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Improvement of IITA Multi-crop Thresher for Sorghum Threshing

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Abstract

The improved small-engine driven sorghum thresher was produced at Fadis Agricultural Research Center with an intention to solve critical threshing problem of farmers consecutively reducing cost of threshing, labor power and grain loss. The machine was produced in the work shop according to its improved design of drum; concave, and other machine parts. Drum and concave diameter, length, thickness of row materials made of and other machine parts were diminished. Consequently the weight of the machine and its cost was decreased. The machine was tested in East Hararghe Zone, Haramaya District at a place called Ganda Haqaa. The variables considered were grain variety (Muira and Fendisha), three levels of drum speed (500,700 and 900 rpm), three concave clearances (15, 19 and 23 mm) and three feed rates (30, 45 and 60 kg/min).The selected experimental design was split-split plot design with three replications. During testing grain moisture content was maintained at 14-16% wet basis. After the test it was observed that the threshing efficiency varied from 88.97 to 97.08%. The obtained output capacities were between 6-8.36 qt/h for the evaluated two sorghum varieties. The average specific fuel consumption was acquired 0.096 lit/qt and 0.103 lit/qt for Muira and Fendisha respectively.

Keywords: Sorghum; threshing; threshing machine; Improvement; threshing performance/ efficiency.

1. Introduction

Within cereal crops, Sorghum has been important staple in the semi-arid tropics of Asia and Africa for centuries. This crop is still the principal sources of energy, protein, vitamins and minerals for millions of the poorest people in these regions (FAO, 1995). In Ethiopia sorghum covered 15 % (1.88 million hectares) of the total grain area. As to production, it contributed 16% (47.52 million quintals), for 5,987,038 private peasants holding and that gives yield per hectare was 25.25qt (CSA, 2017).

Threshing of sorghum can be done traditionally or mechanically. The traditional method of grain separation is laborious, time consuming and uneconomical. This method of threshing consumes more time, compared to mechanical threshing method. Traditional threshing method also causes grain loss, to the extent of 6% (Miah et al. 1994). In survey, it is established that the farmers, especially the women are very keen to adopt mechanical means of threshing to replace traditional one (Khan et al. 2007). Even though, in the country, for mechanical threshing, the technologies like combine harvesters, RF-450 multi-crop thresher, hand operated sorghum thresher, IITA (International Institute of Tropical Agriculture) multi-crop thresher and other threshers are available in limited quantity, their un-appropriation for farmers limit their promotion and utilization.

Combine harvester and RF-450 have good efficiency and high output capacity; however they are imported with hard currency from abroad. So, their purchase price and operation cost is high. Additionally they are complex in operation, repair and maintenance at farmer's level. Due to, the big size of these machines, as compare to the small sizes of the plots plus highly sloppy the topography of the region, make them unsuitable for operation and transportation.

On the other hand, the hand operated sorghum thresher which was developed in our center found to be better in threshing capacity (average 3.37qt/h) as compared to threshing done by hand. Its average threshing efficiency is 93.72%. As the machine is hand operated, it is tire some for the people to use it continuously and the capacity and efficiency will be diminished in prolonged use (Tekalign et al. 2017).

The IITA-multi crop thresher first modified by Selam Vocational Training Center from initially developed by International Institute of Tropical Agriculture (IITA) in Nigeria and imported by SG-2000 was evaluated for sorghum threshing. The evaluation was made in Eastern Oromiya Region of Ethiopia in Haramaya District. Two local sorghum varieties widely produced by the farmers were used. The result obtained were the minimum and maximum mean overall efficiency 64.17 and 79.03%, respectively, while maximum mean threshing efficiency of 87.94% was recorded for the main effect of the feed rate at 8 kg/min. with 11.15% of damaged grains and 9.73% of the grains in their glumes while the total grains loss was 24.33%. The overall analysis of the result indicated very low efficiency and unacceptable level of performance for threshing of these two sorghum local varieties, namely *Muyriya and Fandisha* (Birhanu et al. 2010). Good thresher must be able to have minimum threshing efficiency of 95% with minimal separation losses that is not exciding 2%. The threshed grain should be clean and with the list amount of broken grains and the seeds with glumes not exceeding 5%. The grain containing glumes after having passed through the thresher was considered un-threshed (Singhal et al. 1987).

