DGL for damaged grain losses in percentage terms; and UGL for un-threshed grain losses in percentage terms. GLS stands for grain loss percentage in straw.

Fuel consumption

The machine's economics were directly impacted by the fuel consumption. The refill method was used to measure the fuel consumption. The tractor was started after its fuel tank was completely filled. Ultimately, the fuel was refilled in the tank all the way to the top after the test was finished. The amount of fuel that was refilled was stated in liters per hour.

Cost estimation

The tractor's and the manufactured PTO-driven faba bean thresher's estimated annual and hourly operating costs were based on the tractor's and the thresher's capital costs, interest on capital, labor costs, depreciation, and the cost of repairs and spare parts (Table 1). According to (Wen-yuan Huang *et al.*, 1979), the planter prototype

Table 1: Annual and hourly operational costs of the Tractor and fabricated thresher

Formula No.	Cost estimation	Formula Used	Sources
Fixed Cost			
20	Depreciation	$D_p = \frac{PP - SV}{L \times H}, (EB / h)$	(Kepener <i>et al.</i> , 1987)
21	Interest	$I = \left(\frac{PP + SV}{2} \right) \times \left(\frac{I\%}{H} \right), (EB / h)$	(Kepener <i>et al.</i> , 1987)
22	Insurance & taxes (IT)	$IT = 1\% \text{ of } PP$	(Kepener <i>et al.</i> , 1987)
23	Housing	$Housing = 1\% \text{ of } PP$	(Kepener <i>et al.</i> , 1987)
24	Total fixed cost	$D_p + I + IT + Housing$	(Kepener <i>et al.</i> , 1987)
Variable cost			
25	Repair and maintenance cost	$RM = 10\% \text{ of } PP$	(Kepener <i>et al.</i> , 1987)
26	Total cost per hour	$\frac{Fixed\ cost}{hr} + \frac{Variable\ cost}{hr}$	(Kepener <i>et al.</i> , 1987)

and 25-hp tractor's operational cost components were calculated in Birr (ETB). The threshing machine is anticipated to be used 425 hours annually, and the tractor is expected to have an economic life of 10 years and 850 hours annually.

Where Interest rate: 10%, salvage value (SV): 10%, purchase price (Pp): 123,000 ETB Maintenance and repairs (RM): 10% Taxes and insurance (IT): 1% of PP Housing: 1% of PP FC = 79.19 ETB per litre, fuel consumption: 1.92 litres per hour 25% of fuel is used for lubrication, and the cost (L.C.) is 140 ETB per litre.300 EB per day is the labor cost (LaC), and Dp stands for depreciation.

Experimental Design

A completely randomized design (CRD) was used in the experiment, which was replicated three times in accordance with the factorial experiment principle. There were three replications for each of the three feed rate and drum speed levels. With three replications and a total of 27 test runs (3*3*3 = 27), the experiment design was set up as (32).

Statistical Analysis of data

Genstat 15th edition software was used to statistically analyze the data using variance (ANOVA) and the least significant difference (LSD) test to evaluate the effect of variables and the differences between treatments at a 5% level of significance.

RESULTS AND DISCUSSION

This study aimed to modify an engine-driven soybean thresher's performance to a PTO-driven Faba bean thresher. In terms of threshing capacity (TC), threshing efficiency (TE), cleaning efficiency (CE), grain breakage percentage (GB), and grain loss percentage (GL), the perexamined as a function of feed rate (FR) and drum speed (DS). Faba bean crops had a grain straw ratio of 0.34:1 and a grain moisture content of 10.8% during the experiment.

The Effects of Drum Speed and Feed Rate on Threshing Capacity

Table 1 displays the relationship between threshing capacity and drum speed in faba bean crops at feed rates of 600, 720, and 840 kg/hr and drum speeds of 400, 450, and 500 rpm. The feed rate, drum speed, and the combination of feed rate and drum speed had a significant impact (p < 0.05), according to the analysis of variance (ANOVA). At a drum speed of 400 rpm and feed rate of 840 kg/hr, the maximum threshing capacity was found to be 442 kg/hr; at a drum speed of 500 rpm and feed rate of 600 kg/hr, the minimum threshing capacity was found to be 317.7 kg/hr. For the same increase in feed rate from 600 to 840 kg/hr, the threshing capacity increased from 368 kg/hr to 442 kg/hr at a drum speed of 400 rpm, from 361.7 to 416 kg/hr at a drum speed of 450 rpm, and from 317.7 kg/hr to 403.3 kg/hr at a drum speed of 500 rpm. This means that the grain is blown out by the air fan when the feed rate is constant and the drum speed is increased from 400 to 500 rpm. However, more grain was produced at the grain outlet when the drum speed remained constant and the feed rate was increased from 600 to 840 kg/hr. Feed rate, drum speed, and the combination of feed rate and drum speed had a significant impact on threshing capacity, according to the results of the ANOVA (p<0.05). Table 1 illustrates that as drum speed and feed rate increased, so did threshing capacity. In line with the results reported by Ali-Shamiry and Ali Yahya in 2020, grain output rose in tandem with an increase in feed rate.

