Designing, fabrication and evaluation of threshing unit edible sunflower

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Abstract: A study was conducted to designed, fabricated and evaluated a threshing unit for edible sunflower. 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^{-1}, feed rate; 3000, 2000, 1000 kg (head) h^{-1} with constant concave clearance of 35 mm, diameter drum thresher of 600 mm and length thresher of 1200 mm. The analysis of variance showed that the drum speed (A), feed rate (B) and moisture content (C) affected all parameters of performance significantly at level 1% and moisture content had the most effect on all results. The evaluation results indicated with decreasing moisture content, threshing efficiencies and separation efficiency increased from 98% to 99.22% and 54.45% to 60.98% also seed losses and damage seed reduced from 1.98% to 0.8% and 0.7% to 0.41% respectively. The maximum amount of threshing efficiencies with changing drum speed and feed rate obtained 98.86% and 98.88% also with decreasing drum speed and feed rate separation efficiency increased from 55.63% to 59.13% and reduced slightly from 57.97% to 57.45% respectively. The seed loss was range to 1.3%, 1.51% and 1.16%, 1.63% with changing drum speed and feed rate.

Keywords: edible sunflower seed, thresher, threshing efficiency, separation efficiency, seed loss and damage seed

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1 Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops in the world and is ranked 5th in oil production in the world (FAO, 2006), but it is the most popular and consumption fresh one in some countries such as Iran and Turkey. The edible sunflower seed is usually cultivated in small farmers and is harvested at high moisture content in Iran. The area under sunflower production in Iran has been on the increase; but in Iran and many developing countries there are many problems for edible sunflower planting such as: pest's damage, poor soil fertility, diseases damage, water stress (Mirzabe et al., 2014) and non-availability of suitable machinery for sunflower's sowing, harvest, post harvesting and oil extraction operations (Goel et al., 2009; Mirzabe et al., 2014). It takes a lot of time and requires a large man power labour for removing the seeds from sunflower head. In general, there are two methods for removing sunflower seeds from the sunflower head, including 1) traditional manual method, and 2) mechanical mechanized methods (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. The efficiency of these methods 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 for removing sunflower seeds from the head 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

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(Sudajan et al., 2002). Bansal and Dahiya (2001) studied the effect of threshing techniques on the quality of sunflower seeds. Sudajan et al. (2002) studied the effects of feed rate, drum, type of drum and drum speed on sunflower threshing. Sudajan et al. (2003) investigated power requirements and performance factors of a sunflower thresher. Sudajan et al. (2005) studied the effect of a number of drum characteristics on rasp-bar drum performance for threshing sunflowers. A sunflower threshing unit was designed and fabricated by Sudajan et al. (2005) to study the effect of machine and crop variables and to accumulate enough information for the best possible design of the thresher. A local device for separating sunflower that would utilize both centrifugal and gravitational force was developed by Lotfy (2009). Ismail and Elhenaway (2009) optimized machine parameters of a pedal- operated sunflower threshing using friction drum. The performance of threshing machine is evaluated for its threshing efficiency, cleaning efficiency, visible damage seed, threshing capacity and specific energy consumption. A local device for separating sunflower that would utilize both centrifugal and gravitational force was developed by Lotfy (2009). Mirzabe et al. (2016) studied the effect of air-jet impingement parameters on the removing of sunflower seeds from the heads in static conditions. Azharuddin et al. (2016) designed and fabricated a machine which will separate the seeds from the head sunflower, they stated the main components required to fabricate the machine are Blades, Shaft, Pulley, Disk plates, Blower, Hopper, Tray, Sieves, Motor, V-Belt and Pillow Block Bearings.

Little published literature is available on edible sunflower thresher machines and their performance, power consumption and efficiency. Therefore, this study was conducted to study design and fabrication sunflower head thresher machine and the effect of threshing drum speed, feed rates and moisture content to evaluate its performance and to determine the grain and material other than grain (MOG) separation over the length of the threshing drum.

2 Materials and methods

Initially, the following steps were considered for designing and construction of thresher.

1. A review of the currently existing sunflower seed harvesting machine or in other words sunflower threshing machines in terms of their cost and performance characteristics.

2. A qualitative study of the types of materials and components suitable for the fabrication of the threshing machine and their availability in the market.

