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Investigation the mechanical behavior of canola pods versus effect of impact and friction forces

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Abstract Mechanical properties are important parameters to determine and design threshing equipment or its parts, and, in computer simulation, to analyze, optimize, and control of the seed damage during the threshing, storage, transport and commercialization of grain is very important. In canola combine harvesters, threshing is accomplished by two mechanical actions of impact and friction forces. In this research, the effects of initial moisture content and needed impact and friction energy on threshing of canola pods were studied. An impact device was built based of pendulum mechanism. The experiments were done at three initial moisture content levels of 10, 17 and 24 %w.b. for both impact and friction methods. Three energy levels of 0.069, 0.077 and 0.084 J were used for impact method and for friction method three energy levels of 0.48, 0.584 and 0.719 J. The threshing percentage was measured in each method. By using a frictional device, kinetic friction coefficients at above moisture contents were measured 0.67, 0.72 and 0.76, respectively. The results of analysis of variance of the two methods showed that moisture content and energy have significant affecte on the threshing percentage. The maximum threshing in 10% moisture and 0.077 J energy was 88.81% and minimum threshing in 24% moisture and 0.069 J energy was 48.55%.

Keywords: Canola pod, Energy, Friction, Impact, Initial moisture content, Threshing.

Introduction

Mechanical properties are important parameters to determine to design threshing equipment or its parts, and, in computer simulation, to analyze, optimize, and control of the seed damage during the threshing, storage, transport and commercialization of grain is very important. The design and control of equipment are difficult due to the lack of information on the behavior of the mechanical and physical properties with high moisture content and early harvesting. Equipment size is usually overestimated to compensate for this lack of information, leading to a non-ideal design with cost implications as well as

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inferior quality of the product. These behavior of the mechanical can only be put in practice by the precise knowledge of the mechanical and physical properties characteristics of the grain with high moisture content and early harvesting.

There are numerous methods to measure the mechanical properties proposed in the specialized literature: Azadbakht *et al.* (2012) and De Simone *et al.* (2000) in their research, the relation between moisture and energy for threshing of soy beans and beans found by impact and friction methods. Mesquita and Hanna (1993) and Hoag (1972) used two belt system and ballistic pendulum, respectively, for determination of the relation between moisture and energy for threshing of soy beans. Skromme (1977) reported higher capacity and lower damage to kernels with a twin-rotor system than with a conventional transverse threshing cylinder. The power requirement of the twin-rotor system is expected to be similar to that of the conventional cylinder and concave due to the higher rotational speed, greater length, and smaller diameter of the twin-rotor system.

Brandenburg and Park (1982) made a two belt system which done the threshing operation between two parallel belt with beneath surfaces. Result of their experiment was less losses and more clean seeds. Similar experiments with two belt system and vertical belts were done on threshing grains and vegetables. The amounts of threshing increased by increasing of width and velocity of belts and reduce of distance between them.

In grain combine harvesters, threshing mechanism of canola is mainly accomplished by mechanical action of impact force. Threshing performance is related to moisture content. So the main objective of this study was to find the relation of primitive moisture content and energy consumption on canola pod threshing by two mechanical actions of impact and friction forces.

Materials and methods

Sample preparation

Canolas harvested from the experimental farm in Gorgan, Iran, were used in the study. Samples were stored in a refrigerator at 3 ℃ prior to the drying experiments. Three 10 g samples were dried in an oven at 103 ℃ for 17 h to determine initial moisture content. During harvesting of canola with combine, pod moisture is around 10 to 25% (w.b.), Therefore, canola sample moisture contents were selected at the range of 10, 17 and 24% (w.b.).

Impact test

For impact test, pendulum system was built (Fig.1). The distance between two beams (7) was equal to the length of pivot axle (5) was 21.5 cm. The length of pendulum arm (4) (height of pendulum axle to center of weight (2) was 27.3 cm and its weigh was 16.65 g. There is a gap in sample support (3) that held the pods vertically. Calibrated plate (9) was calibrated from 0 to 180 °. By this plate and pointer angle of impact and return was measured.

