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Canola seeds losses during harvest using grain combine harvester as a function of thermal properties of canola unbroken pod

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Abstract

The present study investigated the thermal properties of canola pods (thermal conductivity, specific heat, and thermal diffusivity), canola losses (natural losses, platform losses, and total combine harvester losses), and unbroken pods in three common canola varieties cultivated in the North of Iran (Hyola 420, Hyola 401, and Hyola 50) at three times of pre-harvest, harvest, and post-harvest. Furthermore, the relation between the thermal properties of canola pods and the amounts of losses during harvest was studied. Thermal conductivity coefficient, specific heat, and thermal diffusivity were determined using line heat source, mixture method, and calculation methods, respectively. Seed losses were calculated, using a built grain collector. The results revealed that adjustments, variety, and sampling time had significant effects on thermal conductivity and specific heat of canola varieties at the probability level of 1%. The effect of the interaction between variety and time on thermal conductivity, specific heat, and thermal diffusivity was considerable at the probability levels of 1% and 5%, respectively. Furthermore, the effects of canola varieties and harvest time on natural losses, total combine harvester losses, as well as unbroken pods were substantial at 1% probability. In addition, a notable relation was observed between thermal conductivity coefficient and platform losses at 5% and unbroken pods at 1%. However, unbroken pods indicated a substantial relation with specific heat and thermal diffusivity at 1%.

Keywords: Canola pod, Harvest losses, Thermal conductivity coefficient, Thermal diffusivity coefficient, Specific heat

Introduction

Since 1970s, canola has not been comparable to any other plants in terms of cultivation due to its high oil content. Therefore, the ensuing significant increase in canola production has been observed mostly in European countries and Canada. In Iran, the lack of raw materials drew the attentions to this plant which is a good source of edible oils (Soleimani and Kasraie, 2012). Management efforts such as the two-stage harvest (which includes harvesting in higher moisture content and then cutting and stripping) and crushing can lead to faster harvest at proper moisture content and reduced losses. In the two-stage harvest, the stems are cut when 30 cm high at the first step, and the pods are possibly untouched so that they would be harvested by the remover head at the due time. The two-stage harvest approach, i.e. striping and harvesting at 35% and 10% moisture, respectively, would significantly decrease the losses, since the pods are stripped off when they look like rubbers. Furthermore, it is worth notifying that as soon as canola seed moisture is reduced to 40%, the weight of the dry matter may still remain unchanged (Afzali and Sheikh-Davoodi, 2008). Thus, finding proper solutions to reduce harvest losses requires knowing the thermal properties of canola, which is the main objective of the present research. In what follows, we review a number of studies conducted on the thermal properties of various crops as well as canola harvest losses.

Researchers have studied the thermal properties of soybean pods in terms of yield moisture content and temperature. It was

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found that a rise in temperature and moisture results in an increase in specific heat from 1.856 to 4.39 (kJ/kg.˚K) as well as in thermal conductivity coefficient from 0.038 to 0.338 (W/m.˚c). In addition, at all temperature levels, higher moisture causes lower thermal diffusivity (Azadbakht *et al.*, 2013). Other scholars have studied the dependence of moisture on thermal properties of peanut pod, shelled peanut, and the skin. They have observed that increasing the moisture may increase specific heat and thermal conductivity coefficient and decrease thermal diffusivity. In this research, specific heat was determined through a vacuum calorimeter through mixing with hot water; thermal conductivity coefficient was measured by line heat source method, and thermal diffusivity coefficient was calculated, using an equation from literature (Bitra *et a*l., 2010). Gharibzahedi *et al*. (2012) analyzed the thermal characteristics of the Iranian black seed and observed that thermal conductivity, specific heat, and thermal diffusivity varied from 0.17 to 0.22 ($W\ m^{-1}K^{-1}$), 1642 to 2035 ($J.kg^{-1}K^{-1}$), and 9.3 to 10.4 × 10^{-8} (m^2s^{-1}), respectively. Scholars have investigated the effect of moisture, temperature, and variety on the specific heat of Pistachio, using a mixed approach. They have found that higher moisture and temperature result in increased specific heat in all varieties within the range of 0.419-2.93 (KJ/Kg.˚c). However, the effect of moisture content was more substantial than those of temperature and variety (Razavi and Taghizadeh, 2007). Researchers have also studied the effect of harvest time on yield and losses of canola seeds and have observed that more seed losses occur over time (Madani *et al.*, 2008). By determining the best harvest time of spring canola as the second cultivation, Rabiei *et al.* (2014) studied the varieties of RGS 003, Hyola 401, Hyola 420, and Hyola 308 at four times. Their findings indicated that the variety of Hyola 401 at the moisture level of 35% and the variety of Hyola 308 at moisture level of 15% had the highest and the lowest yields, respectively.