Thus, the IITA thresher is also inappropriate for its inefficiency (below the optimal value) that is more un-threshed and grain with glum was seen on threshed grain. Moreover the machine works with minimum engine speed otherwise, breakage of the grain is very high. Even with this minimum speed there was grain breakage. Because of these drawbacks practically farmers are not seen using for sorghum threshing. Therefore, improvement of IITA multi crop thresher for sorghum threshing is very important.

Thus, the objective of this work was:-

- To improve the IITA multi crop thresher, so that it fits to the local condition.
- To evaluate the performance of the machine

2. Materials and methods

2.1. Experimental material

The experimental materials were the improved thresher and sorghum. Two varieties of sorghum, *Muira* and *Fendisha* were used during the experiment.

2.2. The improvement work done

The improvement of the machine was done considering, the topography of the region, size of grain production and cost of production of the machine. Since the topography of the study area is hilly and has up and downs, the improved machine size made was small. The machine was produced in the work shop according to its improved design of drum; concave, and other machine parts. Drum and concave diameter, length, thickness of row materials made of and other machine parts were reduced. Consequently the weight of the machine and its cost was decreased. To improve threshing efficiency of the IITA multi-crop thresher for sorghum threshing the drum design was made using Ivanov *et al.* (Ivanov et al. 1979), formula. Also the concave design was changed and on the concave part, wire mesh was built-in which is not found on IITA thresher. The improved drum and concave were shown in fig.2 and 3 below. Both the IITA and The improved machines do not incorporate cleaning system.

2.3. The dimensions of finger types drum

To do distribution of fingers on the drum plate surface the fallowing parameters should be determined (See figure1). The diameter of finger types drum (D) is determined by the formula (Ivanov et al. 1979)

$$D = \frac{M\, t_i}{\pi} + 2\, h \qquad (1)$$

Where:

M= number of plates for finger type drum.

t_i = space between plates mm.

h = the height of the finger mm.

$\pi = 3.14$

The length of finger type drum is determined by

$$L_w = \left(\frac{Z}{K} - 1\right) a \qquad (2)$$

Where:

Z = number of teeth on the drum.

K = number of gaps screw line.

a = space between teeth on drum mm.

The amount of Z depends up on production of the drum m_1 and restricted feed of grain weight for one teeth m_o

$$Z = \frac{m_1}{m_0} \qquad where: m_1 = 0.05 kg/\sec \qquad (3)$$

The amount of m_o for normal condition is given 0.00104667 - 0.035 kg/sec. Number of gaps K is given 2, 3, 4, and 5 high values are taken for more productive drum. The plate length of drum (L_π) can be calculated by the formula

$$L_\pi = L_w + 2\Delta L \qquad \text{Where: } \Delta L = 18 - 12 \text{ mm} \qquad (4)$$

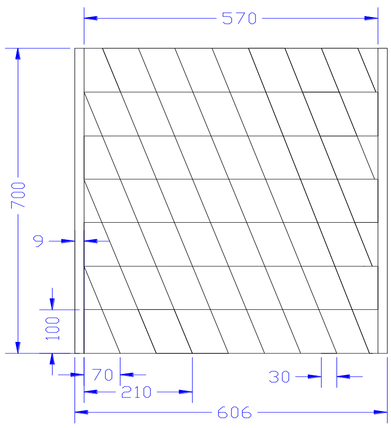

Figure-1.Distribution of teeth on the drum plate surface (Source: own computation, 2018)

