Moisture-Depend some Postharvest Properties of Two Varieties of Safflower

(*Darab* and *Goldasht*)

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Abstract

The moisture-dependent physical properties are important to investigate for designing the post harvest equipments of the product .This study was carried out to determine the effect of moisture content on some physical properties. Four levels of moisture content ranging from 4-22% d.b (wet basis) and 4-22% d.b. for Darab and Goldasht, respectively was used. The average length, width, thickness, geometric mean diameter, equivalent diameter, arithmetic diameter, sphericity, thousand grain mass, angle of repose, grain volume, surface area and aspect ratio ranged from 7.52 to 7.89   mm, 3.95 to4.48 mm, 3.36 to 3.70 mm, 4.51 to 4.99 mm and 4.52 to5.00 mm, 4.89 to 5.36 mm, 60% to 63%, 32.2 to40.7 gr, 43º to 51º, 34.83 to 47.43 mm^3, 57.28 to 70.38 mm^2, 52.57% to 56.74% as the moisture content increased from 4 to 22% d.b. for Darab and from 7.41 to 7.67 mm, 4.59 to 4.74 mm, 3.57 to 3.84 mm, 4.93 to 5.18 mm, 4.88 to 5.12 mm, 5.17 to 5.41 mm, 66.37% to 68.56%, 50.50 to 59.2 gr, 47° to 56°, 40.76 to 53.12 mm^3, 62.27 to 72.38 mm^2, 64.22% to 62.95% with increase in moisture content from 4 to 22% d.b. for Goldasht. Goldasht has higher static angle of repose than Darab in all moisture content levels. As the moisture content increased, the bulk density was found to decrease from 547 to 520 kgm^{-3} and from 640 to 601 kgm^{-3} for Goldasht and Darab, respectively whereas true density and porosity were found to decrease from 1070 to 1010 kgm^{-3} and 48.87% to 48.51% for Goldasht and from 940 to 850 kgm-3, 31.91% to 29.29% for Darab. The static coefficients of friction on various surfaces, namely, galvanized metal, plywood and plastic also increased linearly with an increase in moisture content. For galvanized metal and plastic Darab was higher correlated with moisture content than Goldasht.

Keywords: Safflower, Physical properties, Moisture content, Darab variety, Goldasht variety

Introduction

The safflower is a plant that has the scientific name of Carthamus tinctorius L. The safflower which belongs to the Composite family is cultivated in several parts of the world due to its adaptability at different environmental conditions. In the past, safflower was planted in order to provide the pigment for using in dyeing machine. Today, in addition to that application, its seed is used for the production of seed oil. In order to design equipment for the handling, conveying, separation, drying, aeration, storing and processing of safflower grains, it is necessary to determine their physical properties as a function of moisture content. The knowledge of some important physical properties such as shape, size, volume, surface area, thousand grain weights, density, porosity, angle of repose, of different grains is necessary for the design of various separating, handling, storing and drying systems (Sahay and Singh, 1994). The size and shape are, for instance, important in their electrostatic separation from undesirable materials and in the development of sizing and grading machinery (Mohsenin, 1986). The shape of the material is important for an analytical prediction of its drying behavior. (Esref and Halil, 2007).

Bulk density, true density, and porosity (the ratio of intergranular space to the total space occupied by the grain) can be useful in sizing grain hoppers and storage facilities; they can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Grain bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. Cereal grain kernel densities have been of interest in breakage susceptibility and hardness studies. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Such information is useful in sizing motor requirements for grain transportation and handling (Ghasemi Varnamkhasti *et al.*, 2007). The design of storage and handling systems for buckwheat requires data on bulk and handling properties, friction coefficients on commonly used bin wall materials (galvanized steel, plywood, and concrete), and emptying and filling angles of repose (Parde *et al.*, 2003). Theories used to predict the pressures and loads on storage structures (Janssen, 1895) require bulk density, angle of repose, and friction coefficients against bin wall materials. Also the design of grain hoppers for processing machinery requires data on bulk density and angle of repose. An example of the use of various bulk and handling properties of grains in the design of storage structures is given by Singh and Moysey (1985). The angle of repose determines the maximum angle of a pile of grain with the horizontal plane. It is important in the filling of a flat storage facility when grain is not piled at a uniform bed depth but rather is peaked (Mohsenin, 1986). Hence, current study was conducted on investigate some moisture dependent physical properties of safflower grain namely, dimensions, geometric mean, equivalent and arithmetic diameter, sphericity, thousand kernel weight (TKW), surface area, bulk density, true density, porosity, static angle of repose and static coefficient of friction against different materials.

