Improvement of Asella Wheat and Barley Thresher

Gosa Bekele[1], Degefa Woyessa[2] and Wabi Tafa[3]

[1]Agricultural Machinery and Farm Power Engineering Research Case Team, Oromia Agricultural Research Institute, Asella Agricultural Engineering Research Center, Asella, Ethiopia.
[2]Agricultural Machinery and Farm Power Engineering Research Case Team, Oromia Agricultural Research Institute, Asella Agricultural Engineering Research Center, Asella, Ethiopia.
[3]Agricultural Machinery and Farm Power Engineering Research Case Team, Oromia Agricultural Research Institute, Asella Agricultural Engineering Research Center, Asella, Ethiopia.

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Abstract- Wheat and barley thresher was improved for its threshing capacity and suitability of operation and performance evaluation was done on wheat and barley crops. The size of previous wheat and barley thresher was increased and the feeding system that blows the dust outward to the operator was improved. The major components of the improved wheat and barley thresher include threshing unit, cleaning unit, feeding table, straw and chaff discharging unit and grain discharging unit. It was tested to thresh, separate and clean the wheat and barley seeds. The results showed that the machine had the maximum threshing capacity of 538 and 424 Kg/hr at feeding rate of 1000 Kg/hr and drum speed of 1100 rpm with grain straw ratio of 1:0.96 and 1:1.44 of wheat and barley crops respectively. The maximum threshing and cleaning efficiency of 98.95 and 99.93 %, 98.13 and 97.91 % and grain breakage of 0.52 and 1.06 % at above combination of 1100 rpm drum speed and 1000 Kg/hr feed rate for wheat and barley crops respectively. The maximum fuel consumption recorded were 0.73 and 0.60 liters per hour at moisture content of 12.5 and 11 % (d.b) at the combination of 1000 Kg/hr feed rate and 1100 rpm drum speed for wheat and barley respectively. The successful improvement of this machine is expected to reduce drudgery associated with the traditional method of threshing wheat and barley, and therefore increase productivity of farmers by reducing post-harvest losses.

Index Terms- Threshing, capacity, efficiency, breakage, wheat, barley, drum

I. INTRODUCTION

Crop production is the major part of agricultural production in Ethiopia and over 98% of this is produced by smallholder farming sector (UNDO, 2008). Barley and wheat usage ranges from being used as raw materials in industries for production of malt, beverages, beer, etc. to being consumed directly as food. Its post-harvest processing could be done through traditional method (manual) or modern method. However, manual system of threshing cereal failed to meet up with this growing demand of cereals and is labor intensive (Osueke, 2011). In this sector agricultural activities are done by traditional method in the country as a whole. In addition to tiresome of the activities, farmers are losing substantial parts of their product at each production steps.

In this method, about 40% of the total labor required to produce crop is extended in harvesting and threshing activities. The person hour per output of the method is very low, varying between 40 and 50 person hour per ton for both animal and manual threshing Johnson, (1992). However it is cheap, labor intensive and takes long time hence exposed to tremendous loss. The average post- harvest losses of food crops such as Teff, Wheat and Maize are annually 12.9%, 13.6% and 10.9% respectively Derege A. *et al*, (1989). Among this loss, threshing accounts for large place.

Threshing, the first major post-harvest operation, involves application of mechanical forces to detach grains from straws. The applied forces fall on the straws at random, breaking the straws stochastically, to free the enclosed grains. Some physical phenomena involved in threshing crops are: breakage of the grain pod which is dependent on the intensity of force, the orientation of the pod and moisture content; freedom of the grain from the straw and the passage of them through the concave Simonyan, (2006).

In order to address threshing problem of small- scale agriculture, many efforts have been made by different governmental and non-governmental organizations to replace traditional threshing with introduction of improved mobile threshers that can be locally developed or adopted. The development of mechanical threshers for the purpose has clearly an edge over conventional methods and has reduced the drudgery of work to a great extent. The use of these stationery threshing machines is based on the quick process, level of performance and economy. It is need of the hour to mechanize wheat threshing operation in order to recover better yield completing the operation timely (Ahmad, 2013). There are many factors affecting the performance of threshing machines such as cylinder peripheral speed, feeding rate and moisture content. (Mahmoud, 2007)

Different researchers try to design, develop, select, modify and evaluate many threshers for its performance based on evaluation parameters on cereal crops. Majumdar (1985), Morad (1997), Abdelghany and El-Sahar (1999), Gill *et al*. (2002), Behera *et al* (1990) and others are few of them.

