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Performance Evaluation of a Small-Scale Sunflower Thresher

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Abstract: *Threshing and cleaning are two final operations required for the production of high-quality seeds. Nigerian farmers utilize the traditional methods of threshing sunflower which are a disadvantage in the level of seed quality produced. Against this background, a sunflower thresher was developed and evaluated at seven different cylinder speed (400rpm, 450rpm, 500rpm, 550rpm, 600rpm, 650rpm, 700rpm) and two feed rates (2kg/sec, and 4kg/sec). Performance parameters for the study were threshing and cleaning efficiencies, scatter loss, mechanical grains damage and throughput capacity. The evaluation results show a maximum threshing efficiency of 89% and cleaning efficiency of 75%, minimum scatter loss of 0.39% and maximum grain damage of 0.06% and an average throughput capacity of the thresher was 96.7kg/hr, of seed. The best combination of threshing efficiency 89%, cleaning efficiency 75%, scatter loss 0.67%, mechanical grain damage 0.05% and throughput capacity 137kg/hr, were obtained at 700rpm cylinder speed and 2kg/sec. feed rate. Based on the results for the evaluation obtained, the developed machine whose estimated cost was N125,000:00, is recommended as suitable for small scale sunflower producer.*

Keywords: *Cleaning, Threshing, Throughput Capacity, Sunflower, Small-Scale*

INTRODUCTION

The sunflower belongs to the genus *Helianthus annus L.* "*Helios*" translates to sun in Greek and "*annus*" means the flower is an annual. The sunflower's name is believed to have originated from the connection of the plant to the sun, both in looks and behaviour. At a glance, the sunflower does indeed resemble the sun. Imagine a large circle with bright yellow fiery beams coming out all around it, just as a child would draw the sun in a picture. Second, and most interesting, is the fact that the sunflower actually tracks the sun's position in the sky. Sunflower is one of the most important oil crops in the world and is ranked 5th in oil production in the world (FAO, 2006). Sunflower oil is popular as healthy cooking oil due to its health benefits *i.e.* high in the essential vitamin E and low in saturated fat (Jadhav and Deshpande, 1990; Downey *et al*., 1989; Lotfy, 2009). The edible sunflower seed is usually cultivated by small farmers and is harvested at high moisture content.

The area under sunflower production worldwide has been on the increase; but there are many problems for edible sunflower planting such as: pest's damage, poor soil fertility, diseases damage, water stress (Gol and Nada, 1991; Mirzabe *et al*., 2014; El-Rai *et al*., 2016) and non-availability of suitable machinery for sunflower's sowing, harvest, post harvesting and oil extraction operations (Paulsen and Sabir, 1997; Goel *et al*., 2009; Mirzabe *et al*., 2014).

The world sunflower seed production stood at 32.39 million tonnes from an area of 23.71 million hectares, accounting for 8.5 per cent of the total oilseeds production (FAO, 2006). It takes a lot of time requires a large man power labour for removing the seeds from sunflower head. The seeds could be removed either by traditional manual method or mechanical mechanized methods (Simonyan and Annamalai, 2000; Salokhe *et al*., 2005; Mirzabe *et al*., 2016). Traditionally, the farmers rub the sunflower heads over a brick, stone, piece of metal, wood, rubber or rub the sunflower heads with each other for its threshing. The efficiency of the traditional manual methods depends on the efficiency and experience of the workers but the efficiency is very low in general (Azharuddin *et al*., 2016; Chavoshgoli, 2012; Mirzabe *et al*., 2014). The mechanical methods of removing sunflower seeds are based on beating, friction and simultaneous beating and friction. The machines used are classified as: combined harvester machines and stationary thresher machines. The threshing unit plays a key role in determining the performance of a harvester machine (Dashand and Noh, 1989; Hadad, 2000; Dahiya and Deshpande, 2001; Sudajan *et al*., 2002). Problems of small-scale threshing sunflower seeds from the sunflower heads in Nigeria is due to non-availability of suitable machinery. Manual method of threshing is very low and depends upon the efficiency and experience of the farmers. Manual method of threshing which is one of the most time consuming, laborious and uneconomical method. This method does not encourage high output and often results in low quality product, due to sand, stones and other impurities which enter the seeds. There is a growing need to provide the sunflower farmers with an appropriate thresher because of its economic and industrial importance in Nigeria.