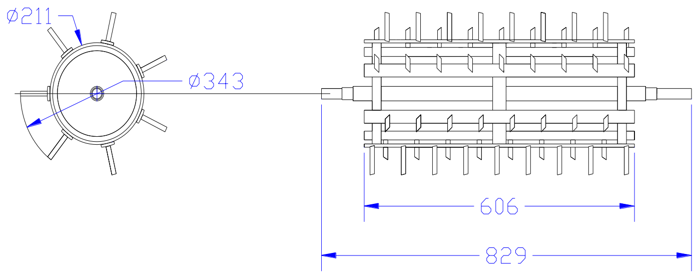

Figure.2. Peg type threshing drum (Source own computation, 2018)

2.4. Description of the machine

The improved machine was designed and developed in the FARC (Fedis Agricultural Research Center). It is a stationary wheel supported and usually pulled by a farmer, which can be moved from place to place by single person. The thresher is consist of the following components:-feeding chute, drum, concave, upper and lower cover, pulleys, stand, transportation wheel, straw discharging outlet and grain outlet. The overall size of the machine is 1130 mm height, 1340 mm length and 840 mm width. Whereas, that of IITA is 1530 mm height, 1460 mm length and 1560 width.

Threshing drum: - The threshing drum has seven row plates which are 6 mm thickness by 20 mm width and 606 mm length made of flat iron sheet. The plates are fixed on top of three wings which are situated along the length of a shaft one in the middle and the other two at the outer side. The two ends of the drum are closed with sheet metal. The shaft is supported on two ball bearings mounted on the surface of the machine frame. It has 30 mm diameter and 829 mm length. The drum outside diameter and length are 343 and 606 mm, respectively. It has 59 corrugated pegs that are disposed along the length of the plates in helical arrangement for better beating and rasping action. The peg's height is 60 mm and its diameter12 (see figure 2 above). While, the IITA thresher shaft diameter is 35 mm and has length 1100 mm. Its drum diameter and length are 455 mm and 800 mm respectively.

Concave: - It is made from iron sheet, reinforcement bar, round bar, angle iron, flat iron and wire mesh. Its length is 626 mm its radices goes decreasing from inlet side 211 up to outlet side 202 mm at the center (in the middle) it has 206 mm (see fig.3 below). The wire mesh has square shaped hole and which is 8 mm by 8 mm size through which the threshed grains are dropped on to grain collector. Straws and chaffs those can't pass through wire mesh were pushed by pegs and thrown out through the straw outlet. On the other hand, the IITA multi-crop thresher has 910 mm concave length and 610 mm concave width.

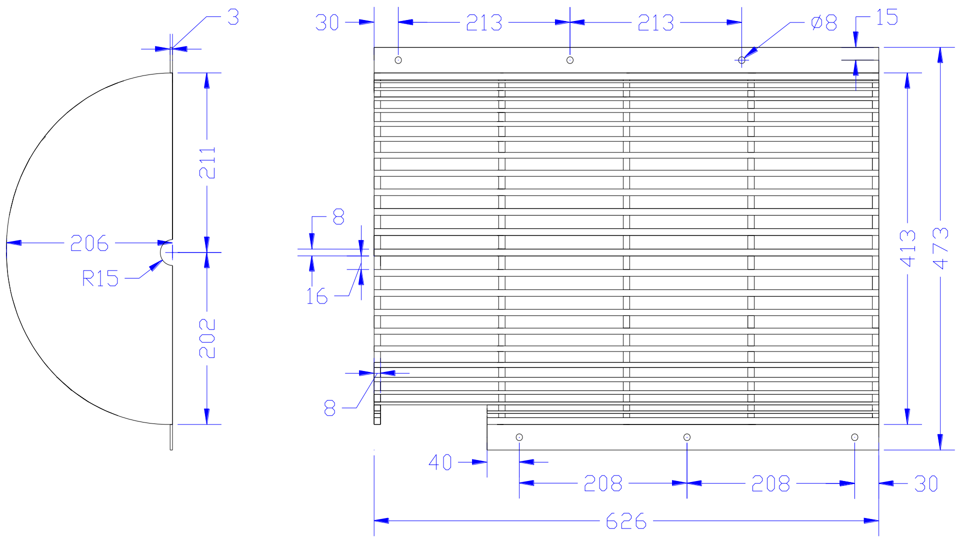

Figure-3.Concave side and top view (Source own computation, 2018)