Asella Rural Technology had modified and tested multi-crop thresher in 1982 and known as Asella wheat and barley thresher. The problem of this thresher is its durability and cleaning system. Brehanu Atomsa (2006) of Harar Rural Technology Research Center (HRTRC) currently called as Fadis Agricultural Research Center (FARC) is extensively working on cleaning efficiency and promising result was obtained. Asella agricultural mechanization research center currently Asella Agricultural Engineering Research Center (AAERC) had modified on durability and it was completely resolved but the size and dusting problem is not that much promising. This wheat and barley crop thresher pushes out ward the material when feeding. There is a full of dust that an operator face when working with the machine and it could not easily take in ward the material to be threshed because the feed inlet position is at the end center of threshing drum. Another problem is its low threshing capacity (200-300kg and 300-400kg) of wheat and barley respectively. Therefore, the aim of initiating this activity is to improve and evaluate for its performance of Asella wheat and barley thresher.

II. MATERIAL AND METHODS

1.1. Material

The material used for prototype production and performance evaluation were: angle iron, sheet metal, square pipe, pulleys, bearings, steel shaft, diesel engine, fuel, bolts and nuts, electrodes, flat iron, round bars, improved wheat and barley thresher, wheat and barley crops.

1.1.1. Instrument

The instruments used during performance evaluation and data collection were: digital balance, spring balance, tachometer, graduated cylinder for measuring fuel, oil and stopwatch.

1.2. Methods

1.2.1. Machine Description

Improved Asella wheat and barley thresher has the following components. These components are feeding table, threshing unit, cleaning unit, grain discharging unit, straw and chaff discharging unit. Threshing drum is made up of rolled sheet metal and steel shaft at the center. It has spike tooth and peg attached on the drum. Spike tooth type has attached on threshing drum with respective arrangement for facilitating straw motion and biting.

Figure1. Improved Asella wheat and barley thresher during performance evaluation

1.3. The threshing Parts Modified

1.3.1. Threshing drum

The principal parameters of the threshing drum are the drum length, the drum diameter, number of beaters on the drum and the drum speed Soja *et al. (*2004).

$$Q = q_o \, x \, L \, x \, M \quad (1)$$

Where:-Q = Feed rate of thresher (kg/s), q_o = Permissible feed rate (kg/s. m) and varies between 0.35 – 0.4; L = Drum length (m) and M = Number of (rows of) beaters.

The thresher was modified as follow: drum diameter increased from 200 mm to 300 mm, the number of beaters also increased from 36 to 48 and 26 to 35 for peg beater and chopper respectively. From equation 1, drum length and threshing capacity has direct relation between them so that increasing drum length and diameter increases the threshing capacity of machine.

1.3.2. Concave

Concave is the lower half of the drum which was served as the discharge through holes for the threshed crops. The clearance between threshing drum and concave was reduced from 45 to 25 mm. Length of the concave was also increased from 940 to 1000 mm. The upper half concave was served as the cover. It was made from rolled sheet metal and served as a cover for the crop material during threshed.

1.3.3. Fan

The air blast created by fan pushes the straw out of the thresher. The fan of wheat and barley thresher has four blades attached to fan shaft mounted on two bearings on each end side to allow free rotation. So, this fan will be improved based on aerodynamic properties of crop. Diameter of the fan increased from 250 to 350 mm and the length also increased from 975 to 995 mm. For agricultural applications, fan speeds are recommended to be between 450 and 1000 rpm (Adane, 2004).

1.4. Selection of Drive and Transmission

1.4.1. Selection of pulley diameters

The pulleys used in the drive system were made of cast iron. Pulley diameters were selected based on the need to reduce the engine speed to the required one. The following equation was used to determine pulley diameters.