To create different levels of energy, three weights (9.32, 12.14, and 14.75 g) were used. These weights were found in try and error method which pods break in the minimum amount, and the seeds not damaged in the maximum amount. According to the Fig.2 and principal of work and energy, the amount of work between place 1 and 2 is equal to sum of change of kinesthetic and potential energy (Vahedian, 2004).

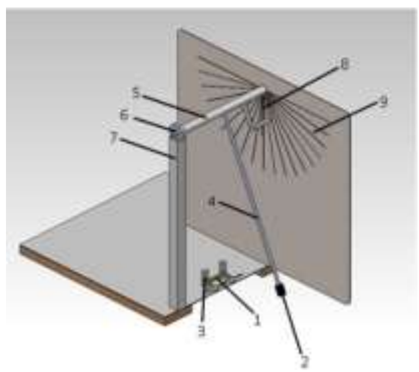

Fig. 1. Pendulum impact system.

1. sampel 2. weight 3. sample support 4. pendulum arm 5. pivot axle 6. bearing 7. beam 8. pointer 9. calibrated plate

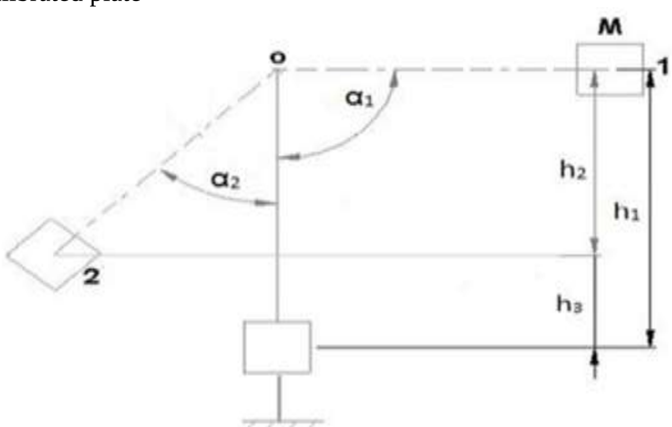

Fig. 2. Impact and after impact angle.

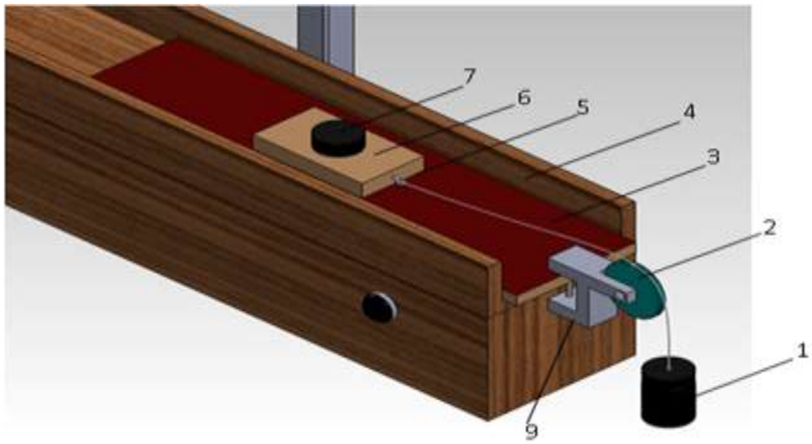

Fig. 3. Friction device.
1.Weight 2.Pulley 3.Lower wooden plate 4.Desk 5.pod place 6.Upper wooden plate, 7.Extera weight

$$\Delta_{1-2} = \Delta(T + V_{g)} \quad (1)$$

After impact, the situation of pendulum in return angle will be in place (2). Kinesthetic energy in place 1 and 2 is zero, so the amount of work after impact is:

$$\Delta_{1-2} = \Delta v_g = Mg[h_1 - h_3] = Mg[h_1 - (h_1 - h_2)] = Mgh_2 \quad (2)$$

where, length of pendulum arm= h_1= R= 27.3 cm, $\alpha_1 = 90$, $h_2 = Rcos\alpha_2$, $h_3 = h_1 - h_2$. According to Eq. (2), three energy levels of 0.069, 0.077 and 0.084 J were measured. To do the experiment, first 10 g of each sample in different moisture levels were weighted and then pods held horizontally in the support place, pods which their canola seeds were separated by impact, weighed and divided by initial weight to calculate the percent of threshing due to impact. This process was repeated three times for all levels and data were analyzed by using of completely randomized design (CRD) and SAS software.