The present research was aimed to determine the thermal conductivity, specific heat, and thermal diffusivity of canola pods, identify various losses at canola harvest, and investigate the relation between these two factors. Moreover, it aimed to study the effect of moisture and harvest time on the amount of seed losses by platform, seed losses in the whole combine harvester, and unbroken pods and to see the effect of thermal properties on canola losses. The results are relevant and applicable to drying before crushing, which is employed in the farm dryer unit, and reducing seed losses at canola harvest.

Material and Methods

Sampling

Initially, the three canola varieties of Hyola 420, Hyola 401, and Hyola 50 were selected from the farms of Aliabad-e Katul, Golestan Province, Iran. The sampling was performed at three times of pre-harvest, harvest, and post-harvest. There were four-day intervals between the harvest periods. When 85 percent of canola seeds were brown, was considered as harvest time. The moisture content of canola pods at pre-harvest, harvest, and post-harvest were found to be 28%, 15%, 8%, respectively. Thermal conductivity, specific heat, and thermal diffusivity of the three varieties of canola pods were determined at the three sampling times. Subsequently, seed normal losses, seed platform losses, seed losses in the whole combine harvester, and unbroken pods were measured; moreover, the relation between the losses and the thermal properties of canola pod was investigated.

Thermal conductivity

The thermal conductivity of canola pods was determined using the line heat source method (Mohsenin, 1980; Bitra *et al.*, 2010; Azadbakht *et al.*, 2013; Yang *et al.*, 2002; Bart–Plange *et al*., 2012). This method is the most common transient method employed in food and agricultural products, which is proper for measuring the thermal conductivity of the masses of agricultural products (Salarikia, 2012). Measuring thermal conductivity, either by non-isolated wire or thermal conductivity probe, is based on a line heat source with infinitesimal diameter, infinite length, and constant longitude heat located in a homogenous cylinder. Equation (1) presents the increase in temperature as follows:

$$\Delta T = \frac{Q}{4\pi K}\left[ln(t) + \ ln\left(\frac{4\alpha}{r^2 e^{0.5772}}\right)\right] \qquad (1)$$

It is the increased temperature at the distance of r from the probe of line heat source (˚C). t is the time for (s), and Q is the heating power per probe length ($W.m^{-1}$); K denotes the thermal conductivity ($W.m^{-1}.˚C^{-1}$), α is the thermal diffusivity (m^2s^{-1}), and r is the distance from line (m) central vector.

Equation (2) demonstrates temperature difference (ΔT) against time normal logarithm (lnt):

$$S = Q.(4\pi K)^{-1} \qquad (2)$$

The thermal conductivity is:

$$k = \frac{Q}{4\pi}\frac{\Delta ln(t)}{\Delta T} \qquad (3)$$

As $Q=IR^2$, the relation (3) can be written as

$$k = \frac{I^2 R}{4\pi s} \qquad (4)$$

R represents the thermal element electrical resistance per length (Ω/m), and I is the input current to heat source.

The test transient heat transfer device (Figure 1) is constructed by a line heat source in PVC cylinder (the height is 300 nm, and the diameter is 110 mm). The cylinder is enclosed at the top and the bottom by a 10-mm fiberglass. A nickel-chromium line heater, 0.127 mm in diameter, is placed along the cylinder main vector which is connected to an adjustable D.C power source (500 mA, 1.5-12 V) (Bitra *et al*., 2010).