The Effects of Drum Speed and Feed Rate on Threshing Efficiency

Table 1 shows the test results for feed rate and drum speed on the faba bean crop's threshing efficiency. ANOVA results showed that threshing efficiency was significantly impacted by feed rate, drum speed, and the combination of both (p < 0.05). Table 1 show that the maximum threshing efficiency of 99.81% was achieved

at a feed rate of 600 kg/hr and a drum speed of 500 rpm, while the lowest threshing efficiency of 98.64% was achieved at a feed rate of 840 kg/hr and a drum speed of 400 rpm. The threshing efficiency dropped from 99.73 to 98.64% as the feed rate increased from 600 to 840 kg/hr at a drum speed of 400 rpm. Likewise the threshing efficiency dropped from 99.78 to 99.24% when the feed rate increased

from 600 to 840 kg/hr at a drum speed of 450 rpm, and from 99.81 to 99.62% when the feed rate increased from 600 to 840 kg/hr at a drum speed of 500 rpm. This study found that increasing the drum speed while maintaining a constant feeding rate improved the threshing efficiency. This resulted from the crop materials being subjected to a high compaction shearing force during faster threshing.

Table 2: Interaction effect of Drum Speed and Feed Rate on performance of faba bean thresher

Drum Speed (rpm)	Feed Rate (Kg/hr)	TC (kg/hr)	TE (%)	CE (%)	GB (%)	GL (%)
400	600	368.0 ^e	99.73 ^c	97.90 ^d	0.00 ^g	1.54 ^f
	720	400.0 ^d	99.21 ^h	97.32 ^h	0.00 ^g	1.43 ^h
	840	442.0 ^a	98.64 ⁱ	97.01 ^{hi}	0.00 ^g	1.37 ^{hi}
450	600	361.7 ^f	99.78 ^b	98.17 ^b	0.64 ^d	1.64 ^d
	720	363.0 ^f	99.42 ^f	97.55 ^f	0.59 ^{dc}	1.56 ^e
	840	416.0 ^b	99.24 ^f	97.38 ^{fg}	0.56 ^{df}	1.49 ^{eg}
500	600	317.7 ^h	99.81 ^a	98.50 ^a	1.14 ^a	1.90 ^a
	720	356.7 ^g	99.71 ^{ad}	97.96 ^c	0.85 ^b	1.73 ^b
	840	403.3 ^c	99.62 ^{ac}	97.64 ^{cc}	0.75 ^c	1.65 ^c
CV (%)		1.7	0.1	0.2	15.4	2.7
LSD (5%)		11.18	0.19	0.34	0.13	0.07
SE(M)		3.73	0.06	0.11	0.04	0.02

TC stands for threshing capacity, TE for threshing efficiency, CE for cleaning efficiency, GB for grain breakage, GL for grain loss, CV for coefficient of variation, LSD for least significance difference, and the values are Mean ± SD. At a 5% level of significance, mean values compared in descending order and followed by the same letter in a column do not differ significantly.

The Effects of Drum Speed and Feed Rate on Cleaning Efficiency

Table 1 shows how feeding rate and drum speed affect cleaning effectiveness. The feed rate and drum speed had a significant impact on cleaning efficiency, according to the results of the ANOVA; however, the combination of both factors had no significant impact on cleaning efficiency ($p < 0.05$). At 500 rpm drum speed and 600 kg/hr feeding rate, the highest cleaning efficiency of 98.50% was achieved; at 400 rpm drum speed and 840 kg/hr feeding rate, the lowest cleaning efficiency of 97.01% was noted. At a constant drum speed, the cleaning efficiency dropped as the feeding rate increased from 600 to 840 kg/hr. However, when the drum's speed was increased from 400 to 500 rpm, the cleaning effectiveness rose. According to the results of Gbabo *et al.* (2013), Muhammad Bashir *et al.* (2018), and Ahmad *et al.* (2013), an increase in drum speed raised the machine's mean cleaning efficiency. Increasing the drum speed raises the blower speed, which produces a strong air blast and improves cleaning effectiveness. The overabundance of crops in the threshing chamber is the reason for the decline in the percentage of cleaning efficiencies by

increasing feeding rate.