Friction test

Friction Device (Fig. 3) was used in this experiment

This device's working principles are that mass 1 that is connected to the plate 6 by a string with a negligible friction moved down, bye this action plate number 6 and the loaded weight start to move. Surfaces used in this test were two pieces of wood with equal dimension 11.5×6.5 cm and 12.5×48. Wooden surfaces were sanded. On the upper wood a 100 g mass was loaded. This amount was measured during several examinations so that in the static status pods don't fail. Between this surfaces two full pods with 10, 17, 24 percents moisture level were putted and kinetic coefficient of friction was calculated with the equation number 5.

According to Figure 4 for moving mass number1 equation 3 is used; and according to figure 5 for moving plate and the loaded mass equation 4 is used.

$$mg - T = m a \quad (3)$$

$$T - \mu_k F_N = (m_1+m_2)\, a \quad (4)$$

According to equations 3 and 4 kinetic coefficient of friction between the involved surfaces is calculated:

$$\mu_k=[mg - (m+M)a]/Mg \quad (5)$$

Where, Extra mass(g) = m_2 , Upper wood mass (g)=m_1 , $M= m_1+ m_2$, kinetic coefficient of friction=μ_k ,

Acceleration of system ($m.s^{-2}$)=a , g= 9.8 ($m.s^{-2}$) , Weight of mass 1 = m

The acceleration of system calculated from equ. 6:

$$x= ½ at^2 \quad (6)$$

Where, Time (s)= t , Acceleration of system ($m.s^{-2}$)=a

Finally, kinetic coefficient of friction obtained 0.67, 0.72 and 0.76 for amount of 10, 17 and 24% moisture content, respectively. By the amount of kinetic coefficient of friction and base on work and energy, from Eq. 7 energy levels of 0.48, 0.584 and 0.719 J were calculated.

$$U=\mu K\, N\, x \quad (7)$$

where, U= energy, N= equal mass of M and x= distance moving.

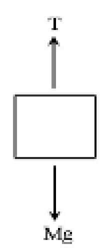

Fig. 4. Weight motion.

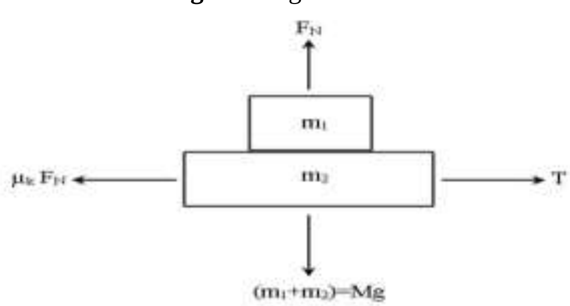

Fig. 5. Extra weight and upper wood motion.

In the experiment, two pods were placed between both wooden corrugated plates and the above energy was applied to separate the soybean pods by friction force. Weight of seperated pods were divided to the initial weight to calculate the percent of threshing due to friction. Completely randomized design (CRD) was used to analyze the data by SAS software.

Results and discussion

Impact test

Table 1 showed results of a variance analysis for percent of canola seeds threshing under different energy and primary moisture for impact test. Effect of energy and moisture on percent of threshing in probability level of 1% is significant.