3. Modeling of the sunflower threshing machine by using SolidWorks modeling software.

4. Fabrication of the seed threshing machine based on the design and modeling details.

5. Testing of the machine for its output and its operations at load and no load conditions.

Calculations were carried out in order to determine the dimensional and other mechanical properties such as Stress, Strain, and Torque etc. so as to withstand the effect of various loading on the machine.

The single shaft cross through the thresher cylinder in grain thresher has long been used in most harvesters (Mohtasebi et al., 2006).

For threshing grain agriculture crops a force F is needed, which is a function of cylinder linear speed as well as the friction coefficients between the crop-crop and crop-metal (Popov et al., 1986).

That:

$$F= F_c + F_r \tag{1}$$

where, F = the force needed for threshing crop, N; F_c = impact force of the cylinder, N; F_r = friction force, N.

The impact force F_c may be calculated from Equation (2) below;

$$F_c = q\ (V_2 - V_1) \tag{2}$$

where, q=feed rate, kg s^{-1}; V_2 = speed of the threshed crop as it exits the cylinder, m s^{-1}; V_1 = speed of the crop as it enters the cylinder, m s^{-1}.

V_2 is usually proportional to the linear speed of the cylinder (V);

$$V_2 = aV \tag{3}$$

where, V = the linear speed of the cylinder, m s^{-1}.

The coefficient a, is an empirical figure depended upon cylinder length, straw humidity, shape of rasp bar, feed rate and physical properties of the threshing unit. For a thresher of 0.8 m in length, humidity of 15%-25%, feed rate of 3.5 kg s^{-1}, the coefficient a, has been determined equal to 0.70-0.85 (Mohtasebi et al., 2006); Inserting

Equation (1) in Equation (2):

$$F_c = q\,(a\mathrm{V} - V_1) \tag{4}$$

F_c is dependent upon many factors such as the friction coefficient, type of breakage of the straw, the intense of threshing, etc. It is however proportional to the total force necessary to thresh the crop, F;

$$F_r = f\,F \tag{5}$$

The coefficient f, for rasp bar type cylinders is equal to 0.65-0.75 and for finger type equal to 0.7-0.8. Inserting Equations (4) and (5) in Equation (1);

$$F = q\,(aV - V_1) + f\,F \tag{6}$$

And therefore,

$$F = [\frac{q(aV - V_1)}{1 - f}] \tag{7}$$

Required power for threshing, P_1 in watts, may be obtained by multiplying both sides of Equation (6) by V:

$$P_1 = FV = [\frac{q(aV - V_1)}{1 - f}]V \tag{8}$$

The total power for the threshing is more than what is shown in Equation (8). Power is also needed to overcome the air resistance against the rotation of the cylinder and the friction force in bearings. This power is calculated from Equation (9), below:

$$P_2 = AV + BV^3 \tag{9}$$

The first term after the equal sign is due to friction and the second term is for air resistance. The A and B are two coefficients. Coefficient A is determined as 0.85-0.90 N per 100 kg mass of rasp bar type thresher cylinder and 5-5.5 N per 100 kg mass of finger types. Coefficient B for cylinder diameters of 550 mm is equal to 0.065 Ns^2 m^{-2} per m of cylinder length of rasp bar type and 0.045 Ns^2 m^{-2} for finger type. The total required power is then:

$$P = P_1 + P_2 = [\frac{q(aV - V_1)}{1 - f}]V + AV + BV^3 \tag{10}$$

This was determined to know the shaft diameter that can withstand the applied loads. For a solid shaft with little or no axial load, the diameter of the shaft was determined using (Mohtasebi et al., 2006).

$$d^3 = \frac{16n}{\pi\tau_{\max}}\sqrt{(K_t M_t)^2 + (K_b M_b)^2} \tag{11}$$

where, d = tube outside diameter, mm; M_t = torsional moment, N mm; M_b = bending moment, N mm; K_t, K_b = combined shock and fatigue factor applied to bending and torsional moment respectively. K_b =1.2 to 2.0; K_t = 1.0 to 1.5; $\tau_{\max}$ = allowable stress (55 MPa for shaft without key way and 40 MPa for shaft with key); n = safety coefficient.

To calculate the moments, the imposed forces must first be determined as follows (Mohtasebi et al., 2006):

1. Horizontal forces, which are reaction to the threshing force and friction. These forces may be calculated from the total power requirement.

2. Vertical forces due to the weight of the components on thresher shaft.

According to Azharuddin et al. (2016) M_t can be calculated as:

$$M_t = \frac{60P}{2\pi N} \tag{12}$$

where, P = power required to drive and threshing, w; N = speed of the shaft, rpm.