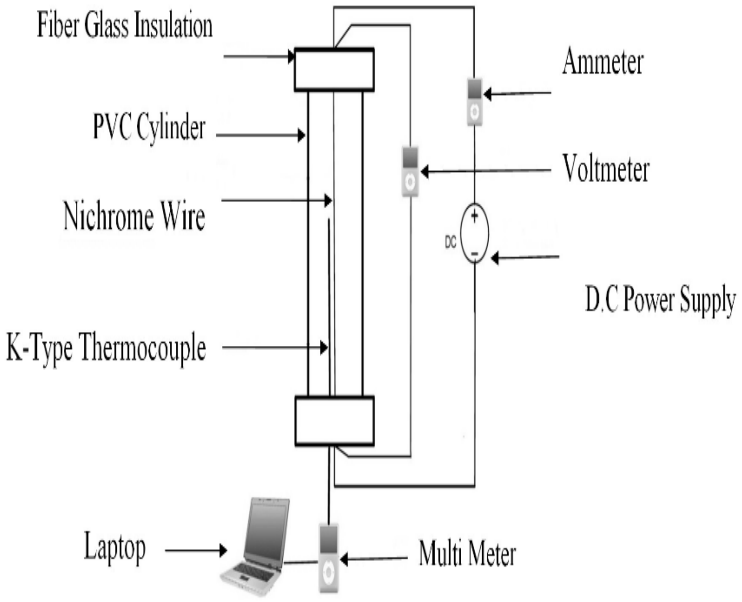

Fig.1. Line heat source device

In order to measure the core line, a K-type thermocouple of STANDARD ST-941 with the accuracy of 1˚C (made in China) was applied. The thermocouple was mounted on a base at a distance of 12 mm from the heat line source. During the test, it was assumed that the temperature of the container was fixed (constant); therefore, a K-type thermocouple was embedded in the outer surface of the container to monitor the temperature. Considering the recorded temperature per second of the data logger output, the schematic chart of the temperature value was drawn in the time natural logarithm within 600 seconds of the test. The slope and coefficient of determination (R^2) were measured for each sample. The thermal conductivity was determined, using the charts in which R^2 value was larger than 0.990 (Azadbakht *et al.*, 2013).

Specific heat

Specific heat was determined using mixture method (Mohsenin, 1980; Bitra *et al.*, 2010; Razavi and Taghizadeh, 2007; Azadbakht *et al*., 2013; Bart–Plange *et al*., 2012). In order to measure the specific heat of the canola pods at a constant pressure, the calorimeter was first put in the refrigerator to cool down, as shown in Figure 2. Therefore, the low lost heat was negligible. Two hundred g of distilled water was boiled and then added to the calorimeter. Afterwards, the temperature was measured and recorded. Ten g of the sample was then added to the calorimeter at a given temperature (25˚C). The mixture was allowed to balance thermally. Finally, the specific heat of the pod was calculated, using balance Eq. (5).Between the heat acquired or lost by water and calorimeter and the heat acquired or lost by the sample (Azadbakht *et al.*, 2013).

$$C_s = \frac{C_w W_w (t_a - t_w) - C_c W_c (t_i - t_a)}{W_s (t_i - t_a)} \qquad (5)$$

C_s is the specific heat of the sample (kJ/kg.˚C), C_w is the specific heat of water (kJ/kg.˚C), W_w is the added mass of water (g), t_a is the balance temperature (˚C), t_w is the initial temperature of water (˚C), C_c is the specific heat of the calorimeter (kJ/kg.˚C), W_c is the bucket mass of the calorimeter (g), t_i is the initial temperature of the sample (˚C), and W_s is the mass of the sample (g).

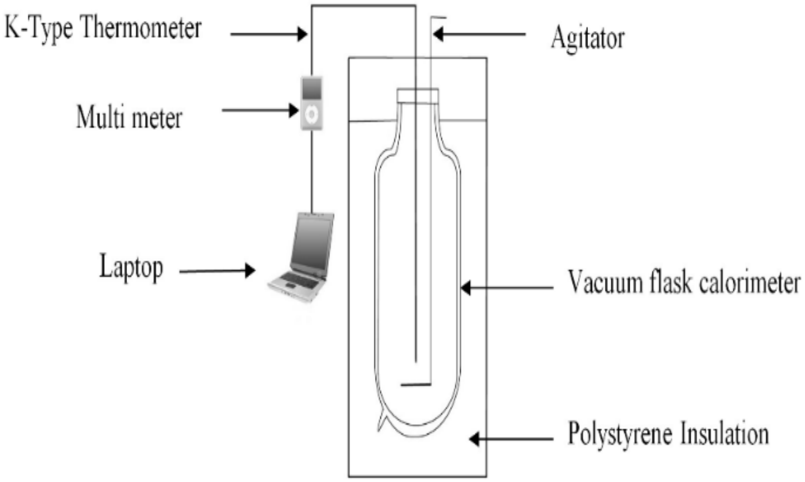

Fig. 2. Vacuum calorimeter

Thermal diffusivity

The thermal diffusivity of the pods was obtained by Eq. (6) (Ariara and Haque, 2001; Azadbakht *et al.*, 2013; Yang *et al.*, 2002; Bart–Plange et al., 2012).