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \quad (2)$$

Where: N_1 and N_2 are rpm of driving and driven pulleys; D_1 and D_2 are diameters of driving and driven pulleys

The values of D_1, D_2 and N_1 was 140 mm, 225 mm and 2500 rpm and the maximum determined value of N2 was equal to 1372.55 rpm

1.4.2. Selection of the drive

V-belt and pulley arrangements were used in this work to transmit power from the engine to the drum and fan shaft. The main reasons for using the v-belt drive was its flexibility, simplicity, and low maintenance costs. Additionally, the v- belt has the ability to absorb shocks there by mitigating the effect of vibratory forces (Khurmi and Gupta, 2005).

1.4.3. Determination of belt contact angle

The belt contact angle is given by the following equation (Khurmi and Gupta, 2005).

$$\varphi = Sin^{-1}\left(\frac{R-r}{C}\right) \tag{3}$$

The angles of wrap for the smaller and larger pulleys are determined by the following equation:

$$\alpha_1 = 180 - 2Sin^{-1}\left(\frac{R-r}{C}\right) \tag{4}$$

$$\alpha_2 = 180 + 2Sin^{-1}\left(\frac{R-r}{C}\right) \tag{5}$$

Where: R = radius of larger pulley, mm; r = radius of smaller pulley, mm; α_1 = angle of wrap for the engine pulley, deg; α_2 = angle of wrap for the drum shaft pulley, deg; C = is the center distance between the two center pulleys.

Therefore, by using the above equations the determined values of φ, α_1 and α_2 were 4.34^0, 171.32^0 and 188.68^0.

1.4.4. Determination of belt length

The length of belt appropriate to drive the system was calculated using the equation given below by Shigley and Mischike (2001).

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \tag{6}$$

$$L = 2*0.76 + \frac{3.14}{2}(0.255 + 0.14) + \frac{(0.255 - 0.14)^2}{4*0.76} = 2.144\,m$$

The closest standard length of the belt was selected from standard table and this value was 2101 mm. Since the belt is B type of V- belt we add to inside length 43 so, the exact length of v belt is equal to 2144 mm. Then the exact center distance was determined by the following equation (Khurmi and Gupta, 2005):

$$C = \frac{K + \sqrt{K^2 - 32(D_2 - D_1)^2}}{16} \tag{7}$$

$$K = 4L - 6.28(D_2 + D_1) \tag{8}$$

Where: L = belt length, m; C = center distance between pulleys, m; D_2 = pitch diameter of driven pulley, m; D_1 = Pitch diameter of driver pulley, m.

Since the calculated length of v belt is equal to the closest standard belt the exact center distance is also correct. Therefore, center distance was equal to 760 mm. Speed of the belt was calculated by using the following equation as given by Khurmi and Gupta (2005).

$$v = \frac{\pi D_1 N_1}{60} \tag{9}$$

$$v = \frac{3.14*0.14\,mm*2500\,rpm}{60} = 18.32\,m/s$$

This determined value was the highest for performing performance evaluation.

1.4.5. Bearing Selection

Bearing selection was made in accordance to American Society of Mechanical Engineers (ASME, 1995) standard as given by Hall *et al.* (1988). Therefore, UCP of 605 block bearing was selected.

1.4.6. Determination of Belt Tensions

To determine tensions on the tight and slack sides of the belt the following equations was used (Khurmi and Gupta, 2005).

$$T_1 = T - T_c \tag{10}$$

$$T = \sigma_{\max} a \tag{11}$$

$$T_c = mv^2 \tag{12}$$

Where: T_c and T= the centrifugal and maximum tension of the belts (N); T_1 and T_2 = tension in the tight and slack sides (N); σ max= maximum safe normal stress (N/mm^2); a = is cross sectional area of belt (mm^2); m = mass per unit length of belt (kg/m) and v = is speed of belt (m/s).

Values of σ_{max}, a and m are taken from standard tables. So their values were: 2.1 n/mm^2, 81 mm^2 and 0.108 Kg/m respectively. Since the pulley is double line the number of belts used was also two. Therefore, the values of of T_1, T and T_c determined by equations 10-12 were equal to 267.70, 340.20 and 72.50 N. For the smaller pulley, tension on the drum was equal to half of the bigger Pulley tensions because the belt is single line. Therefore, the values of these forces were 133.85, 170.10 and 36.25 N.