Table 1. Variance analysis of threshing canola pod under different energy and primary moistures (Impact test)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F-value
Moisture (Mc)	2	2017.4	1008.7	**11.71
Energy (J)	2	2058.82	1029.41	**11.95
J ×Mc	4	1064.55	266.14	*3.09
Error	18	1551.77	86.17	

** * Significant in statistic level of 1 and 5 %.

It also showed that interaction effect of moisture and energy on threshing in probability level of 5 % is significant for impact test. In order to study two ways effect of different factors on threshing of grains, compare of mean was done by LSD method, hereby, compare of mean energy levels in each level of moisture and compare of mean different moisture level in each level of energy was done separately and results presented in Tables 2.

According to Table 2 in moistures 10 % there was not significant different of threshing between different energy levels, and was significant difference between 17 and 24% moistures levels between different energy levels. In this moisture levels threshing will increase by increasing in energy levels. There was not significant difference between 0.069 and 0.084 J energy levels and in 0.077 J energy level was significant difference between different moisture levels. It means that if energy is very high or very low, increase in moisture doesn’t have any effect on the amount of threshing. Also it was observed that maximum threshing in 10% moisture and 0.077 J energy was 88.81%. Minimum threshing in 24% moisture and 0.069 J energy was 48.55%.

Canola pod with higher moisture, contact between its edges of the pod was stronger than lower moisture, then more energy was needed to separate two edges at 24% moisture.

Table 2. Energy and moisture compare of mean on the percent of canola pod threshing (Impact test)

	Moisture (w.b.%)		Energy (J)
24	17	10	
Ba 48.55	Ba 55.56	82.14 Aa	0.069
ABb 64.2	Aa 78.63	Aa 88.81	0.077
Aa 78.16	Aa 81.32	Aa 83.45	0.084

* Same capital letters in each column and same small letters in each raw show not significant different (LSD1%). Note: Same capital letters in each column and same small letters in each row shows no significant different (LSD%1).

The effects of different energy on threshing of pod at different primary moisture content with impact test. By increasing energy and decreasing moisture, pod threshing increased in all three moisture content levels as shown in Fig.6.

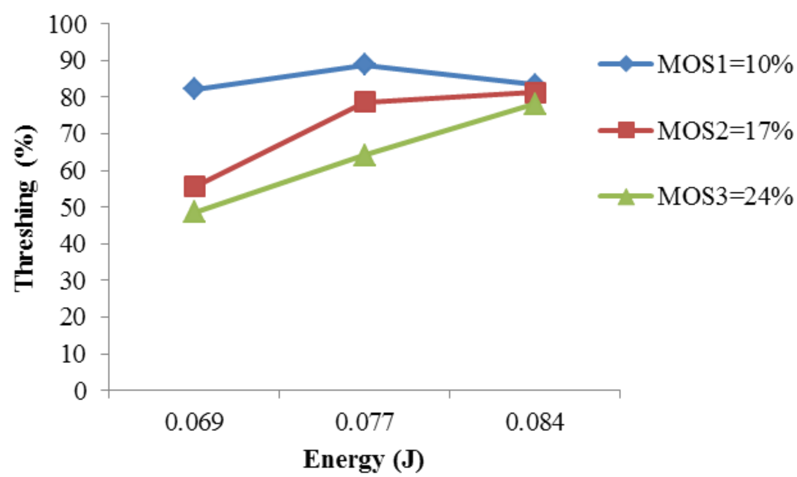

Fig. 6. Effects of energy on threshing canola pod in different moisture at impact test.