$$\alpha = \frac{K}{\rho C_p} \qquad (6)$$

α represents the thermal diffusivity (m^2s^{-1}), K is the thermal conductivity ($W.m^{-1}°C^{-1}$), ρ is the bulk density ($kg\ m^{-3}$), and C_p is the specific heat ($J\ kg^{-1}°c^{-1}$).

To measure the density of cumulus, a cylinder with known mass and volume was filled with pods without a gap and then was weighed. With knowing the volume of a cylinder (diameter of 26.44 mm and height of 71.04 mm), the bulk density was obtained.

Canola losses

In order to determinethe canola losses, natural losses, seed losses by platform, seed losses in the whole combine harvester, and unopened pods were studied. Thus, a wooden frame with the dimensions of 50cm×50cm was provided. In each harvest time, the natural losses were initially estimated. Following that, in order to determine the combine harvester platform losses, the frame was placed at point 1 in Figure 3 to determine the combine harvester losses. In addition, the frame was placed at point 2 in Figure 3 to determine the losses of the whole combine harvester.

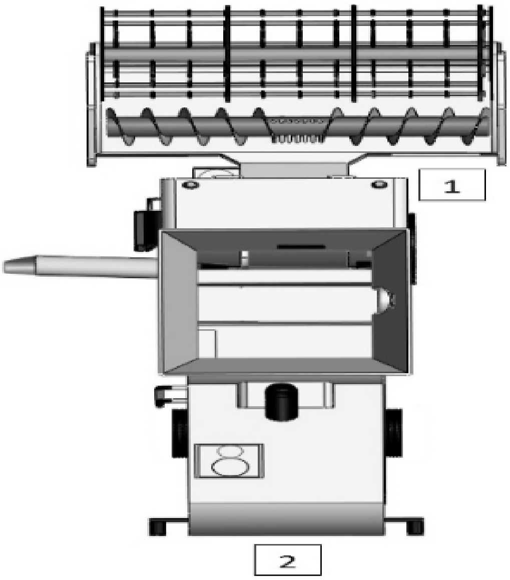

Fig. 3. The position of the wooden frame to the combine harvester in the field

The seeds in the frame were then collected by a built grain collector (Figure 4) and weighed. The collector was equipped with a silicon filter, which kept the seeds inside, and an air filter, which prevented the collector from being damaged by dust.

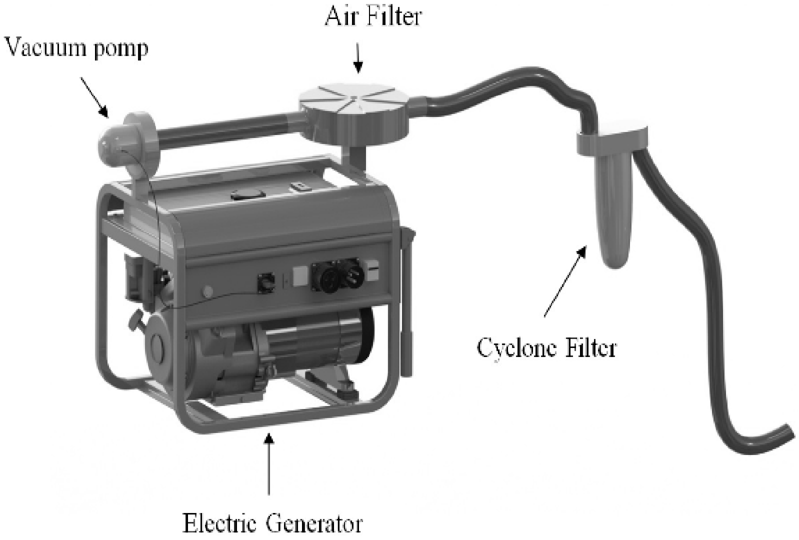

Fig. 4. Field grain collector

Results and Discussion

Natural losses

Changing the variety and the sampling time significantly influenced the canola natural losses at the probability level of 1%. Moreover, it was observed that the interaction between the variety and the sampling time at 1% affected the natural losses. The maximum and minimum values of natural losses were 0.56 and 0.04 g m^{-2}, respectively; post-harvest and pre-harvest in term of time; and, Hyola 420 and Hyola 50 in term of varieties.