MATERIALS AND METHODS

2.1 Materials

The thresher was designed and constructed at the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Samaru –Zaria, Kaduna State-Nigeria with latitude 12° 12'N, longitude 07° 37'E at 550 m altitude (Adeyemi *et al*., 2019). Materials required for constructing the thresher include: 1.5 mm mild steel sheet, 4 mm flat bars, 25 mm shafts, 9 mm iron rods, 1.5-inch angle bars, Gauge 12 electrode, Pulleys, V-belts, bearings, and bolts and nuts.

2.2 Description of the Thresher

The developed sunflower thresher consists of a frame, the hopper, the threshing drum, shaft, sieve, knives and the cleaning mechanism (Fig. 1 and Appendix A). Frame is the major support structure of the machine by withstanding the load acting on it. All the components fabricated were assembled over the frame. The frame is made by using standard sections available i.e. the angle plates which are 50mm×50mm, 5mm thick and the angle is 90° between the adjacent plates. The angle plates are cut to the requirement and welded together (Rizvi *et al*., 1993; Sudajan, 2003; Sudajan, 2016). The threshing drum as shown in Fig. 1 is housed in the concave and drum cover which were made from a horizontal cylinder of 600 mm in diameter and 600 mm long. The concave is the lower half of the cylinder perforated with 3.5 mm in diameter to serve as discharge holes for the threshed materials. The clearance between threshing drum and concave was 130, 100 and 70 mm at inlet, center and outlet, respectively. The upper half serves as the cover. Three semi-circular folds of the same diameter with inclination of 15° were made from metal serve as a cover of the concave and help the crop material to move from inlet to outlet without accumulation. Three special knives made of stainless steel with 150 mm in diameter were fixed in the initial half on the concave at distance of 100 mm between them starting from the entrance to the middle of the concave. The action of these knives interacted between the actions of beaters to help in cutting the crop materials easily, reduce the impact force by the beaters and prevent the accumulation and rotation the straw around the drum.

Fig. 1 Developed Sunflower Thresher

The cleaning system of the thresher functions when the threshed capsules fall on the sieve, the air blast of the blower push the straw out of the machine and the seed fall on the slippage surface to the seed discharge duct. The slope angle of sieve toward the horizontal plane was equal 5 ˚. The sieves specifications were selected according to the maximum dimension for the seed (length) as follows; diameter of sieve hole was 3.5 mm, total area of sieve holes was 0.99 per 1m^2 and the distance between two neighboring holes is 1.29 mm as suggested by Ebiad (2005).

2.3 Performance Evaluation of the Thresher

The sunflower threshing unit operates on the principle of axial flow movement of the material with diameter drum thresher of 600mm and length thresher of 1200 mm. The performance was evaluated in terms of output threshing efficiency, separation efficiency, percentage of seed losses and damage seed. Evaluation was carried out with *Galami Badami* variety at different levels of moisture contents; 40%, 30% and 20% (w. b.) and at different peripheral velocities of drum speeds; 17.23, 12.56, 7.85 m/s, feed rate; 3000, 2000, 1000 g/s with constant concave clearance of 35 mm.

2.3.1 Threshing Efficiency, T_e

This can be defined as the ratio of quantity of threshed grain in sample to the total quantity of grains in sample, the threshing ability of the thresher is determined using the relationship below (Ndrika, 1994):

$$T_e = 100 - [\frac{Qu}{QT} \times 100] \quad (1)$$

where,
T_e = Threshing Efficiency (%)
Q_u = Quantity of un-threshed sample, (kg)
Q_T = Total quantity of grain sample, (kg)

2.3.2 Cleaning Efficiency

This is defined as the ratio of grain collected to the total mixture of grain and chaff received at the main outlet. The cleaning efficiency is determined using the following relationship (Ndrika, 1994):

$$C_c = \frac{WT - Wc}{WT} \times 100 \quad (2)$$

where,
C_c = Cleaning efficiency, (%)
W_c = Weight of chaff at the main outlet of the thresher, (kg)
W_T = Total weight of grain and chaff received at the main outlet, (kg)