Critical speed was calculated from the following Equation (Thomson, 1998):

$$w_n = \sqrt{g\frac{\Sigma M_i y_i}{M_i y_i^2}} \tag{13}$$

where, w_n = critical speed,rad s^{-1}; M_i = weight, N; y_i = deflection, mm; g = gravitational acceleration, 9.81 rad s^{-2}.

In this research, the first edible sunflower threshing unit designed and fabricated (Figure 1) that operates on the principle of axial flow movement of the material. The threshing mechanism consisted of a threshing drum, which rotates inside a two section concave (separator) and the thresher was powered by tractor PTO (Model MF 285) and the speed was set by tractor engine throttle the power from the tractor PTO was transmitted to the threshing drum by use of chains and sprocket wheel. Axial of thresher consists of a main shaft on which sets of arms are placed and due to the sensitivity of the mechanical properties of the seeds, the flexible blade plates have been used also due to the higher level of friction with grain (the effect of rubbing), the seed is better segregated from the head sunflower. The concave was made of wire rods with a distance of 26 mm is used as the main separator of grain from material other grain (Figure 2). The concave clearance was fixed at about 35 mm, which had proved satisfactory in the preliminary tests. The length of the concave of the threshing unit was 1.4 m. Figure 2 show that feeder was made from tow arm of type thresher on axial that accelerate and help to threshing action. The diameter and length of threshing drum were 0.6 and 1.2 m, respectively.

Figure 1 Fabricated sunflower threshing unit

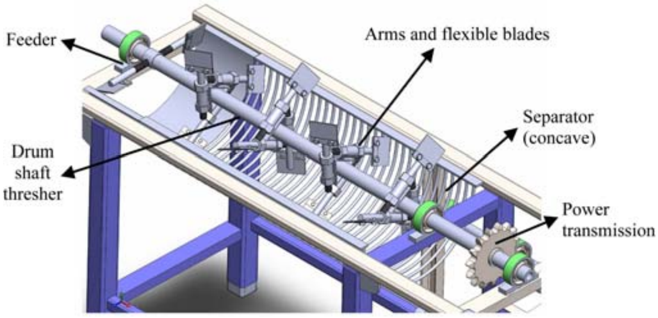

Figure 2 Parts of thresher unite

The Iranian sunflower seeds (Galami Badami variety) used in this study which were obtained from the Experimental Orchard of University of Tabriz that sunflowers heads were harvested by the traditional method at the time of harvesting season.

The following performance indicators were used for the evaluation (RNAM, 1995): output threshing efficiency, separation efficiency, damage seed, seed losses. The performance of the developed threshing unit was evaluated against Three threshing drum speeds of 550, 400, and 250 rpm, equivalent to peripheral velocities 17.23, 12.56, 7.85 m s^{-1} respectively, and the three feed rates, 1000, 2000, 3000 kg (head) h^{-1}, also the average moisture contents of seeds and heads were considered at 40% (moisture harvesting), 30% and 20% (w.b%).

Threshing speeds and feed rates at different moisture content by using a randomized complete block design (RCBD) of a 3×3×3 factorial experiment with three replications in each treatment, and the least significant difference (LSD) of comparison between treatment is at the 1% and 5% level (Sudajan et al. 2003) After the test run, the samples collected from different point of under separator (concave) that were cleaned to determine grain and MOG separation over the concave length. The samples of threshed seed, broken pieces of head, the straw passed down through concave openings and the material ejected from the straw outlet were collected and separated.

3 Result and discussions

3.1 Effect of drum speed, feed rate and moisture content on threshing efficiency

The analysis of variance showed that the drum speed (A), feed rate (B) and moisture content (C) significantly affected threshing efficiency (Table 1). It was observed that the effect of moisture content was the most significant, followed by feed rate and drum speed. Among the first-order interactions, the order of importance was BC, AB and ABC being significant at the 1% and 5% level of significance respectively but the effect of the AC did not differ significantly.