Platform seed losses

Changes in the sampling time at 1% influenced the platform losses. The minimum losses were observed at the pre-harvest time due to the high moisture content.

Seed losses in the whole combine harvester

Changes in variety and harvest time affected seed losses at the probability level of 1%. The highest seed losses were assigned to the variety of Hyola 420; however, the lowest losses were observed in the variety of Hyola 50. The minimum seed losses were noticed in the pre-harvest period, which significantly increased over time to such an extent that post-harvest losses were 4 times more than the pre-harvest losses.

Unbroken pods

Changes in variety and harvest time influenced the value of canola unbroken pods at the probability level of 1%. The variety of Hyola 50 had the minimum unbroken pods, and the maximum amount of unbroken pods was observed at the pre-harvest time.

The relation between canola harvest losses and thermal properties of canola pods

Losses and thermal conductivity

The variety and the sampling time influenced the thermal conductivity coefficient at the probability level of 1%. Moreover, the interaction between the variety and the sampling time had a substantial effect on the thermal conductivity at this level. The maximum and minimum values of the thermal conductivity were 0.47 $(Wm^{-1}{}^{\circ}c^{-1})$ and 0.16 $(Wm^{-1}{}^{\circ}c^{-1})$ in the varieties of Hyola 50 and Hyola 420 in pre-harvest and post-harvest periods, respectively.

According to Table 1, the thermal conductivity is correlated with platform seed losses and unbroken pods at the probability levels of 5% at 1%, respectively. Moreover, it was observed that the thermal conductivity with the coefficient of 4.16 had a negative, inverse relation with platform seed losses. In other words, the higher thermal conductivity at a given composition the lower canola losses. It was also found that the thermal conductivity with the coefficient of 67.74 was directly correlated with unshelled pods.

Table 1- Analysis of regression of grain losses and thermal conductivity

Variable	DF	Natural losses	Platform grain losses	Whole combine harvester grain losses	Unbroken pod
Thermal conductivity	1	-0.062^{ns}	-4.16^{*}	-7.84^{ns}	67.74^{**}
Intercept	1	0.021^{ns}	2.14^{**}	4.83^{**}	-2.84^{ns}

According to Table 1 and considering the coefficients, Eq. (7) demonstrates the relation between thermal conductivity and platform seed downfall. In addition, Eq. (8) indicates the relation between thermal conductivity and unbroken pods as follows:

$$Loss\ of\ platform = 2.14 - 4.16\ K \qquad (7)$$

$$Unbroken\ pods = -2.84 + 67.74\ K \qquad (8)$$

According to Figure 5, the increased thermal conductivity reduces platform losses. When the thermal conductivity is high, this means that the moisture is high as well. Therefore, the losses are reduced through increasing the thermal conductivity and the moisture. Moreover, increased thermal conductivity and higher moisture result in an increase in the number of unbroken pods.

Losses and specific heat

The variety and the sampling time at the probability level of 1% and their interaction at the probability level of 5% were highly influential for the specific heat of canola pods. The maximum and minimum specific heat was 2.47 (kJ kg$^{-1\circ}$c^{-1}) and 0.69 (kJ kg$^{-1\circ}$c^{-1}) for the varieties of Hyola 420 and Hyola 50 at pre- and post-harvest periods, respectively.

According to Table 2, the regression coefficient of specific heat showed no significant relations with natural losses, platform seed losses, and combine harvester losses; nevertheless, this regression coefficient played a significant role in the relation between specific heat and unbroken pods at the probability level of 1%. According to Table 2, the specific heat with the coefficient of 11.45 was directly correlated with unshelled pods.