Tensions on the tight and slack sides of the belt were estimated using the equation given Khurmi and Gupta, (2005):

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu\alpha_1 \cos ec\frac{\beta}{2}} \tag{13}$$

Where: μ = coefficient of friction between a belt and a pulley; β = groove angle in deg. From design book = 40^0 and α_1 = angle of wrap on small pulley in rad.

It is determined by multiplying angle of wrap and π then divides to 180^0 so the result is equal to 2.9886. Finally the value of T_2 is equal to 160.67 N. again for the smaller pulley T2 was equal to half of the bigger pulley since the belt is single and it was equal to 80.34 N.

According to Khurmi and Gupta (2005) torsional moment (T_r) due to double belt and single belt tensions was determined using the following equation.

$$T_r = (T_1 - T_2)\frac{D_2}{2} \tag{14}$$

Where: T_1 = tension on tight side of a belt (N); T_2 = tension on slack side of a belt (N) and D_2 = is the diameter of driven pulley (m).

Therefore, the determined value of T_r was equal to 13.65 Nm.

1.4.7. Shaft diameter determination

Shaft must have adequate torsional strength to transmit torque and not over stressed. The diameter of the threshing drum and fan shaft was determined using maximum shear stress theory. It was mounted on bearings and transmits power through v- belts and pulleys. The threshing drum shaft was supported by two bearings (R_1 & R_2). On this shaft there was a load of threshing drum with beaters and crop materials that were uniformly distributed along the section of shaft (F). Pulleys (P) were placed at a specified distance to the left having specified weight each and tension forces due to belts.

The total bending moment was determined by using the following equation.

$$M = \sqrt{M_V^{\,2} + M_H^{\,2}} \qquad (15)$$

Where: M_V = vertical bending moment, Nm and M_H = horizontal bending moment, Nm

During force analysis the maximum bending moment of drum shaft was observed at bearing nearest to the single line pulley and the vertical and horizontal bending moment was equal to 37.04 Nm and 1 Nm respectively. Therefore, from the above equation bending moment was equal to 37.05 Nm.

According to (ASME) code (ASME, 1995); the diameter of threshing shaft was calculated using theory of maximum shear stress.

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

Where: - d = Shaft diameter, Ss = Allowable shear stress for shaft ($42N / mm^{2)}$ from design book, K_b = Shock factor for bending moment = 2, K_t = Shock factor for torsional moment = 2, M_b = Maximum bending moment (N. m), T= Maximum torque (N. m) and *fs* = factor of safety which is = 3 for agricultural equipment's. Finally a shaft diameter of 31 mm was determined and the standard shaft diameter selected was equal to 35 mm.

1.5. Working Principle

The crop material put on the feeding table is pushed into the inlet of drum when engine put on. The drum which gets power from an engine rotated in the concave is used to thresh the crop material. As the crop threshed, grain passes to grain outlet and straw to straw outlet. The grain passed through a concave fall on grain collector and discharged to outside the machine. The straw, chaff and unwanted materials are passed to straw outlet by the help of air pressure created by blower and systems applied on the drum due to peg and chopper arrangements. Blower and drum shaft consist of pulleys at one of their end. Pulleys on each shaft are connected together with the help of belt to transmit power to each shaft.

1.6. Collected Data

The following data were collected during performance evaluation of improved Asella wheat and barley thresher. Technical specification, threshing capacity, threshing efficiency, visible grain breakage, grain– straw ratio, grain loss and optimum number of labors required to operate.

1.7. Performance Evaluation

The following parameters were determined during performance evaluation of this improved Asella wheat and barley crop thresher. Some of these parameters were: threshing capacity, threshing efficiency, grain breakage, cleaning efficiency, grain loss.

a) Threshing capacity (kg/hr)

The weight of grains (whole and damaged) threshed and received per hour at the main grain outlet was called capacity. At the end of each test, total threshed grain was collected from the main grain outlet. The capacity will be calculated from the following equation:

$$T_c = \frac{W_g}{t} \times 60\,\mathrm{min}/\,hr$$

(17)

Where: - Tc- threshing capacity (kg/hr); W_g – Weight of threshed grain at main outlet (kg) and t – Recorded time of threshing (min)

b) Threshing efficiency (% TE)