A. Mechanical Grain Damage, M_d

This is the ratio of the quantity of the broken grains in sample to the total quantity of grain collected in the sample. The mechanical grain damage is determined using Eqn. (3) (Ndrika, 1994):

$$M_d = \frac{Qb}{QT} \times 100 \quad (3)$$

where,

M_d = Mechanical grain damage (%)

Q_b = Quantity of broken grains in the sample (kg)

Q_T = Quantity of total grains (kg)

B. Scatter Loss

This is the loss acquired due to grain scattering around the thresher during the threshing. The scatter loss is determined using the relationship in Eqn. (4). (Ndrika, 1994):

$$S_L = \frac{QL}{QT} \times 100 \quad (4)$$

where,

S_L = Scatter Loss (%)

Q_L = Quantity of grains scattered around the thresher (kg)

Q_T = Total quantity of grain sample (kg)

C. Throughput Capacity, T_c

This is the total quantity of the materials that passes through thresher in a given time. The grain throughput capacity is determined using the relationship in Eqn. 5 as suggested by Ndrika, (1994):

$$T_C = \frac{Qm}{T}, \text{ (kg/hr)} \quad (5)$$

where;

C_{th} = Throughput capacity, (kg/hr)

Q_m = Quantity of material that pass through the grain collector of the threshing(kg)

T = Time taken to complete the operation (hr)

D. Statistical Analysis

Tabular and graphical methods were used to compare the effects speed and feed rate on threshing efficiency, cleaning efficiency, scatter losses, seed damage and throughput capacity.

RESULTS AND DISCUSSION

The sunflower thresher performance parameters (i.e. threshing and cleaning efficiencies, scatter loss, mechanical grain damage and throughput capacity) were obtained from the evaluation carried out to determine the performance of the machine at two different feed rates (2kg/sec and 4kg/sec) at different cylinder speed (400rpm, 450rpm, 500rpm, 550rpm 600rpm, 650rpm and 700rpm) at constant moisture content of 15% dry basis and 4cm concave clearance. The sunflower performance parameters were summarized in the Table-1.

Table-1 Summary of various performance parameters of sunflower thresher at different feed rate

S/N	Cylinder speed (rpm)	Threshing efficiency Te (%)		Cleaning efficiency Ce (%)		Scatter loss S_l (%)		Mechanical grain Md (%)		Throughput capacity Tckg/hr	
		2kg	4kg	2kg	4kg	2kg	4kg	2kg	4kg	2kg	4kg
1.	400	51	33	43	40	0.39	0.57	0.03	0.04	40	70
2.	450	57	37	43	45	0.43	0.64	0.03	0.04	50	80
3.	500	64	42	54	50	0.48	0.72	0.04	0.04	60	90
4.	550	70	46	59	55	0.53	0.79	0.04	0.05	70	100
5.	600	76	50	64	60	0.58	0.86	0.04	0.05	80	110
6.	650	83	54	70	65	0.62	0.93	0.05	0.06	90	120
7.	700	89	58	75	70	0.67	1	0.05	0.06	100	130
$\bar{x}$		70	45.71	59	55	0.53	0.79	0.04	0.05	70	100
SD		12.717	8.3617	10.717	10	0.0943	0.1436	0.0076	0.0083	8.164	8.164
CV (%)		18.167	18.293	18.165	18.182	17.798	18.177	18.898	16.66	11.66	8.16

$\bar{x}$ = mean; SD = Standard deviation; CV = Coefficient of variation (%), T_e = Threshing efficiency (%), C_e = Cleaning efficiency (%), S_l = Scatter Loss (%), M_d = Mechanical grain damage (%), T_c = Throughput capacity (kg/hr)

3.1 Effect of Cylinder Speed on Threshing Efficiency at different Feed Rates

The Table-1 and Fig. 2 showed linear increase in the threshing efficiency with increase in the cylinder speed. Also, there is a decrease in threshing efficiency with a decrease in feed rate. The maximum threshing efficiency of 89% was obtained at a low feed rate of 2kg/sec and at a cylinder speed of 700rpm. The minimum threshing efficiency of 33% was obtained at a high feed rate of 4kg/sec and low speed of 400rpm cylinder speed. This increase in the threshing efficiency with an increase in the cylinder speed was attributed to impact forces applied to the sunflower seed materials. While a decrease in threshing efficiency with an increase in feed rate was attributed to the excessive sunflower material in the threshing chamber of the machine.