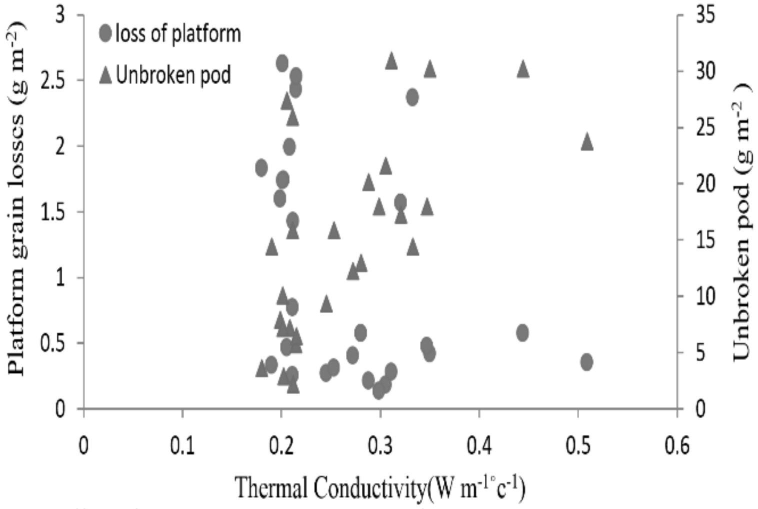

Fig. 5. Effect of thermal conductivity on platform grain losses and unbroken pods

Table 2. Analysis of regression of grain losses and specific heat

Variable	DF	Natural losses	Platform grain losses	Whole combine harvester grain losses	Unbroken pod
Specific heat	1	0.027^{ns}	-0.52^{ns}	-0.75^{ns}	11.45^{**}
Intercept	1	0.16^{ns}	1.72^{**}	3.74^{**}	-0.12^{ns}

By considering Table 2 and the coefficients, we can obtain the relation between the specific heat of canola pods and that of the unbroken pods by Eq. (9):

$$Unbroken\, pods = -0.12 + 11.45\, C \qquad (9)$$

According to Figure 6, the amount of the unbroken pods increases by higher specific heat and moisture.

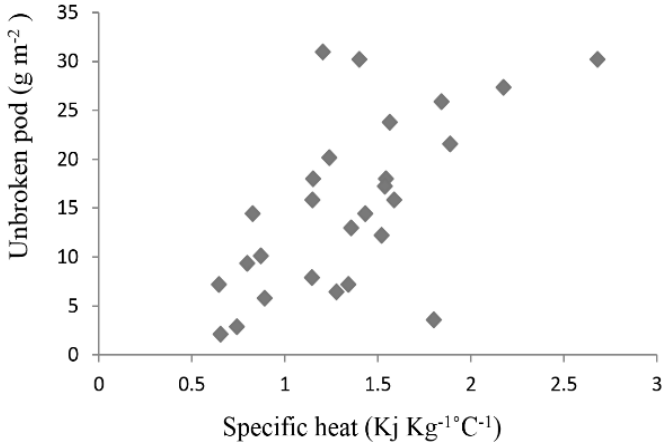

Figure 6- Effect of specific heat on unbroken pods

Losses and thermal diffusivity

The interaction between the varieties and the sampling time had a significant effect on the thermal diffusivity at the probability of 5%. The maximum and minimum values of thermal diffusivity were 1.87×10^{-6} (m^2s^{-1}) and 6.59×10^{-7} (m^2s^{-1}) in pre- and post-harvest periods, respectively, for the variety of Hyola 401.

As Table 3 depicts, the regression coefficient of thermal diffusivity and unbroken pods was effective at the probability level of 1%. Additionally, a negative, inverse relation was noticed between thermal diffusivity with the coefficient of 6183351 and the number of unshelled pods.

Table 3. Analysis of regression of grain losses and thermal diffusivity

Variable	DF	Natural losses	Platform grain losses	Whole combine harvester grain losses	Unbroken pod
Thermal Diffusivity	1	53110^{ns}	475242^{ns}	668464^{ns}	-6183351^{**}
Intercept	1	0.13^{ns}	0.4^{ns}	1.86^{*}	23.37^{**}

Equation (10) presents the relation between the thermal diffusivity of canola pods and unbroken pods with respect to Table 3 and the coefficients:

$$Unbroken\ pods = 23.37 - 6.18 \times 10^{6}\ C \quad (9)$$

As Figure 7 shows, the unbroken pods decrease by increasing the thermal diffusivity of canola pods.