Threshing efficiency is the ability of the thresher that separating the grain from the straw and the stuck correctly. It was calculated according to the following equation:

$$\%\,TE = \frac{T_G - Un_G}{T_G} \times 100$$

(18)

Where: T_G = Weight of total grains input per unit time, kg and Un_G = Weight of un-threshed grains per unit time, kg.

c) Cleaning efficiency (% CE)

It is the ability of the thresher that can separate grain from the chaff and straw and calculated according to the following equation

$$\%\,CE = \frac{W}{W_O} \times 100$$

(19)

Where: W = Weight of grains from the main output opening after cleaning, kg and W_O = Weight of grains and small chaff from the main output opening, kg.

d) Broken/damaged grain (% GB)

All physically damaged/broken grains were visually observed, manually sorted and weighed using digital balance. Damage due to mechanical threshing was determined as the ratio of weight of the actual damaged kernels to the weight of a sample taken.

$$\%\,GB = \frac{W_b}{W_s} x100$$

(20)

Where:- W_g – percentage of broken grain; W_b – weight of broken (damaged) grains (g) and W_s – Weight of sample taken (g)

e) Grain-Straw Ratio

Grain-straw ratio was determined by taking the sample of material that was threshed. The samples is placed in sealed plastic containers and taken to the laboratory where the grains and straw are separated by hand. The straw and grains from each sample was kept paired. After weighing, the samples was dried to specific hours and then reweighed.

1.8. Experimental Design

The experimental design was a split-split plot design according to the principle of factorial experiment with three replications. The two levels of crop types was assigned to main plot, the three levels of threshing drum speed was assigned to sub plot, while the three levels of feeding was assigned to sub-sub plot, each with three replications. The experiment design was laid as 2*3*3 with three replications and had total of 54 test runs (2*3*3*3 = 54)

1.8.1. Statistical Analysis

The data were subjected to analysis of variances following a procedure appropriate for the design of the experiment (Gomez and Gomez, 1984) and using GenStat 15th edition statistical software. The treatment means that were different at 5% levels of significance were separated using least significant difference (LSD 5%) test. The least significant difference (LSD) test was performed for the mean values of threshing capacity, threshing efficiency, cleaning efficiency, percentage of visible grain breakage and percentage of grain loss in relation to crop type, threshing drum speed and crop feeding level.

III. RESULTS AND DISCUSSION

This study was undertaken to improve and evaluate the performance of a thresher prototype capable of threshing wheat and barley crops at three level of drum speed and three feeding level. Performance indicators such as threshing capacity (TrC), threshing efficiency (TrE), cleaning Efficiency (ClE), percentage of visible grain breakage (GrB) and percentage of grain loss were used to assess functional fulfillment of the improved thresher. The result obtained were analyzed and discussed under the following heads.

1.9. Effects of Drum Speed and Feed Rate on Performance Parameters of Improved Thresher

i. Threshing Capacity

Table 1 showed the relation between drum speed and threshing capacity in wheat and barley crop at drum speed of 900 rpm, 1100 rpm, and 1300 rpm and feed rates of 800, 900 and 1000 Kg/hr. The maximum threshing capacity was observed to be 538 and 424 Kg/hr at drum speed of 1100 rpm and feed rate of 1000 Kg/hr and minimum threshing capacity was 408 and 316 Kg/hr at drum speed of 900 rpm and feed rate of 800 Kg/hr for wheat and barley crop respectively. As the feed rate increased from 800 to 1000 Kg/hr, the threshing capacity increased from 408 to 514.67 Kg and 316 to 408 Kg at 900 rpm drum speed for wheat and barley respectively. Similarly for the same range of feed rate the threshing capacity increased from 410.67 to 538 Kg and 326.67 to 424 Kg; 408 to 536 Kg and 322.67 to 426 Kg at drum speed of 1100 rpm and 1300 rpm, for wheat and barley respectively and which is similar to the finding of Behera *et al* (1990) and Chukuwa (2008).