2.5. Power required to combing off grains from sorghum head

The power required to thresh grains from the glum of sorghum heads is expressed as (Khurmi et al. 2005):

$$P = T_t * \omega \tag{5}$$

Where,

P = is the power required (watts)

T_t = torque of the drum (Nm)

ω = angular velocity (rad/s)

$$\omega = \frac{2\,\pi\,N}{60} \tag{6}$$

Where:

N = speed of the threshing drum (rpm)

F = the impact force required to thresh sorghum (N)

r = the distance of point of force application from axis of rotation (m)

The torque resulting from individual force is given by:

$$T = F_i \times r_i \tag{7}$$

Where, F_i and r_i force and radius, respectively

Total torque (T_t) on the drum was calculated as follows:

$$T_t = T \times K_b \tag{8}$$

Where, K_b = the number of pegs on the drum

Torque, $T = F_r$ (9)

Assuming that force acts per unit length of tong, taking force per 10 mm segment of length.

$$F_t = F/10\ mm = 0.1\ F/mm \quad (10)$$

The torque resulting from individual force is given by,

$$T = F_i \times r_i \quad (11)$$

Where, F_i and r_i and i^{th} force and i^{th} radius, respectively.

Resultant torque

$$T = F_1 r_1 + F_2 r_2 + \ldots\ldots + F_i r_i = \sum_{i=1}^{i=n} F_i\ n \quad (12)$$

Where,

n = number of length segments given by, torque required to combine off grains from straw and glum

This is set by, $P = T_t\ \omega$ (13)

Where ω = angular velocity in rad S^{-1}

2.6. Experimental site

The performance test of the machine was done in East Hararghe Zone, Haramaya district at the place known as *Ganda Haqa*, which is near *Aboday town*. The site is the major sorghum growing area in the Zone.

2.7. Experimental method

The experiment was done using the farmer's harvest at grain moister content ranging between 14-16%. The moister content of the grain was determined by moister tester called Dole–400. Grain straw ratio was determined by weighting the sample grain and straw. The thresher is equipped with 5HP Honda engine and its fuel consumption liter per quintal was calculated. Two sorghum varieties; *Muira* and *Fendisha*, three concave clearances 15, 19 and 23 mm, three levels of drum speeds 500,700 and 900 rpm and three levels of feed rates 30, 45 and 60 kg/min were selected for the test. The threshing time was recorded by a stopwatch for each test run. The grain was collected at main outlet and straw outlet. Three samples were taken from each test of grain and straw outlet. From each sample clean, with glum, un-threshed and broken grain were separated, weighed and recorded. The above procedure was repeated thrice for all parameter combination tests.

2.7.1. Threshing efficiency

The formulae used (Agidi et al. 2013) in computing the threshing efficiency, threshing capacity and the percentage damaged grain as follow: Threshing efficiency (T_e): It is the ratio of the mass of threshed sorghum to the total mass of the sorghum heads expressed in percentage and is given as:

$$T_e = \frac{M_t}{M_a} \quad (14)$$

Where,

T_e= the threshing efficiency (%)

M_t = mass of threshed sorghum (g)

M_a= the total mass of grain head (g)

2.7.2. Threshing capacity

Capacity (kg/h): machine capacity was calculated as follows:

$$C = \frac{M}{t} \quad (15)$$

Where:

C = machine capacity (kg/h)

M = the mass of total yield (kg)

t = the time utilized in threshing operation (h)

2.7.3 .Grain damage

Damaged grain was calculated as follows (%):

$$\text{Damaged grain} = \frac{D_g}{T_g} \quad (16)$$

Where,

D_g = Mass of damaged grain kg

T_g= Total mass of grain, kg

2.8. Experimental design

The selected experimental design was R.C.B.D (Randomized Complete Block Design) factorial design with three replications. This design was selected to analyze the data collected during the experiment and it fits the treatment factors. The two sorghum varieties were taken as the main plot treatment factors, three concave clearances as sub-plot treatment factors, three rpm as sub-sub-plot and three feed rates as sub-sub-sub-plot treatment factors with three replications as block .To analyze the treatment factors by split plot design laid down (2x3x3x3) x3 factorial combinations with three replications, which result 162 test runs.