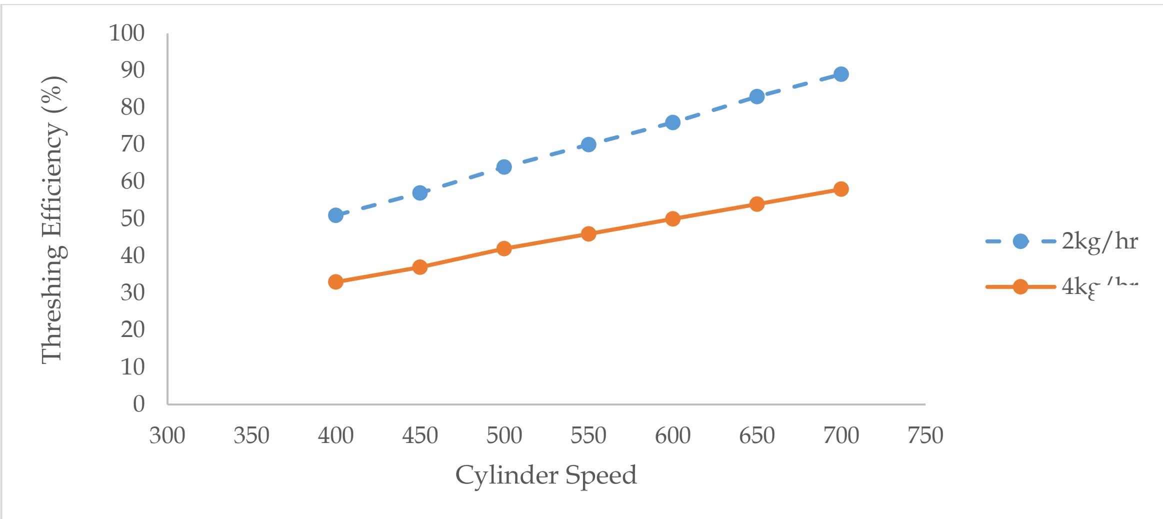

Fig. 1 Effect of cylinder speed on threshing efficiency at different feed rates

3.2 Effect of Cylinder Speed on Cleaning Efficiency at different Feed Rates

The cleaning efficiency increases linearly with increase in the cylinder speed and decreases linearly with the feed rate (Table-1 and Fig. 3). The maximum cleaning efficiency of 75% was obtained at a low feed rate of 2kg/sec and a at cylinder speed of 700rpm. While the minimum cleaning efficiency of 40% was obtained at a cylinder seed of 400rpm and 4kg/sec feed rate. The linear relationship in the increase cleaning efficiency with increase in the cylinder speeds was attributed to increase in the velocity of the blower caused by an increase in the cylinder speed. A decrease in cleaning efficiency with an increase in the feed rate was attributed to the high volume of sunflower seed materials to be handled by cleaning unit. Consequently, allowing some chaffs to be discharged through the grain outlet.