Table 1 Analysis of variance of the results of the performance of the sunflower threshing unit

Source of variation	df	F-value			
		Threshing Efficiency	Separation Efficiency	Seed loss	Seed Damage
Replication	1				
Drum Speed (A)	2	12.426**	108.146**	11.643**	42.592**
Feed Rate (B)	2	45.198**	25.357**	47.203**	8.002**
Moisture Content% (w.b.), (C)	2	313.497**	293.585**	348.869**	228.785**
A*B	4	3.687**	6.767**	3.984**	0.453 ns
A*C	4	0.979ns	1.60 ns	0.723 ns	2.115 ns
B*C	4	5.203**	13.428**	5.457 ns	0.445 ns
A*B*C	8	2.146*	2.348*	2.144*	0.493 ns
Error	52				
Total	81				

Note: ** Highly significant at 1% level; * significant at 5% level; ns, non-significant; df, degrees of freedom.

Evaluation results from Figure 3 and Figure 4 indicated that the threshing efficiency increased from 98.53% to 98.86% then decreased to 98.73% for speed drum between 7.85 to 17.23 m s^{-1} also this result is 98.40% to 98.88% and 98.70% for the feed rate level from 3000 to 1000 kg (head) h^{-1}. These trend shows that the highest threshing efficiency was obtained at about 12.56 m s^{-1} of speed and 2000 kg (head) h^{-1} of feed rate. These tendency shows that the effect of speed on the threshing efficiency was due to the high impact of the threshing drum on the head sunflowers due to the increase in speed to certain amount. Inner friction coefficient and collision material with together thresher is important reason for increasing threshing efficiency with changing feed rate to feed rate about of 2000 kg (head) h^{-1}.

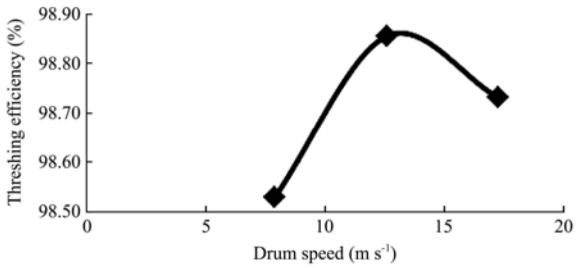

Figure 3 Effects of drum speed on threshing efficiency

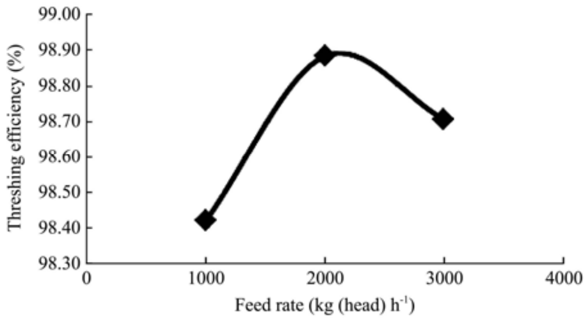

Figure 4 Effects of feed rate on threshing efficiency

Figure 5 indicates that the threshing efficiency increased from 98% to 99.22% almost linearly with the decreasing of moisture content from about of 40% to 20%(w.b.). This is an indication that at lower moisture content, cohesion of seeds on flower head sunflower will be low. This result is similar to the results obtained by Sudajan et al. (2005) with respect to the effect of moisture content on threshing efficiency.

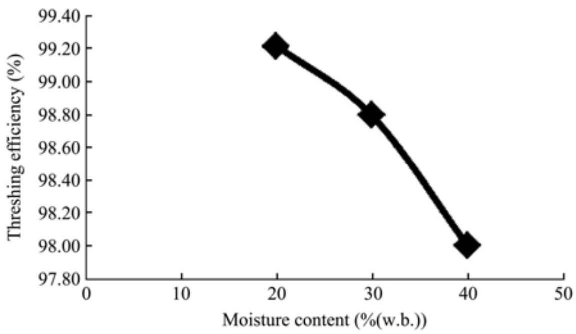

Figure 5 Effects of moisture content on threshing efficiency

3.2 Effect of drum speed, feed rate and moisture content on separation efficiency

Table 1 indicates that the variance analysis of the main effects of drum speed, feed rate and moisture content significantly affected separation efficiency at the 1% level and results are similarity with results of threshing efficiency. The effect of moisture content was the most significant.

With increasing speed from 7.85 to 17.23 m s^{-1}, separation efficiency reduced from 59.13 to 55.63 (Figure 6). The results are possible due to the high impact of the threshing drum and the further breaking of the head and flower sunflowers which passes through concave.