Notations

L length, mm	Φ static coefficient of friction
W width, mm	θs static angle of repose, deg
T thickness, mm	ε porosity, %
S surface area, mm^2	Dg geometric mean diameter, mm
R^2 correlation determination	Dp equivalent diameter, mm
R$_a$ aspect ratio	Da arithmetic diameter, mm
M moisture content, %	V volume, mm^3
Mi initial moisture content, %	Sp sphericity, %
Mf final moisture content, %	ρb bulk density, kgm-3
Wt total weight of sample, g	ρt true density, kgm-3
ΔWw weight of required water, g	

1. Materials and Methods

Two of popular varieties of cleaned safflower were obtained from Plant and Seed Institute in Karaj, Iran. The initial moisture content of seeds was determined by oven method (Tabatabaeefar, 2003) and in order to achieve the desired moisture level as 4,12, 16, and 22 (%d.b), the rewetting formula was used Eq.(1), and to allow the moisture be absorbed by samples were placed in refrigerator.

$$\Delta W_w = W_t \frac{(M_f - M_i)}{(100 - M_f)} \tag{1}$$

A digital caliper was used to determine length, width, and thickness of about 20 randomly selected grains of each sample. The geometric mean, Dg, equivalent, Dp, and arithmetic diameter, Da, in mm was calculated by considering prolate spheroid shape for a safflower grain and hence Eq (2), Eq (3) and Eq (4), respectively (Mohsenin, 1986).

$$D_g = (LDT)^{\frac{1}{3}} \tag{2}$$

$$D_p = \left[L \frac{(W + T)^2}{4} \right]^{\frac{1}{3}} \tag{3}$$

$$D_a = \frac{(L + W + T)}{3} \qquad (4)$$

The sphericity (Sp) defined as the ratio of the surface area of the sphere having the same volume as that of grain to the surface area of grain, was determined using following formula (Mohsenin, 1986).

$$S_p = \frac{(LDT)^{\frac{1}{3}}}{L} \qquad (5)$$

Thousand kernel weight (TKW) was measured by counting 100 seeds and weighing them in an electronic balance to an accuracy of .001 and then multiplied by 10 to give mass of 1000 kernels. Jain and Bal (1997) have considered grain volume, V and surface area, S may be given by:

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W + T)^2\right] \qquad (6)$$

$$S = \frac{\pi B L^2}{(2L - B)} \qquad (7)$$

where

$$B = \sqrt{WT} \qquad (8)$$

The aspect ratio (Ra) was calculated by (Omobouwajo *et al.*, 1999).

$$R_a = \frac{W}{L} \qquad (9)$$

The true density is a ratio of mass sample of grains to its pure volume. It was determined by the toluene displacement method (Mohsenin, 1986). Bulk density is the ratio of the mass sample of grains to its total volume. It was determined by filling a predefined container with from a constant high, striking the top level and then weighing the constants (Dashpande *et al.*, 1993). The porosity is the ratio of free space between grains to total of bulk grains. That was computed as:

$$\varepsilon = \frac{\rho_k - \rho_b}{\rho_k} \times 100 \qquad (10)$$

The coefficient of static friction was determined with respect to different surfaces: plywood, plastic and galvanized metal. A hollow metal cylinder (Fig. 1) of diameter 75mm and depth 50mm and open at both ends was filled with the seeds at the desired moisture content and placed on adjustable titling surface such that the metal cylinder did not touches the surface. Then the surface was raised gradually until the filled cylinder just started to slide down (Razavi and Milani, 2006).