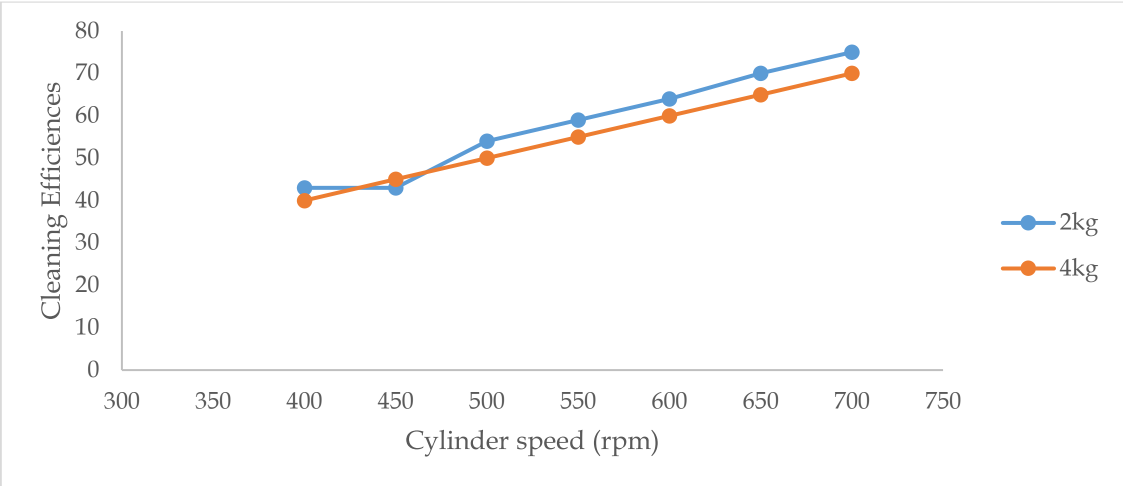

Fig. 3 Effect of cylinder speed on cleaning efficiency at different feed rates

3.3 Effect of Cylinder Speed on Scatter Loss at different Feed Rates

Table-1 and Fig. 4 show that the percentage of the scatter loss increase with an increase in cylinder speeds and feed rates. The maximum percentage of scatter loss of 1.00%, was obtained at 700rpm cylinder speed and 4kg/sec feed rate. While the minimum percentage of scatter loss of 0.39% was obtained at 2kg/sec feed rates and 400rpm cylinder speed.

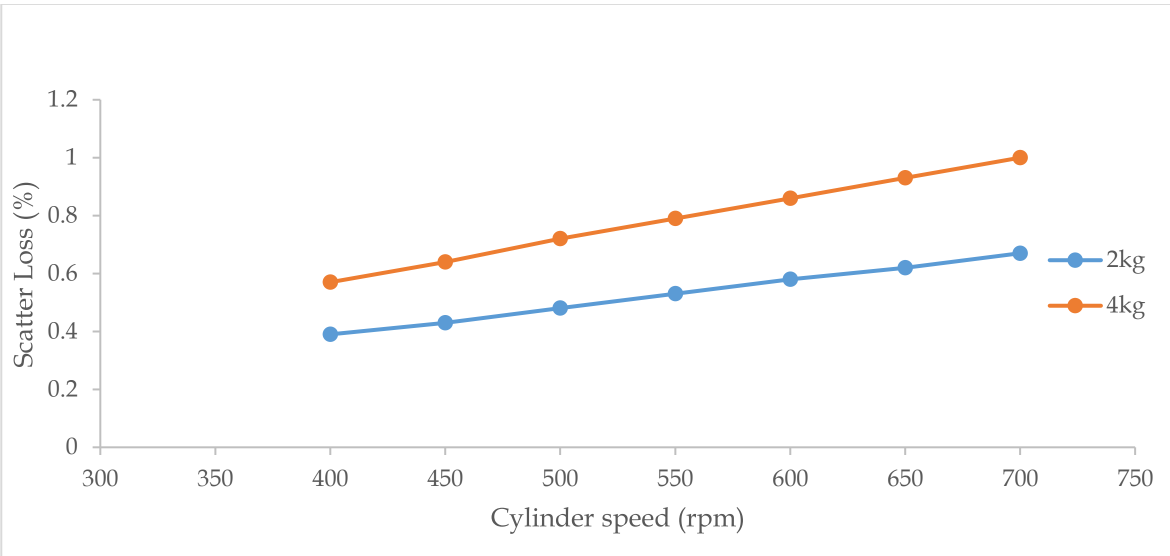

Fig. 4 Effect of cylinder speed on scatter loss at different feed rates

3.4 Effect of Cylinder Speed on Mechanical Grain Damage at different Feed Rates

Table-1 and Fig. 5 show the percentage of mechanical grain damage increases with an increase in cylinder speeds and feed rates. The maximum percentage of the mechanical grain damage of 0.06% was obtained at 700rpm cylinder speed ad 4kg/sec feed rate. While the minimum percentage of mechanical grain damage of 0.03% was obtained at 400rpm cylinder speed and 2kg/sec feed rate. This increases attributed to increase in the impart force on the sunflower seeds. Consequently, causing more grain damaged during threshing operation.