3. Result and discussion

Under MSTAT program by selecting R.C.B.D factorial design the processed data was analyzed and the following results obtained. Coefficient of variation was 1.84% for pure grain, 32.08% for grain with glum and 22.90% for un-threshed grain. At alpha level 0.050 least significant deferent values for pure, with glum and un-threshed grain were 0.379, 0.3907 and 0.048 respectively. After the test it was observed that the threshing efficiency varied from 88.97 to 97.08%.

Maximum threshing efficiency of 97.08% was obtained with *Fandisha* at drum speed of 900 rpm, concave clearance of 15 mm and feed rate of 30 kg/min (Fig 4). The minimum 88.97% was observed at feed rate of 60 kg/min, drum speed of 500 rpm and concave clearance of 23 mm (Fig 6). Regarding grain with glum its highest percentage 9.75 was seen at feed rate of 60 kg/min, drum speed of 500 rpm, and drum-concave clearance 23 mm. whereas, the lowest percentage 2.34 was recorded at feed rate of 30 kg/min, drum speed of 900 rpm and drum-concave clearance 15 mm.

Highest un-threshed grain 1.34% was noticed at feed rate of 60 kg/min, speed of drum 500 rpm and drum-concave clearance of 19 mm. However, the lowest percentage was 0.58 at feed rate 30 kg/min speed of 900 rpm and concave-clearance of 15 mm. From the above facts, it is possible to say threshing efficiency increases with increasing drum speed in a given range. Increasing feed rate raises threshing efficiency to certain limit thereafter decreases. Increasing concave clearance decreased threshing efficiency and resulted in more un-threshed grain on the sorghum head.

For Muira variety the maximum threshing efficiency was 96.58% (Fig.7) at feed rate of 30 kg/min, drum speed of 900 rpm and drum-concave clearance of 15 mm. Whereas, the minimum value of 89.33% (Fig.9) was noted at feed rate of 45 kg/min, drum speed 500 rpm and drum-concave clearance of 23 mm.

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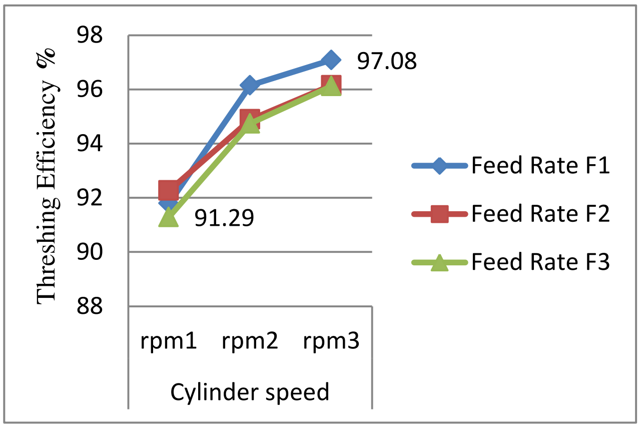

Figure- 4. Effect of feed rate and drum speed on threshing efficiency using Fendisha variety and drum-concave clearance of 15 mm.

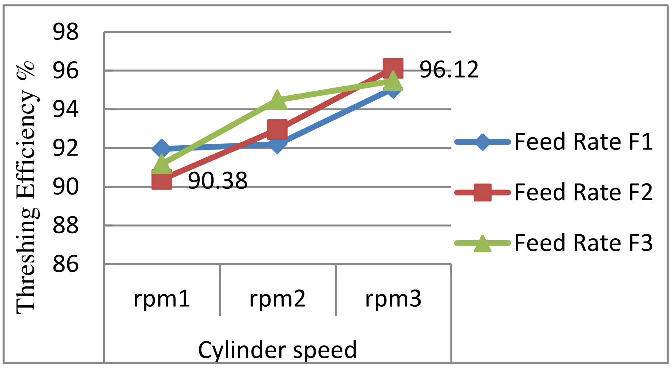

Figure- 5. Effect of feed rate and drum speed on threshing efficiency using Fendisha variety and drum-concave clearance of 19 mm.