The Effects of Drum Speed and Feed Rate on Grain Breakage

It is evident from (ANOVA) table 2 that the only factor that significantly affected grain breakage was drum speed. On the other hand, there was no discernible impact of feed rate or feed rate plus drum speed on grain breakage. At 500 rpm, the highest recorded breakage was 0.91%. At all feeding rates and a drum speed of 400 rpm, the lowest breakage was found to be 0.00%. The greater impact of the drum's pegs to separate the grain from the ear heads caused more grain breakage at higher speeds, as evidenced by the higher breakage percentage. These outcomes are comparable to those of Ishola *et al.* (2011).

The Effects of Drum Speed and Feed Rate on Grain Loss

From (ANOVA) table 1 and 2, It is evident that feed rate and drum speed had a big impact on grain loss. Conversely, there was no discernible impact on grain loss from the combination of feed rate and drum speed. Grain

Table 3: Main effect of drum speed and feed rate on machine performance

Drum Speed (rpm)	TC (kg/hr)	TE (%)	CE (%)	GB (%)	GL (%)
400	403.30 ^a	^{99.20} c	97.41 ^c	0.00 ^c	1.45 ^c
450	380.20 ^b	99.48 ^b	97.70 ^b	0.60 ^b	1.57 ^b
500	359.20 ^c	99.71 ^a	98.03 ^a	0.91 ^a	1.76 ^a
Feed rate (Kg/hr)					
600	349.10 ^c	^{99.77} a	98.18 ^a	0.60 ^a	1.69 ^a
720	373.20 ^b	99.45 ^b	97.61 ^b	0.48 ^b	1.57 ^b
840	420.40 ^a	99.20 ^c	97.34 ^c	0.44 ^b ^c	1.51 ^c
CV (%)	1.7	0.1	0.2	15.4	2.7
LSD (5%)	6.45	0.11	0.19	0.08	0.04
SE(M)	2.15	0.04	0.09	0.03	0.01

TC stands for threshing capacity, TE for threshing efficiency, CE for cleaning efficiency, GB for grain breakage, Gl for grain loss, CV for coefficient of variation, LSD for least significant difference, and the values are Mean ± SD. At the 5% level of significance, mean values compared in descending order and followed by the same letter in a column do not differ significantly.

Loss as it can be seen from the Table 1 the maximum grain loss of 1.90 % was recorded at 500 rpm of drum speed and 600 Kg/hr of feed rate. While a minimum grain loss of 1.37% was recorded at 400 rpm drum speed and 840 kg/hr feeding rate. As the feeding rate increased from 600 to 840 Kg/hr, at a drum speed of 400 rpm, the grain loss percentage decreased from 1.54 to 1.37%. Similarly, for the same range of feeding rate and at a drum speed of 450 rpm, the grain loss decreased from 1.64 to 1.49%. At a constant drum speed, the grain loss percentage decreased as the feeding rate increased, while at a constant feeding rate, the grain loss percentage increased as the drum speed increased. That may be due to the increment in drum speed which leads to more grain loss by blower.

CONCLUSION

The percentage of grain breakage, percentage of total grain loss, threshing capacity, threshing efficiency, and cleaning efficiency were determined based on the operational parameters of the machine, and the findings were statistically analyzed. The maximum threshing capacity of 442 kg/hr was observed at a combination of 400 rpm drum speed and 840 kg/hr feed rate, according to the impact of operational parameters on machine performance parameters. At 500 rpm and 600 kg/hr feeding rate, the highest threshing and cleaning efficiencies of 99.81 and 98.50%, respectively, were noted. At a feeding rate of 500 rpm and 600 kg/hr, the maximum grain loss and breakage of 1.90 and 1.14% were noted. Additionally, at the maximum drum speed and feed rate, the maximum fuel consumption during the threshing process was 1.92 lit/hr. The machine's threshing capacity,

threshing efficiency, and percentage of grain breakage all increased as drum speed and feeding rate increased, according to the results. On the other hand, when feed rate increased and drum speed increased while feed rate remained constant, cleaning efficiency and total grain loss decreased. Overall, the study's findings indicated that the modified and assessed threshing machine was effective and promising for the process of threshing faba beans. It is advised to use a combination of 450 rpm drum speed and 840 kg/hr feed rate to get the best results for threshing capacity, threshing efficiency, and cleaning efficiency.

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