The results of this paper are in agreement with the findings of other research workers. Azadbakht *et al.* (2012) for threshing of soybean pods showed that maximum threshing was at minimum moisture content and maximum energy level, which was 83.4%, and the least threshing was at maximum moisture content and minimum energy level was 3.3%. De Simone *et al.*, (2000) the relation between moisture and energy for threshing of beans was found by impact and friction methods, They found that in both methods probability of breaking the pods vary with moisture, and breaking them with high moisture is more difficult. Impact testes on bean pods showed that dry pods need less energy than wet pod to break, and pods with 13.3 and 15.3% moisture completely break and beans get out of the pods. But pods with 17.3% moisture, crack slowly and with 18.4% moisture never break. In impact method needed energy for threshing, was reported between 0.09 to 0.015 J and in friction method it was between 0.21 to 0.48 J. In friction experiments, they realized that pods with 13.3% moisture completely opened and beans get out of the pods, in 17.3% moisture, beans were still in the pods (pods just open) and in 18.4% moisture, beans never get out of the pods. In friction testes they found that friction coefficient between pods increased with increase of moisture. Mesquita and Hanna (1993) by two belt system showed that soybean pod with 10% moisture content had good threshing action and 93% of the beans got out of the pods, however in 16 and 21% moisture, threshing action reduce to 90 and 79% . They reported that 0.12 J energy needed for threshing canola pod. Hoag (1972) in an experiment by ballistic pendulum showed by reducing the moisture content of the soybean pods, the amount of breaking energy of pod will reduce. Canola pod with moisture between 10 to 15% needed energy for threshing was 0.013 to 0.018 J.

Friction test

Results of a variance analysis for percent of canola seeds threshing under different energy and primary moisture for friction test was shown in Table 3. Effect of energy and moisture on percent of threshing in probability level of 1 and 5% was significant, respectively. It was also showed that interaction effect of moisture and energy on threshing is not significant for friction test.

Table 3. Variance analysis of threshing canola pod under different energy and primary moistures (friction test)

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean square**	**F-value**
Moisture (Mc)	2	18656.43	9328.21	**136.81
Energy (J)	2	795.25	397.62	*5.83
J ×Mc	4	134.67	33.66	^{ns} 0.49
Error	18	1227.26	68.18	

**, * Significant statistical level of 1 and 5%. And ns not significant.

Threshing will increase by increasing in energy levels was shown in Fig.7. It was also showed threshing will increase by increasing in moisture levels (Fig.8).

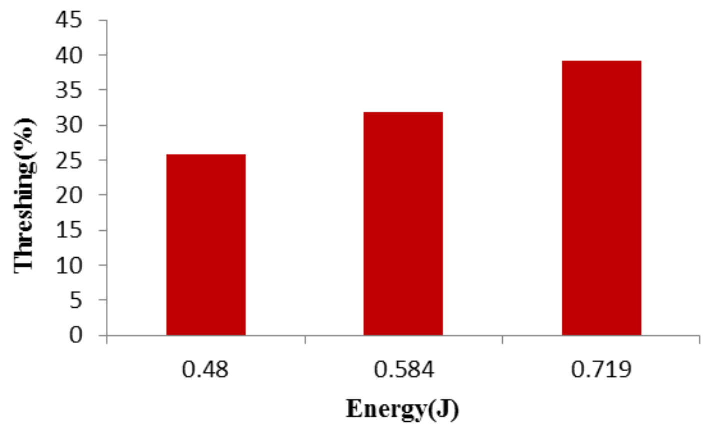

Fig. 7. Effects of energy on threshing of canola pod in friction test.

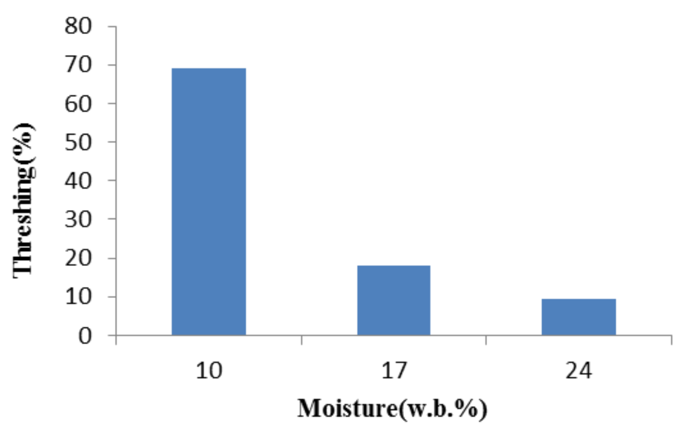

Fig. 8. Effects of moisture on threshing of canola pod in friction test.

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