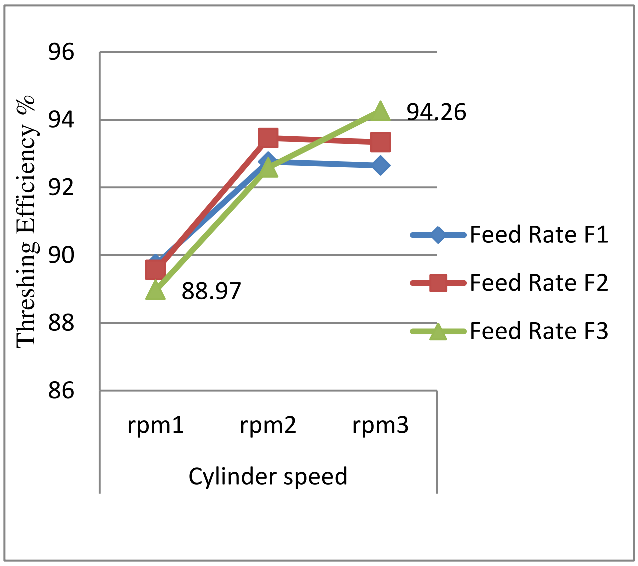

Figure-6. Effect of feed rate and drum speed on threshing efficiency using Fendisha variety and drum-concave clearance of 23 mm.

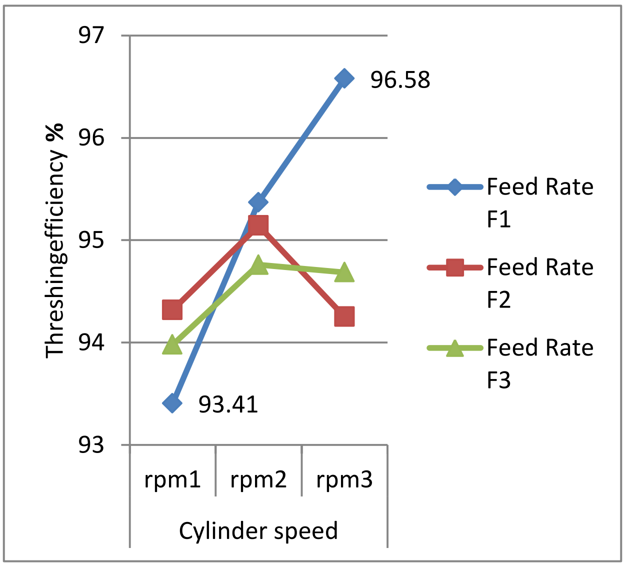

Figure-7. Effect of feed rate and drum speed on threshing efficiency using Muira variety and drum-concave clearance of 15 mm.

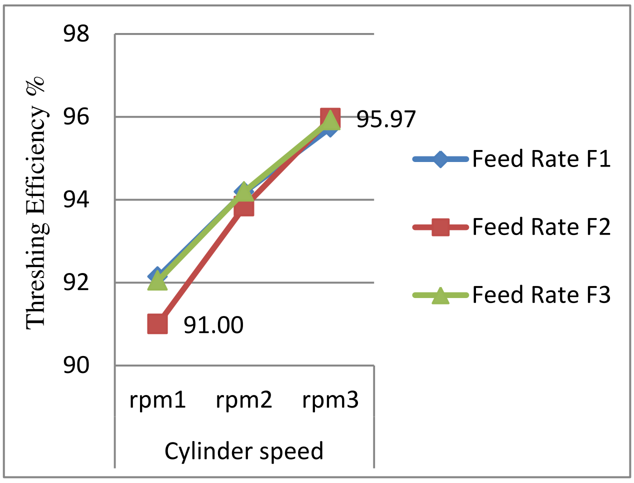

Figure-8. Effect of feed rate and drum speed on threshing efficiency using Muira variety and drum-concave clearance of 19 mm.