Table 1. Effect of drum speed and feed rate on performance evaluation of improved thresher on wheat and barley crop (moisture content 12.5 % and 11 % and grain straw ratio of 1:0.96 and 1:1.44 respectively)

Drum speed (rpm)	Feed Rate (Kg/hr)	Threshing Capacity (Kg/hr)		Threshing Efficiency (%)		Cleaning Efficiency (%)		Grain Breakage (%)		Fuel consumed (Lit)	
		Wheat	Barley	Wheat	Barley	Wheat	Barley	Wheat	Barley	Wheat	Barley
900	800	408	316	99.81	99.84	96.27	90.26	0.0955	0.07	0.60	0.54
	900	462.67	364	99.91	99.87	97.23	93.02	0.41	0.32	0.62	0.60
	1000	514.67	408	99.93	99.91	97.7	93.05	0.5	0.41	0.77	0.72
1100	800	410.67	326.67	99.85	99.87	96.67	96.97	0.14	0.53	0.53	0.48
	900	485.6	372	99.93	99.91	97.78	97.51	0.44	0.82	0.59	0.55
	1000	538	424	99.95	99.93	98.13	97.91	0.52	1.06	0.73	0.60
1300	800	408	322.67	99.83	99.85	97.37	94.77	0.233	0.83	0.56	0.56
	900	478.67	369.33	99.92	99.89	98	96.05	0.467	1.31	0.62	0.63
	1000	536	416	99.95	99.92	98.4	96.41	0.597	1.62	0.70	0.70

Results of the analysis of variance (ANOVA) revealed that the feed rate and crop type had significant effect ($p < 0.05$) whereas drum speed, interaction of crop type and drum speed, interaction of crop type and feed rate, interaction of drum speed and feed rate, and interaction of crop type, drum speed and feed rate had no significant effect ($p > 0.05$) on threshing capacity.
Table 2 show the effect of threshing drum speed, feeding rate, crop type and the combined effect of drum speed and feed rate on mean threshing capacity.

Parameter	Source of variation			Measure of differences	
	Drum Speed (DrS)	Crop type (CrT)			
		Wheat	barley	LSD (5%)	SE(M)
	900	461.8^{a}	362.7a	15.13	4.80
	1100	482.5^{b}	368.7a		
	1300	474.2ab	369.3a		
	Feeding rate (FR)	Wheat	barley		

TrC (Kg/hr)	800		413.3^{a}	321.8^{a}	12.65	4.27
	900		475.6^{b}	362.9^{b}		
	1000		529.6^{c}	416.0^{c}		
	Interaction(DrS*FR)				17.07	5.90
		800 Kg/hr	900 Kg/hr	1000 Kg/hr		
	900 rpm	362.0^{a}	413.3^{b}	461.3^{c}		
	1100 rpm	375.3^{a}	420.5^{b}	481.0^{d}		
	1300 rpm	365.3^{a}	424.0^{b}	476.0^{cd}		

Means followed by the same letters do not have significant difference at 5% level of probability

Threshing Efficiency

The test result of feed rate and drum speed on threshing efficiency for wheat and barley has been given in the Table 1. It is evident from the Table that the maximum threshing efficiency 98.95 % and 99.93 % was obtained at the 1000 Kg/hr of feed rate and 1100-rpm speed for wheat and barley respectively. While the minimum threshing efficiency of 99.81 % and 99.84 % was obtained at the feed rate of 800 Kg/hr and drum speed of 900 rpm for wheat and barley respectively. As the feed rate increased from 800 to 1000 Kg/hr, the threshing efficiency increased from 99.81 % to 99.93 % and 99.84 % to 99.91 % at 900 rpm drum speed for wheat and barley respectively. Similarly for the same range of feed rate the threshing efficiency increased from 99.85 % to 99.95 % and 99.87 % to 99.93 %; 99.83 % to 99.95 % and 99.85 % to 99.92 % at drum speed of 1100 rpm to and 1300 rpm, for wheat and barley respectively and which is similar to the findings of Behera *et al* (1990).

The analysis of variance (ANOVA) revealed that drum speed and feeding rate had significant effect ($p < 0.05$) whereas crop type and the interaction of crop type and drum speed, interaction of drum speed and feed rate, interaction of crop type and feed rate and interaction of crop type, drum speed and feed rate had no significant effect ($p > 0.05$) on threshing efficiency. Table 3 show the effect of drum speed, feeding rate, crop type and the combined effect of drum speed and feed rate on mean threshing efficiency.