The static angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using the apparatus (Fig. 2) consisting of a plywood box of 140-160-35mm and two plates: fixed and adjustable. The box was filled with the sample, and then the adjustable plate was inclined gradually allowing the seeds to follow and assume a natural slope (Tabatabeefar, 2003). Finally, the data were analyzed statistically and figures were plotted using Excel software 2007.

2. Results and discussion

A summary of the dimensions of Darab cultivar is shown in Table 1. All dimensions were increased with an increase in moisture content from 4% to 22% d.b. The increasing trend in axial dimensions, with gain in moisture content, was due to filling of capillaries and voids upon absorption of moisture and subsequent swelling (Table 1).

One thousand kernel weight (TKW) was increased significantly at 5% level of probability from 32.2 to 40.7 g as the moisture content increased from 4 - 22 d.b.(Fig. 3). Linear Relationship for one thousand kernel weight based on moisture content, M, was determined as follows:

(for Darab)	M*(1000)*= 0.471M + 30.51	$R^2 = 0.995$	(1)
(for Goldasht)	M(1000)= 0.479M + 49.00	$R^2 = 0.978$	(2)

The surface area of safflower grains increased from 57.28 to 70.38 mm^2, when the moisture content of grains increased from 4 to 22% d.b for Darab and from 62.27 to 72.38 when the moisture content of grainsa increased from 4 to 22% d.b for Goldasht. Milani *et al.* (2007) reported an increased in surface area of cucurbit seeds of three varieties at different moisture contents in the range of 5.18 - 42.76% d.b.

For Darab the sphericity of safflower grains increased from 0.60 to 0.63 with an increase in moisture content from 4 to 22% d.b. but for Goldasht the sphericity of safflower grains increased from 0.66 to 0.68 with an increase in moisture content from 4 to 22% d.b. The volume and aspect ratio of safflower grains have the same behavior. From table 1 it can be seen that geometric mean diameter, equivalent diameter and arithmetic diameter have the same behavior with increase in moisture content for both Darab and Goldasht. In this regard Esref and Halil (2007) found similar result for white speckledred kidney bean grains. The values of the bulk density for different moisture levels linearly decreased from 640 to 601 kg m^{-3} for Darab and from 547 to 520 kg m^{-3} for Goldasht (Fig. 4). The bulk density of seed was found to bear the following relationship with moisture content:

$$\text{(for Darab)} \qquad \rho_b = -2.204M + 654.2 \qquad R^2 = 0.857 \qquad (3)$$

$$\text{(for Goldasht)} \qquad \rho_b = -1.491M + 556.6 \qquad R^2 = 0.862 \qquad (4)$$

The above equations show that changing in moisture content has a greater impact on values of bulk density of Darab grains and equation 1 has greater slope. The decrease in bulk density for Goldasht grains is more linear than Darab ($R^2_{eq2} > R^2_{eq1}$). A similar decreasing trend in bulk density has been reported by Gupta and Das (1997) for corn seed. Whereas Parde *et al.* (2003) reported that the standard bulk density of Koto buckwheat increased significantly from 603.90 to 612.90 kgm^{-3} with an increase in moisture content from 14.8 to 15.8 %. With a further increase in moisture content, the standard bulk density decreased significantly.The true density and the moisture content of grain can be correlated as follows:

$$\text{(for Darab)} \qquad \rho_t = 0.013M^2 - 3.609M + 1083 \qquad R^2 = 0.992 \qquad (5)$$

$$\text{(for Goldasht)} \qquad \rho_t = -0.375M^2 + 5.051M + 923.8 \qquad R^2 = 0.942 \qquad (6)$$