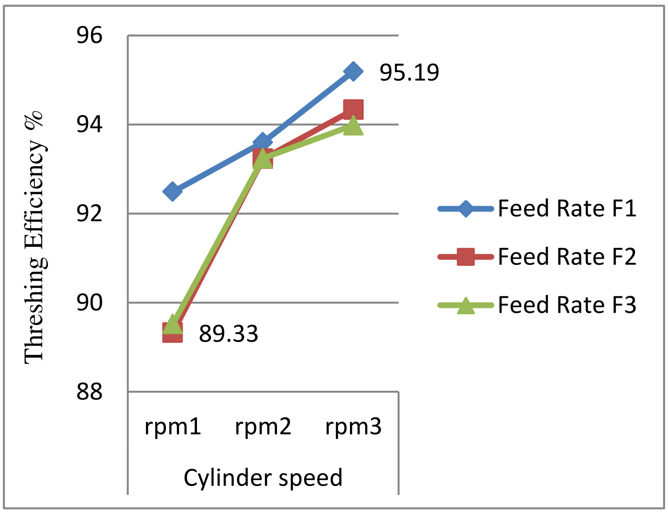

Figure-9. Effect of feed rate and drum speed on threshing efficiency using Muira variety and drum-concave clearance of 23 mm.

Moreover, the maximum amount of grain with glum was 9.33 % was recorded at feed rate of 45 kg/min, drum speed 500 rpm and drum-concave clearance 23 mm. However, the lowest was 2.84% at feed rate of 30 kg/min, drum speed 900 rpm and drum-concave clearance of 15 mm. The highest un-threshed grain 1.35% was recorded at feed rate of 60 kg/min, drum speed of machine 500 rpm and cylinder-concave clearance of 23 mm. On the other hand, the lowest percentage was 0.57 at feed rate 30 kg/min, drum speed of machine 900 rpm and drum concave clearance of 19 mm. Grain with glum and un-threshed grain are quite the opposite with threshing efficiency in order that, their values are decreased by means of increasing drum speed. The range analysis showed significant difference value for sorghum varieties.

The output capacity of the machine was evaluated for both *Muira* and *Fendisha* varieties by long duration test using three sample sorghum harvests 25.07 qt, 32.10 qt and 40.12 qt .at recommended feed rate 30 kg/min, drum speed 900 rpm and drum-concave-clearance of 15 mm. Long duration test result indicated that the machine output capacity was between 7.71-8.36 qt/hr for variety of *Muira* and 6.07-7.37 qt/h for *Fendisha*. The average specific fuel consumption was observed 0.096 lit/qt and 0.103 lit/qt for *Muira* and *Fendisha* respectively (see figure 10 and 11) below. Due to its compact head *Muira* was showed the utmost output capacity of the machine.