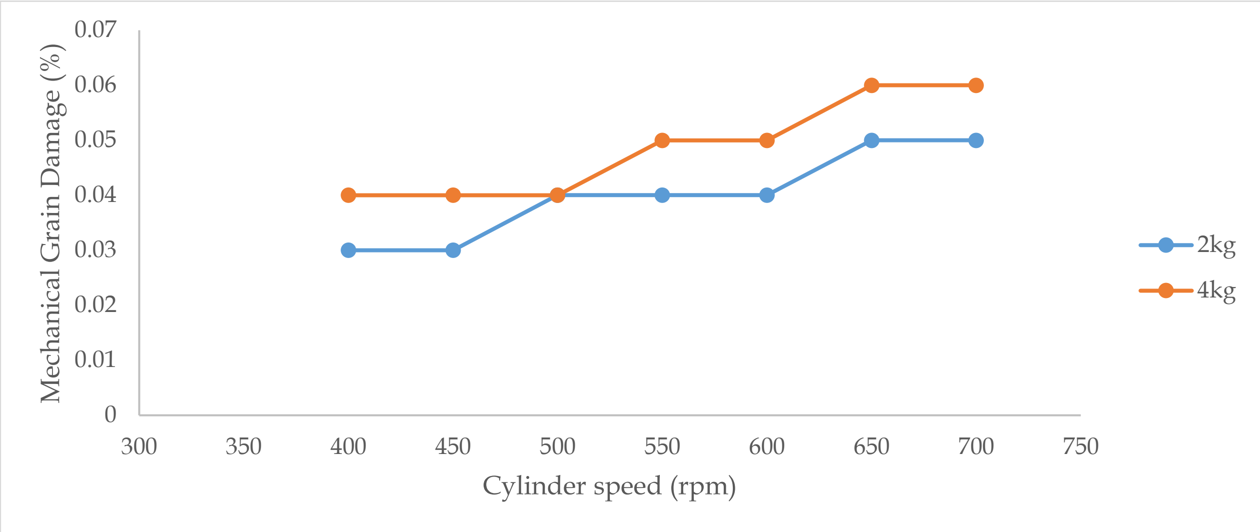

Fig. 5 Effect of cylinder speed on mechanical grain damage at different feed rates

3.5 Effect of Cylinder Speed on the Throughput Capacity at different Feed Rates

The throughput capacity increases with an increase in cylinder speeds and feed rates. The maximum throughput capacity of 137kg/hr was obtained at 700rpm cylinder speed an 4kg/sec feed rate. While the throughput capacity of 96.7kg/hr was obtained at 400rpm cylinder speed and 2kg/sec feed rate (Table 1 and Fig 6). This increase is attributed to decrease in the threshing time u to high cylinder speed and impart force of the threshing unit.

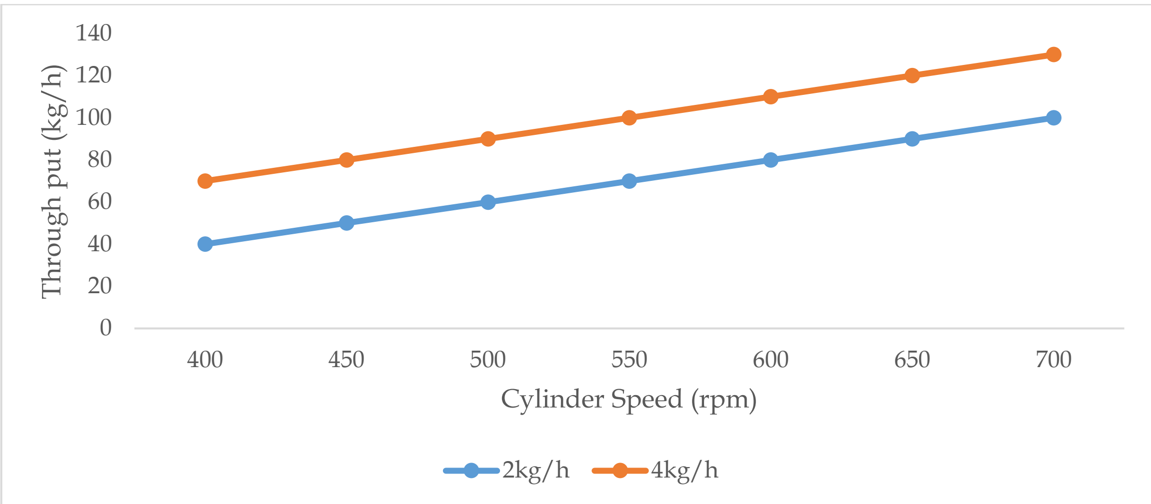

Fig. 6 Effect of cylinder speed on the throughput capacity at different feed rates