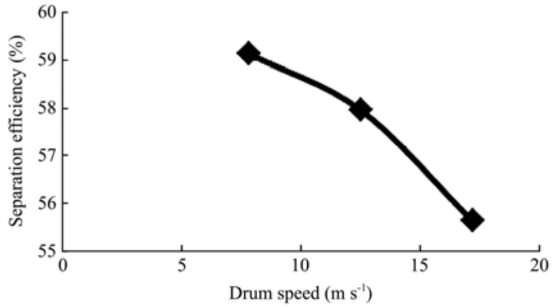

Figure 6 Effects of drum speed on separation efficiency

Figure 7 shows separation efficiency increased almost linearly with changing the feed rate 1000 to 3000 kg (head) h^{-1}. This result is due to increasing of rubbing and colliding materials together.

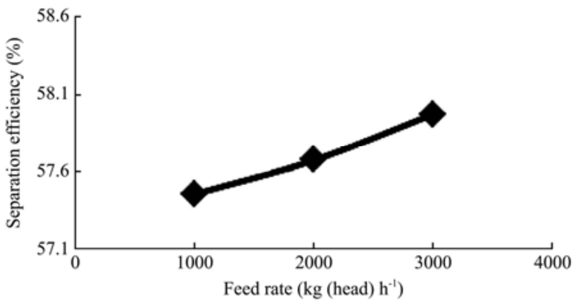

Figure 7 Effects of feed rate, kg(head) h^{-1} on separation efficiency

Moisture contents had the most significant effect on separation efficiency in comparison with drum speed and feed rate as in Figure 8 indicated with changing moisture contents from 20% to 40% amount of separation efficiency decreases from 60.98%to 54.45%. It is because of reduction properties of brittleness sunflower heads and flowers at about moisture content 20% and this factor cause to product less other material grain (MOG) by means of beating thresher. This result compares well with the findings reported by Adekanye and Olaoye (2013) for cowpea thresher, and Sudajan et al. (2002) for sunflower thresher.

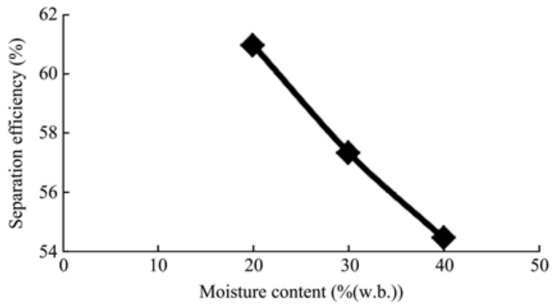

Figure 8 Effects of moisture content % (w.b.) on separation efficiency

3.3 Effect of drum speed, feed rate and moisture content on seed loss

The seed losses are including seeds and unthreshed seeds that get out from end of axial thresher mostly. Table 1 shows the analysis of variance of the main effects on seed losses. The results showed that the effect of A, B, C factors were significant at level 1% and A*B*C at level 5%, that moisture content has the most significant effect flowed by feed rate and drum speed.

With investigation of Figures 9, 10 and 11 the results indicated that the grain losses were between 0.80% and 1.98% for drum speeds, feed rates and moisture contents that most changing is for moisture contents and with reduction it the seed losses decreased. This result is due to reduced adhesion seeds on heads especially in the center of heads and thus reduced unthreshed sunflowers.