Table 3. Means of threshing drum speed, feeding rate, crop type and their interaction on threshing efficiency

Parameter	Source of variation				Measure of differences	
	Drum Speed (rpm)		Crop type			
			Wheat	Barley	LSD (5%)	SE(M)
TrE (%)	900		99.8178 a	99.8756 a	0.05919	0.01420
	1100		99.9100 b	99.9044 a		
	1300		99.8989 bc	99.8878 a		
	Feeding rate (Kg/hr)		Wheat	Barley	0.05677	0.01665
	800		99.8333 a	99.8567 a		
	900		99.8511 a	99.8911 ab		
	1000		99.9422 b	99.9200 b		
	Interaction(drum speed*feed rate)				0.04357	0.01510
		800 Kg/hr	900 Kg/hr	1000 Kg/hr		
	900 rpm	99.8283 ab	99.7900 b	99.9217 c		
	1100 rpm	99.8633 a	99.9200 c	99.9383 c		

	1300 rpm	99.8433 a	99.9033 c	99.9333 c		

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

ii. Cleaning efficiency

The relationship between feed rate, drum speed and cleaning efficiency is presented in the Table 1. The maximum cleaning efficiency of 98.40 % and 97.91 % was obtained at 1000 Kg/hr feed rate and 1300 and 1100 rpm of drum speed for wheat and barley crops respectively, whereas a minimum cleaning efficiency of 96.27 % and 90.26 % was obtained at 800 Kg/hr feed rate and 900 rpm of the drum speed for wheat and barley respectively. As the feed rate increased from 800 to 1000 Kg/hr, at drum speed of 900 rpm, the cleaning efficiency increased from 96.27% to 97.23 % and 90.26 % to 93.05 % for wheat and barley respectively. Similarly for the same range of feed rate the cleaning efficiency increased from 96.67 % to 98.13 % and 96.97 % to 97.91 %; 97.37 % to 98.40 % and 94.77 % to 96.41 % at drum speed of 1100 rpm and 1300 rpm, for wheat and barley respectively. Above results revealed that for all set of observations minimum and maximum cleaning efficiency were obtained at the feed rate of 800 and 1000 Kg/hr respectively. The cleaning efficiency increased with increasing in speed of the drum from 900 to 1300 rpm for wheat and increased from 900 rpm to 1100 for barley. However, at 1300 rpm drum speed, cleaning efficiency is below drum speed of 1100 rpm for barley.

As evident from Table 1 that with increased in drum speed the cleaning efficiency increased. Since the speed of blower increased with drum speed, the cleaning efficiency was also affected considerably. The increase of the drum speed causes increase of blower speed, resulting high air blast, thereby increased the cleaning efficiency.

Result of the analysis of variance (ANOVA) revealed that drum speed, feeding rate and the interaction of crop type and drum speed had significant effect ($p < 0.05$) on cleaning efficiency. On the other hand crop type and the interaction of crop type and feed rate, interaction of drum speed and feed rate, interaction of crop type, drum speed and feed rate had no significant effect ($p > 0.05$) on cleaning efficiency.

Table 4 show the effect of cylinder speed, feeding rate, crop type and the combined effect of drum speed and feed rate on mean cleaning efficiency.

Table 4. Means of threshing drum speed, feeding rate, crop type and their interaction on cleaning efficiency

Parameter	Source of variation			Measure of differences	
	Drum Speed levels (rpm)	Crop type			
		Wheat	barley	LSD (5%)	SE(M)
ClE (%)	900	97.07^{a}	92.11^{a}	1.018	0.319
	1100	97.53^{a}	97.46^{b}		
	1300	97.92^{a}	95.74^{c}		
	Feeding rate (Kg/hr)	Wheat	barley	1.053	0.354
	800	96.77^{a}	94.00^{a}		

	900		97.67^{a}	95.53^{bc}		
	1000		98.08b	95.79^{c}		
	Interaction(drum speed*feed rate)				1.253	0.435
		800 Kg/hr	900 Kg/hr	1000 Kg/hr		
	900 rpm	93.27^{a}	95.13^{d}	95.38^{d}		
	1100 rpm	96.82^{bc}	97.64^{b}	98.03^{b}		
	1300 rpm	96.07^{cd}	97.03^{bc}	97.40^{b}		