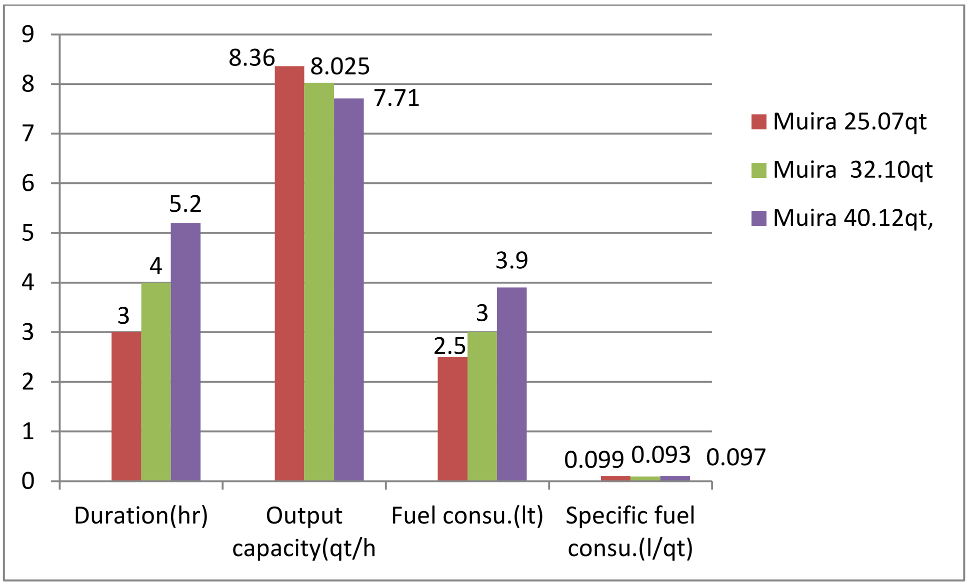

Figure-10 Long duration test of improved sorghum thresher on Muira variety

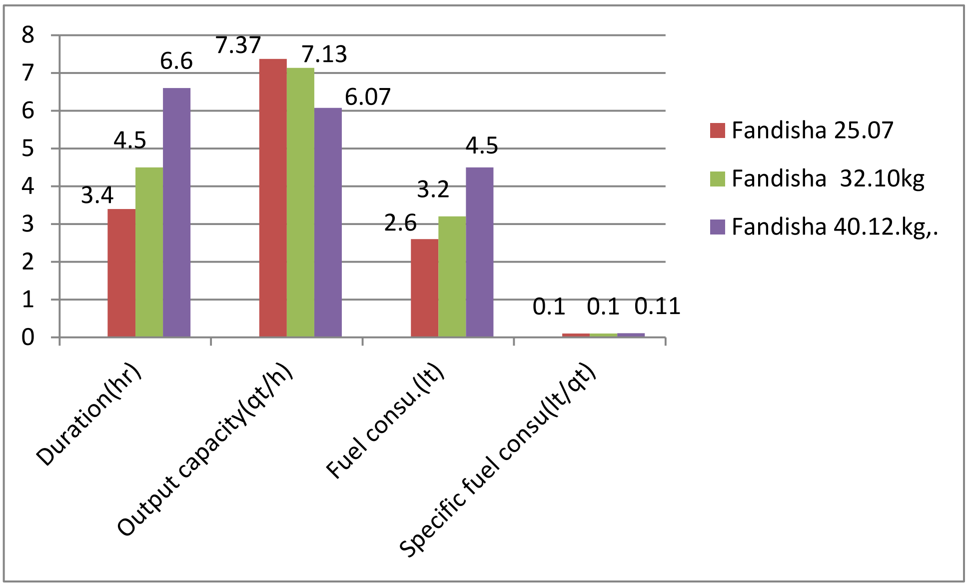

Figure.11 Long duration test of improved sorghum thresher on Fendisha variety

Figure12. The improved engine driven sorghum thresher.

1. Engine
2. Drum upper cover
3. Inlet
4. Drive pulley
5. Driven pulley
6. Wheel
7. Stand
8. Grain outlet
9. Lower cover
10. Straw outlet
11. Handles

4. Conclusion and recommendation

The improved sorghum thresher found to be better in threshing efficiency. The values were superior 88.97 to 97% yet; the optimum condition for threshing evaluation was set for threshing efficiency being 95%. Long duration test result indicated that the machine output capacity was between 7.71-8.36 qt/hr for variety of *Muira* and 6.07-7.37 qt/h for *Fendisha*. Breakage of grain and total grain loss was negligible at normal working condition

The machine is of low cost, effective, efficient, small in size, and simple for repair and maintenance. At the time of evaluation of the machine farmers showed their interest for purchase of this machine under investigation. In the current market engine for this machine costs between 10,000-15,000 birr ($370-556 USD) and could lift the cost of the machine to 40,000 – 45,000 birr ($1481-1667USD) which is affordable by many farmers individually or in group.

Finally, for both Fendisha and Muira varieties to get maximum threshing efficiency and output capacity users should be adjust drum speed to 900 rpm drum concave-clearance on 15 mm and feed rate at 30 kg/min also considering recommended moister content of the grain.

5. Acknowledgement

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