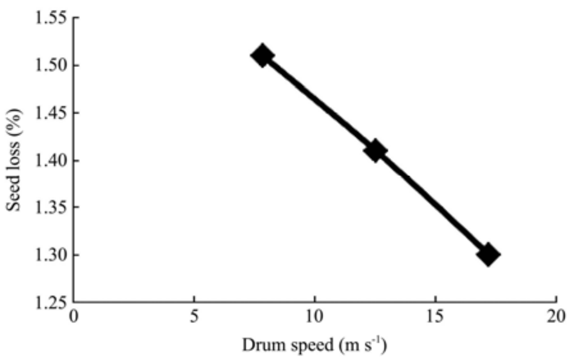

Figure 9 Effects of drum speed, m s^{-1} on seed loss%

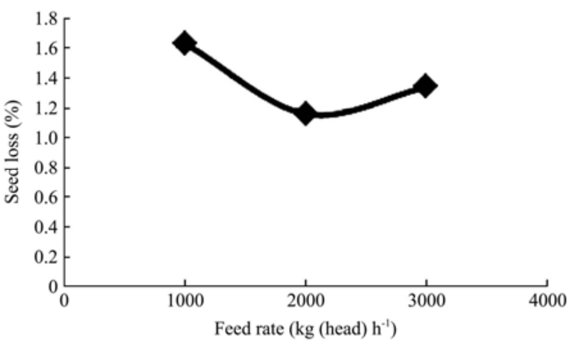

Figure 10 Effects of feed rate, kg(head) h^{-1} on seed loss%

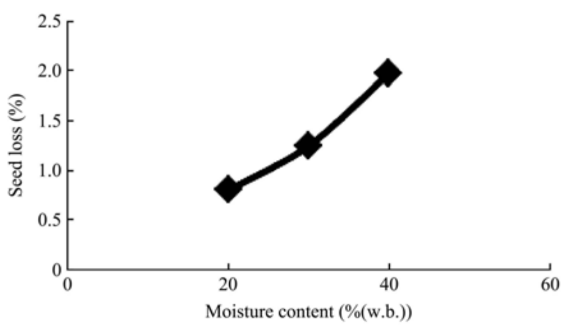

Figure 11 Effects of moisture content %(w.b.) on seed loss%

3.4 Effect of drum speed, feed rate and moisture content on seed damage

Table 1 indicates that the analysis of variance of the main effects of drum speed, feed rate and moisture content significantly affected grain damage at the 1% level. This is while interactions of the factors have not effect significantly. The effect of moisture content on grain damage was the most significant, followed by drum Speed and feed rate.

Figure 12 and 13 indicated with changing drum speed from 7.85 to 17.23 m s^{-1} and moisture content from 20% to 40% (w.b.) damage seeds increase from 0.50% to 0.63% and 0.41% to 0.70% respectively. This result may be due to the reasons that at higher moisture content the husk of grains becomes soft, which is liable to break due to shear force and with decrease in moisture content, the hardness of grain increased causing less breakage. Also, this increase was due to higher impact levels imparted to the crop during threshing at higher drum speeds. This trend agrees with the one reported by and Sudajan et al. (2003) for sunflower threshers.

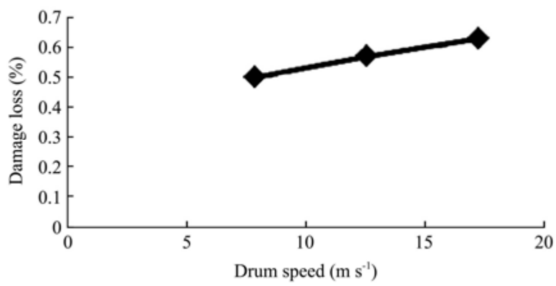

Figure 12 Effects of drum speed, m s^{-1} on damage seed%

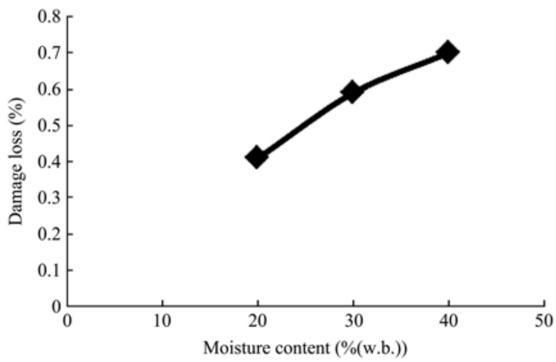

Figure 13 Effects of moisture content %(w.b.) on damage seed%

4 Conclusion

A sunflower threshing was designed, fabricated and evaluated. It consists mainly of the feeding assembly, the axial threshing unit, concave (separator) and power transmission unit.

The factors of drum speed, feed rate and moisture content affected the threshing efficiency, separation efficiency, seed loss and seed damage during sunflower threshing and they was found to be in the range of 98.4% to 99.22%, 54.45% to 60.98%, 0.80% to 1.98% and 0.41% to 0.70% respectively for all factors.

The threshing efficiency tend to decrease with the increase of moisture content from 20% to about 40% (w.b.) while changing the drum speed and feed rate, this tendency was nonlinear.

With increasing of drum speed and moisture content, separation efficiency decreased. While the amount increased for changing feed rate from 1000 to 3000 kg (head) h^{-1}.

The percentage of seed losses decreased as drum speed as increased and this amount increased with the increasing of moisture content. While with the feed rate increasing, the decreased then increased slightly.

The changing in drum speed from 7.85 to17.23 m s^{-1} and moisture content from 20% to 40% (w.b.) leading to reduction damage seed from 0.50% to 0.63% and 0.41% to 0.70%.

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