For both Darab and Goldasht true density values decrease with increase in moisture content but the decrease is polynomial. It can be noted that Goldasht has greater true density than Darab in all moisture content levels (Fig. 5).

$$\text{(for Darab)} \qquad \varepsilon = 0.001M^2 - 0.100M + 32.32 \qquad R^2 = 0.99 \qquad (7)$$

$$\text{(for goladasht)} \qquad \varepsilon = 0.010M^2 - 0.281M + 49.80 \qquad R^2 = 0.865 \qquad (8)$$

The porosity of Darab safflower grains decreased polynomialy at the 5% level of probability from 31.91% to 29.29% with the increase in moisture content from 4 – 22% d.b. but for Goldasht the increase is not as much linear $R^2 = 0.865$ (Fig. 6). Goldasht has greater values of porosity in all moisture content levels. Moisture content has greater impact on porosity of Darab grains (from 31.90 to 29.29 d.b). The relationship between porosity and moisture content can be represented by the following polynomial equations:

The static coefficient of friction of safflower grains on three surfaces (plastic, plywood and galvanized metal) against different levels of moisture content are presented in Fig. 7. It was observed that the static coefficient of friction increased (probability < 0.05) with increase in moisture content for all the surfaces. This is due to the increased adhesion between the grains and the material surfaces at higher moisture values. Increases of 52.7%, 52.6% and 67.6% were recorded in the case of plastic, plywood and galvanized metal for Darab but for Goldasht the values of 22.2%, 83.3% and 60% were obtained, respectively, as the moisture content increased from 4 – 22% d.b. for Darab and Goldasht. For both variety at all moisture contents, the least static coefficient of friction was on galvanized metal. This may be owing to smaller cohesive force between grains and the galvanized metal than the other materials used . The relationships between static coefficient of friction and moisture content on plastic, plywood and galvanized metal can be represented by the following equations:

	$\varphi_{wood} = 0.010M + 0.337$	$R^2 = 0.978$	(9)
For Darab	$\varphi_{galv} = 0.012M + 0.295$	$R^2 = 0.992$	(10)
	$\varphi_{plas} = -0.000M^2 + 0.023x + 0.271$	$R^2 = 0.996$	(11)
	$\varphi_{wood} = 0.013M + 0.264$	$R^2 = 0.948$	(12)
For Goldasht	$\varphi_{galv} = 0.010M + 0.261$	$R^2 = 0.984$	(13)
	$\varphi_{plas} = -0.000M^2 + 0.023M + 0.281$	$R^2 = 0.832$	(14)

Similar results were found by Sahoo and Srivastava (2002) for okra. Parde *et al*. (2003) reported that the friction coefficient against plywood, galvanized steel and concrete surfaces for the Koto buckwheat cultivar increased significantly 0.26 to 0.31, 0.25 to 0.29 and 0.38 to 0.43 respectively, with increase in moisture content from 14.8 % to 17.9 %. The authors continued for significantly increasing the moisture content variation required more than 1 %. The experimental results for the static angle of repose with respect to moisture content are shown in Fig. 8. The values of the static angle of repose were found to increase significantly at the 5% level of probability from

43º to 51° and from 47º to 56° for Darab and Goldasht respectively. The static angle of repose for safflower has the following relationships with its moisture content.

(for Darab)	$\theta st = 0.432M + 40.15$	$R^2 = 0.842$	(15)
(for Goldasht)	$\theta st = 0.517M + 44.26$	$R^2 = 0.939$	(16)

Figure 8 shows that Goldasht has the greater static angle of repose in all moisture content levels and the increase in static angle of repose is more linear for Goldasht than Darab. From equations (15) and (16), it can be resulted that increase in moisture content has greater impact on static angle of repose of Goldasht (m=.517). Tabatabeefar (2003) found that the values of dynamic angle of repose for corn increased from 34.7º to 45° in the moisture range of 0 to 22% d.b. Parde *et al.*, (2003) reported that the emptying angle of repose for Koto buckwheat cultivar remained constant at about 23.5° from 14.8 to 15.8% mc and then increased significantly and the filling angle of repose did not differ significantly at 14.8 to 16.6% but increased significantly to 28.4° at 17.9%.