CONCLUSION

A sunflower thresher was developed and evaluated at seven different cylinder speed (400rpm, 450rpm, 500rpm, 550rpm, 600rpm, 650rpm, 700rpm) and two feed rates (2kg/sec, and 4kg/sec). Performance evaluation of the small-scale sunflower thresher was successfully carried out. Parameters evaluated were threshing and cleaning efficiencies, scatter loss, mechanical grains damage and throughput capacity. The evaluation results show a maximum threshing efficiency of 89% and cleaning efficiency of 75%, minimum scatter loss of 0.39% and maximum grain damage of 0.06% and an average throughput capacity of the thresher was 96.7kg/hr, of seed. Besides, the best mixture of threshing efficiency 89%, cleaning efficiency 75%, scatter loss 0.67%, mechanical grain damage 0.05% and throughput capacity 137kg/hr, were obtained at 700rpm cylinder speed and 2kg/sec. feed rate.

CONFLICT OF INTEREST

The authors declare no competing interest

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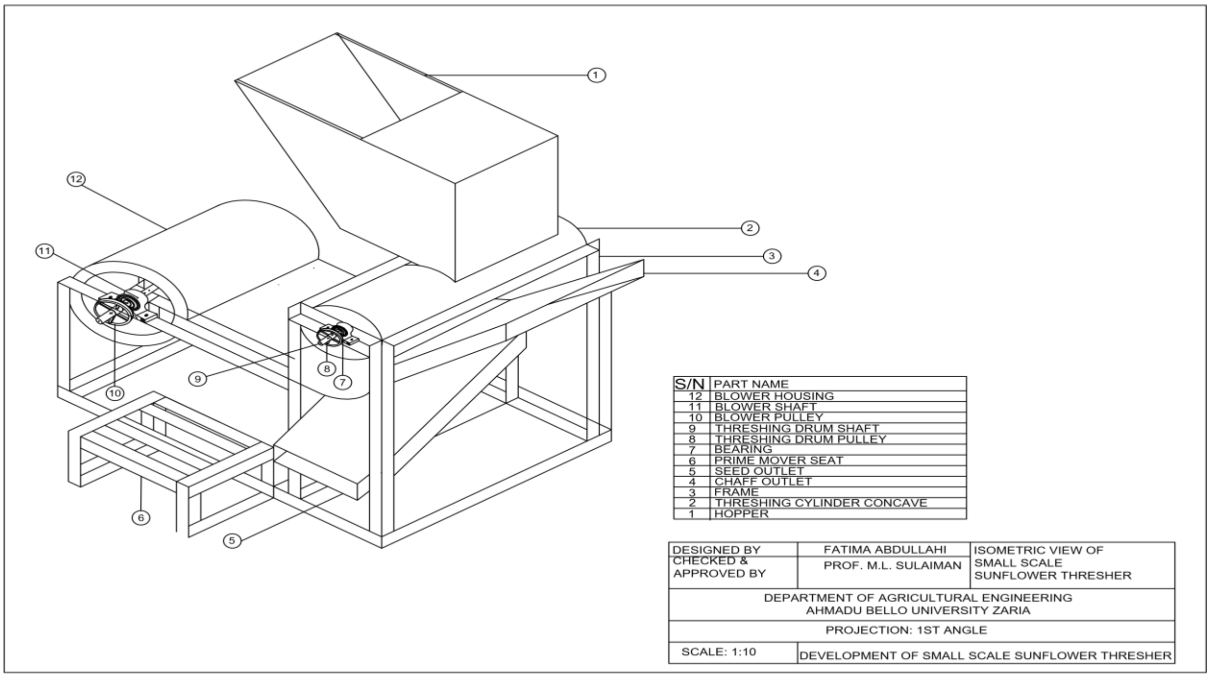