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

iii. *Grain Breakage*

Table 1 showed the relation between drum speed, feed rate and grain breakage in wheat and barley crops at the drum speed of 900 rpm, 1100 rpm and 1300 rpm and feed rate of 800, 900 and 1000 Kg/hr. The maximum breakage observed to be 0.597 and 1.62 % at higher drum speed of 1300 rpm and feed rate of 1000 Kg/hr for wheat and barley crops respectively. There was moderate breakage at drum speed of 1100 rpm and minimum breakage of 0.0955 and 0.070 % were obtained at drum speed of 900 rpm and feed rate 800 Kg/hr for wheat and barley respectively. More grain breakage at higher speed was due to greater impact by pegs of drum to detach the grain from ear heads, which reflected in the increase of breakage percentage at higher speed.

Result of the analysis of variance (ANOVA) revealed that drum speed, feeding rate and the interaction of crop type and drum speed had significant effect ($p < 0.05$) whereas crop type, interaction of crop type and feed rate, interaction of drum speed and feed rate and interaction of crop type, drum speed and feed rate had no significant effect ($p > 0.05$) on threshing efficiency. Table 5 show the effect of drum speed, feeding rate, crop type and the combined effect of drum speed and feed rate on mean grain breakage.

Table 5. Means of threshing drum speed, feeding rate, crop type and their interaction on Grain Breakage

Parameter	Source of variation				Measure of differences	
	Drum Speed level (rpm)		Crop type			
			Wheat	barley	LSD (5%)	SE(M)
GrB (%)	900		0.327^{a}	0.266^{a}	0.1732	0.0513
	1100		0.366^{a}	0.802^{b}		
	1300		0.432^{a}	1.251^{c}		
	Feeding rate (Kg/hr)		Wheat	barley	0.1925	0.0637
	800		0.147^{a}	0.474^{a}		
	900		0.439^{b}	0.816^{b}		
	1000		0.539bc	1.029^{c}		
	Interaction(drum speed*feed rate)				0.2078	0.0721
		800 Kg/hr	900 Kg/hr	1000 Kg/hr		
	900 rpm	0.070^{a}	0.363^{b}	0.455^{b} c		
	1100 rpm	0.332^{b}	0.632^{ce}	0.788^{de}		
	1300 rpm	0.530bc	0.887^{d}	1.108^{f}		

Means followed by the same letter (or letters) do not have significant difference at 5% level of probability.

1.10. Conclusion and Recommendation

1.10.1. Conclusion

The performance evaluation of improved wheat and barley thresher was conducted under farmers' field. The following are the main conclusions drawn from the study. The grain straw ratio of wheat and barley crops at which performance evaluation of the thresher performed is 1:0.96 and 1:1.44 respectively. The maximum threshing capacity was found 538 and 424 Kg at drum speed of 1100 rpm and feeding rate of 1000 Kg/hr for wheat and barley crop respectively. The threshing and cleaning efficiency were 98.95 and 99.93 %, 98.13 and 97.91 % for wheat and barley crops respectively and grain breakage were 0.52 and 1.06 % at above combination of speed and feed rate for wheat and barley crops respectively. As compared to the previous thresher the improved one had more than 200 Kg/hr threshing capacity. The maximum fuel consumption of the engine was equal to 0.77 and 0.72 liter for wheat and barley at the maximum drum speed and feed rate respectively.

1.10.2. Recommendation

From the study result improved wheat and barley thresher was more effective and efficient than the previous thresher for its capacity and suitability of operation. Farmers must used combination of 1100 drum rpm and 1000 Kg/hr feed rate in order to get high values of threshing capacity, threshing efficiency and cleaning efficiency based on crop moisture.

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AUTHORS

First Author – Gosa Bekele, BSc. in Agricultural Engineering and Mechanization and MSc. In Agricultural Machinery Engineering, email gosaagem@gmail.com

Second Author – Degefa Woyessa, BSc. in Agricultural and Bioprocess Engineering, E-mail: degefawoyessa20007@gmail.com

Third Author – Wabi Tafa, BSc. in Agricultural and Bioprocess Engineering, E-mail: wabitafa@gmail.com

Correspondence Author – Gosa Bekele, contact number +251912263915