Conclusions

All the studied physical properties of safflower grains depend on their moisture contents. The following conclusions are drawn from the investigation on physical properties of two varieties of safflower grains for moisture content range of 4 to 22% d.b. for Darab The average length, width, thickness, geometric mean diameter, equivalent diameter, arithmetic diameter, sphericity, thousand grain mass, angle of repose, grain volume, surface area, bulk density, true density, porosity, and aspect ratio, for safflower grains ranged from 7.52 to 7.89 mm, 3.95 to4.48 mm, 3.36 to 3.70 mm, 4.51 to 4.99 mm and 4.52 to5.00 mm, 4.89 to 5.36 mm, 60% to 63%, 32.2 to40.7 gr, 43º to 51º, 34.83 to 47.43 mm^3, 57.28 to 70.38 mm^2, 640 to 610 kgm^3,940 to 850 kgm^3,31.91% to 29.29% and 52.57% to 56.74% and from 7.41 to 7.67 mm, 4.59 to 4.74 mm, 3.57 to 3.84 mm, 4.93 to 5.18 mm, 4.88 to 5.12 mm, 5.17 to 5.41 mm, 66.37% to 68.56%, 50.50 to 59.2 gr, 47° to 56°, 40.76 to 53.12 mm^3, 62.27 to 72.38 mm2, 547 to 520 kgm^3, 1070 to 1010 kgm^3,48.87% to48.51%, 64.22% to 62.95% for Goldasht in the moisture content increase from 4 to 22% d.b respectively. The change in moisture content has greater impact in the bulk density of Goldasht was higher correlated with moisture content than Darab but for true density and porosity   Darab has higher correlation with moisture content. The static coefficient of friction on various surfaces increased linearly with increase in moisture content. For Darab the galvanized metal as a surface for sliding offered the maximum friction followed by plywood and plastic but for Goldasht plywood shows the maximum friction while the static coefficient of friction for galvanized metal and plastic is almost the same.

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Table 1. Some physical properties of Darab variety dependent on moisture content.

MC (%)	L (mm)	W (mm)	T (mm)	D_g (mm)	D_p (mm)	D_a (mm)
4	7.52±0.62	3.95±0.54	3.36±0.32	4.51±0.54	4.52±0.56	4.89±0.38
12	7.75±0.57	4.22±0.45	3.46±0.23	4.76±0.63	4.78±0.64	5.15±0.66
16	7.78±0.56	4.43±0.37	3.71±0.23	4.95±0.31	4.97±0.32	5.30±0.34
22	7.89±0.41	4.48±0.61	3.70±0.19	4.99±0.31	5.00±0.32	5.36±0.30

Table 2. Some physical properties of Goldasht variety dependent on moisture content.

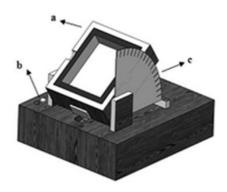| MC (%)	L (mm)	W (mm)	T (mm)	D_g (mm)	D_p (mm)	D_a (mm)
4	7.41±0.34	4.59±0.31	3.57±0.32	4.93±0.29	4.88±0.28	5.17±0.27
12	8.08±0.44	4.96±0.38	4.05±0.26	5.45±0.32	5.38±0.31	5.70±0.32
16	7.78±0.48	4.63±0.32	3.74±0.33	5.13±0.33	5.08±0.32	5.40±0.34
22	7.67±0.32	4.74±0.27	3.84±0.19	5.18±0.19	5.12±0.18	5.41±0.18