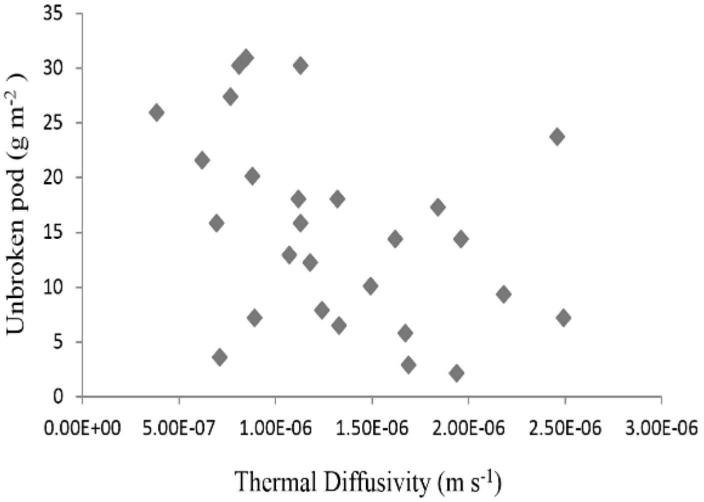

Fig. 7. Effect of thermal diffusivity on unbroken pods

Conclusion

The analysis of seed losses demonstrated that the minimum natural losses, platform losses, and combine harvester seed losses were observed in the pre-harvest period. Therefore, early harvesting may remarkably reduce the amounts of losses. Moreover, studying the canola varieties also revealed that the varieties of Hyola 420 and Hyola 50 had the maximum and minimum seed losses, respectively. Investigating the unbroken pods showed that the highest amount of unbroken pods was observed in the pre-harvest period. In addition, the minimum amount of unbroken pods was attributed to the variety of Hyola 50. In point of fact, the best variety, in terms of losses, was Hyola 50, and the best time was the pre-harvest time due to its lowest amount of losses. The results obtained revealed that the whole combine harvester losses are larger than the platform losses, indicating the high losses in the other parts of the combine harvester. Canola seeds are so tiny that require an accurate adjustment of combine harvester at harvesting in order to minimize the losses of this strategic product. Increased thermal conductivity reduces platform seed losses, while it increases the losses of unbroken pods. Increased specific heat also increases the unbroken pods. However, the higher thermal diffusivity of canola pods reduces the amount of the unbroken pods.

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تلفات دانه کلزا هنگام برداشت با کمباین برداشت غلات تحت تاثیر خواص حرارتی غلاف نشکسته کلزا

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چکیده

در تحقیق حاضر،خواص حرارتی غلاف کلزا شامل ضریب رسانندگی حرارتی، گرمای ویژه و ضریب انتشار حرارتی و میزان تلفات کلزا شامل تلفات طبیعی، تلفات پلاتفرم، تلفات کل کمباین و غلاف کوبیده نشده در سه سطح رقم مرسوم کلزای کشت شده در شمال ایران (هایولا 50، هایولا 401 و هایولا 420) و در سه زمان قبل از برداشت، حین برداشت و پس از برداشت اندازه‌گیری شدند. سپس ارتباط بین خواص حرارتی غلاف کلزا با میزان تلفات هنگام برداشت کلزا بررسی شد. ضریب رسانندگی با روش منبع حرارت خطی، گرمای ویژه از روش مخلوط و ضریب انتشار از طریق فرمول محاسبه شدند. برای اندازه‌گیری مقدار تلفات دانه از جاروبرقی صحرایی ساخته شده استفاده گردید. نتایج نشان داد که تغییرات، رقم و زمان نمونه‌برداری بر ضریب رسانندگی حرارتی و گرمای ویژه در سطح احتمال یک درصد معنی‌دار بوده است. و نیز اثر متقابل رقم و زمان بر ضریب‌رسانندگی در سطح یک درصد و بر گرمای ویژه و ضریب انتشار حرارتی در سطح 5 درصد موثر بوده است. همچنین اثرات رقم و زمان برداشت بر تلفات طبیعی، تلفات کل کمباین و غلاف کوبیده نشده در سطح یک درصد موثر بود. همچنین مشاهده شد بین ضریب رسانندگی حرارتی و تلفات پلتفرم در سطح 5 درصد و باغلاف کوبیده نشده در سطح یک درصد ارتباط معنی‌دار بود. و همچنین غلاف کوبیده نشده با گرمای ویژه و ضریب انتشار حرارتی در سطح یک درصد ارتباط معنی‌دار داشت.

واژه‌های کلیدی: غلاف کلزا، تلفات برداشت، ضریب رسانندگی حرارتی، ضریب انتشار حرارتی، گرمای ویژه.

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