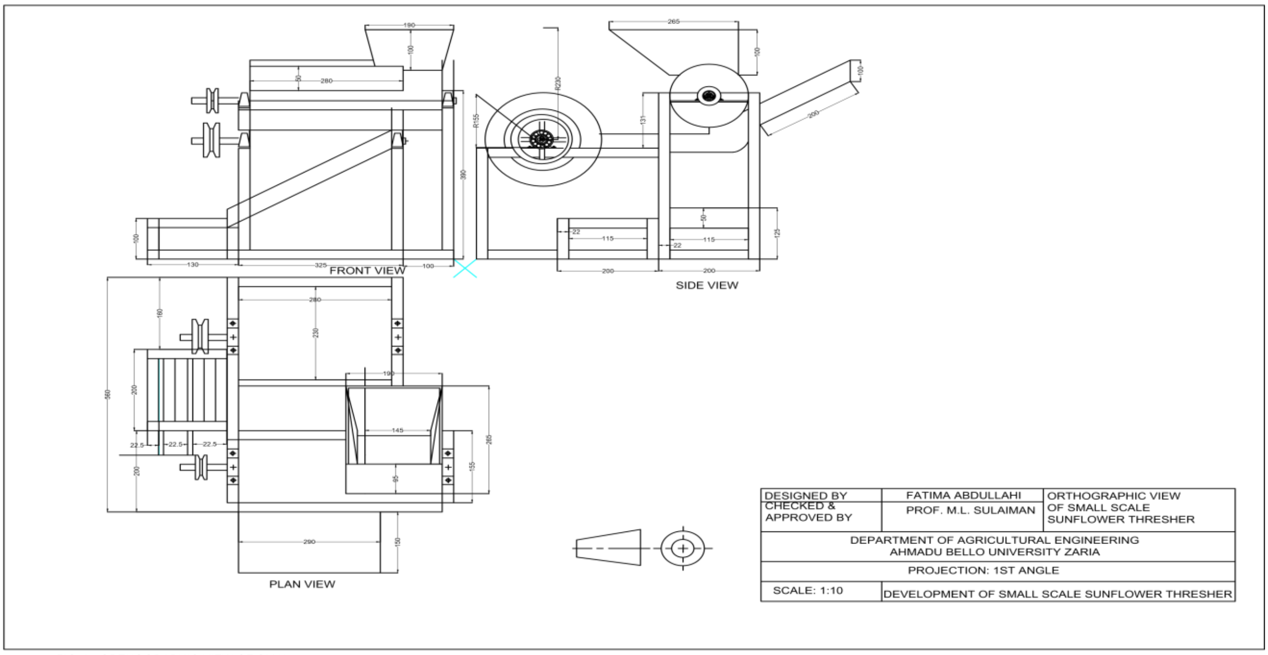
APPENDIX 1

Isometric and Orthographic Views of Small-Scale Sunflower Thresher



FIG;1: ISOMETRIC VIEW OF SMALL SCALE SUNFLOWER

Fig. a Isometric Views of Small-Scale Sunflower Thresher



FIG; 2 : ORTHOGRAPHIC VIEW OF SMALL SCALE SUNFLOWER THRESHER

Fig. b Orthographic view of small-scale sunflower thresher

APPENDIX 2
Bill of Estimate and Materials Evaluation

Table-a Bill of Estimate and Materials Evaluation

S/N	Material/ specification	Quantity	Unit Price (#)	Total price (#)
1	1.5mmmild steel sheet	1.5 sheets	26,000	39,000
2	1.5-inch angle bars	2	5,500	11,000
3	Auto Cad	1	5,000	5,000
4	4mm flat bars	2	7,500	15,000
5	Gauge 12 electrode	1 packet	2,000	2,000
6	25mm shafts	2	15,000	30,000
7	Pulleys	2	2,000	4,000
8	V-belts	2	350	700
9	204 bearings	2 pairs	2,500	5,000
10	9mm iron rods	1	5,000	5,000
11	Bolt and nuts	8	190	1520
12	Petrol	1 gallon	1,000	2,600
13	Miscellaneous	-	5,000	5,000
Total				125,820