Figure 1. Apparatus to determine empting angle of repose

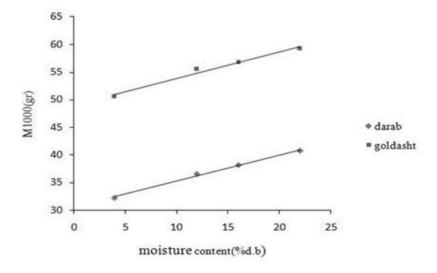Figure 2. Apparatus to determine coefficient of static friction

Figure 3. Effect of moisture content on M(1000): Goldasht (□) and Darab (◊)
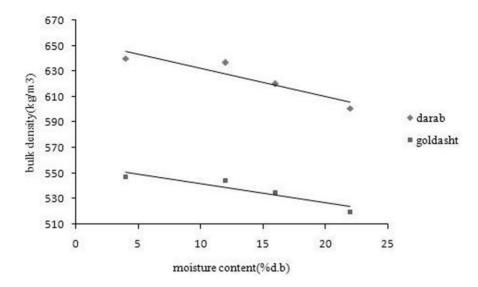
Figure 4. Effect of moisture content on bulk density: Goldasht (□) and Darab (◊)
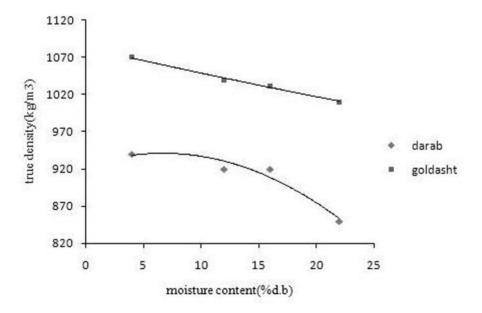

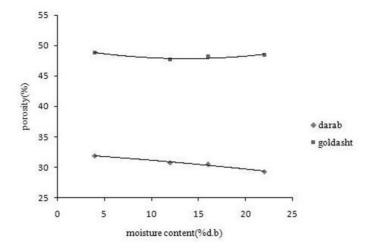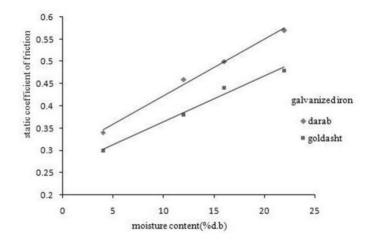Figure 5. Effect of moisture content on true density: Goldasht (□) and Darab (◊)
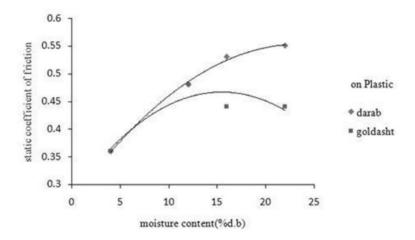
Figure 6. Effect of moisture content on porosity: Goldasht(□) and Darab (◊)
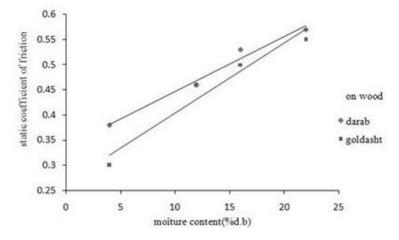
Figure 7. Effect of moisture content on static coefficient of friction: Goldasht(□) and Darab (◊)
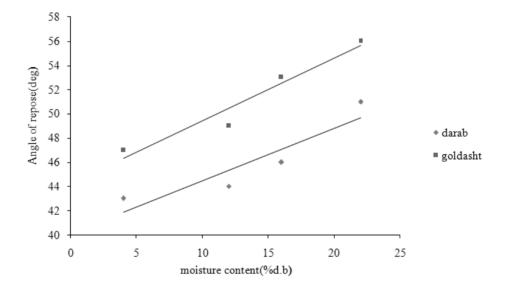
Figure 8. Effect of moisture content on static angle of repose: Goldasht (□) and Darab (◊)