Effects of Moisture Content on Some Physical Properties of Apricot Kernel (CV. Sonnati Salmas)

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ABSTRACT

Investigation of physical properties of apricot kernel is necessary for the design of equipment for processing, transportation, sorting and separating. In this research the physical properties of apricot kernels have been evaluated as a function of moisture content vary from 2.86 to 13.03% (w.b.). With increasing in moisture content, kernel length, width, thickness, geometric mean diameter and surface area increased; the sphericity varyied from 62.2% to 62.9%; mass, thousand grain mass, volume and true density increased from 0.437 to 0.484 (gr), 437.4 to 484 (gr), 0. 431 to 0.473 (cm^3) and 1015.7 to 1023.5 (kg/m^3), respectively; The porosity and bulk density decreased from 47.21 to 42.71% and 580.02 to 540.11 (kg/m^3) respectively. The angle of static friction on all surfaces increased as the moisture content increased

Keywords: Apricot kernel, physical properties, moisture content, Sonnati Salmas, Iran

1. INTRODUCTION

Apricot (*Prunus Armenia* L.) has an important place in human nutrition and apricot fruits can be used as fresh, dried or processed fruit. Stone-fruit crops, including apricot are temperate fruits which are grown in climates with well-differentiated seasons. Mechanisms against the impact of low winter temperatures and frost damage have been developed by species growing under these conditions. Dormancy and freezing tolerance are the main mechanisms developed against these difficulties and, although they could be independent (Irving and Lamphear, 1967), freezing tolerance cannot be developed adequately without growth cessation (Fuchigami *et al.,* 1971), which marks the onset of dormancy. As known, the fruit of apricot is not only consumed fresh but also used to produce dried apricot, frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products etc. Moreover, apricot kernels are used in the production of oils, benzaldehyde, cosmetics, active carbon, and aroma perfume (Yildiz, 1994). Apricot is rich in minerals such as potassium and vitamins such as β- carotene, which is the pioneer substance of mineral A, is necessary for epithelia tissues covering our bodies and organs, eye-health, bone and teeth development and working of endocrine glades. Moreover, vitamin A plays an important role in reproduction and growing functions of our bodies, in increasing body resistance against infections. Iran is the second apricot producer in the world with 275580 ton production and 8.2% share (FAO, 2005). In Iran, the most widely produced types are Tabarzeh, Kardi Damavandi, Nakhjavan and Sonnati. Turkey, Iran, Italy, Pakistan and France are the principal apricot countries. Trees are also grown in Spain, Japan, Syrian Arab Republic and Algeria. Iran has exported more than 680 tones to different countries in 2005 (FAO, 2005). The trees of these types of apricot are high, strong and grow rapidly and have wide and shallow branches. They bear fruits every year in fertile and irrigated soils. The distance between trees is approximately 10 m, average fruit weight ranges between 20 and 60 g, dried substance percentage in fruit is 18–28%, pH value is between 4.0 and 5.0 and their color are yellow. Their harvesting phase is between the last of June and the beginning of July. The first three of these varieties are evaluated as dry products; the other three are evaluated as fresh products. The agriculture of apricot needs extensive labor and energy. In Iran, apricot fruits are harvested at about 77% moisture level (Agricultural Statistical Bulletin (ABS), 2005). Apricot pits are also separated into shells and kernels in the regional conglomerates which have washing, sorting, and breaking and separation units. The resulting shells are generally used as fuel .The physical properties of apricot are important for the design of equipments for harvesting and post-harvesting technology transporting, storing, cleaning, separating, sorting, sizing, packaging and processing it into different food. Since currently used systems have been generally designed without taking these criteria into consideration, the resulting designs lead to inadequate applications. These results in a reduction in work efficiency, an increase in product loss. Therefore, determination and consideration of these criteria have an important role in designing of these equipments.

Many studies have reported on the physical and mechanical properties of kernels, seeds and fruits such as Dutta *et al.* (1988) for gram, Gupta and Das (1997) for almond nut and kernel, Ogut (1998) for white Lupin, Aydin (2002) for Hazel nuts, Kaleemullah and Gunasekar (2002) for arecanut kernels, Gezer *et al.* (2002) for apricot pit and its kernel, Sahoo and Srivastava (2002) for okra seed, Konak *et al.* (2002) for chickpea seeds, Puchalski, Brusewitz and Slipek (2003) for Apple, Aydin (2003) for Almond nut and kernel, Baryeh and Mangope (2003) for pigeon pea, Khazaei and Mann (2004) for Sea Buckthorn Berries, Mamman, Umar and Aviara(2005) for *Balanites Aegyptiaca* Nuts, Kashaninejad *et al.*(2005) for pistachio nuts and kernels, Karababa (2006) for popcorn kernels, ElMasry *et al* (2006) for Potato, Oluwole, Aviara, and Haque for Sheanut, Keramat Jahromi *et al* (2007) for Date Fruit (cv. Lasht), Keramat Jahromi *et al* (2007) for Bergamot *(Citrus medica)* Fruit, Razavi *et al*. (2007) for pistachio nuts and their kernels and Ghadge, Vairagar and Prasad (2008) for Chick Pea Split (Cicer arietinum L.).

As it can be found from literature review, there was no published paper about the physical properties of Iranian apricot kernel.

It is clear that investigating on physical and mechanical properties of apricot kernel is very essential and practical for its processing, transportation, sorting and separating. Then for achieving this aims, some important physical properties of apricot such as axial dimensions, thousand grain mass, true and bulk density, porosity, spherisity and Angle of static friction on 4 level of moisture were determined.

Nomenclature			
L	Length	V	Volume
W	Width	T_d	True density
T	Thickness	B_d	Bulk density
Dg	Geometric mean diameter	M_{1000}	Thousand grain mass
Φ	Sphericity	P	Porosity
S	Surface area	θ	Angle of static friction
M	Mass	Mc	Moisture content

2. MATERIALS AND METHODS

Sonnati Salmas apricot kernels (Fig.1) used for this study were collected from the orchard located in Salmas village in west Azarbayjan, Iran in august 2007. Broken pits and foreign matters such as dust, dirt, stones and chaff were removed from 7 kg apricot pit then 4 kg apricot kernel was obtained. Apricot kernels were cleaned by exposing them to air screen cleaner for foreign matters. All products were kept in the room temperature for two days. Moisture content was immediately measured on arrival. The kernels were divided into four batches in order to obtain four moisture levels for the experiments. For obtain the desired water contents of apricot kernel, the moisture of kernel samples were measured at six day intervals after apricots harvesting. The first water content of kernel was 13.03%, then after 6 days the water content of apricot kernels had fallen down to 8.81%, 4.1% and 2.86%(w.b.), respectively. Moisture contents of the kernels were determined by using a standard method (USDA, 1970).

Figure 1. Sonnati Salmas apricot kernels.

One hundred apricots randomly selected and its kernel some parameters including length (L) in mm, width (W) in mm, thickness (T) in mm, kernel mass (m) in gr, volume (V) in cm^3, true density (T_d) in kg/m^3, geometrical mean diameter (D_g) in mm, sphericity (Φ) factor and surface area (S) in mm^2 measured. Geometrical dimensions and mass of kernels, measured by micrometer and digital balance with accuracy 0.01mm and 0.001g respectively. By use of three dimensions, geometrical mean diameter, sphericity factor and surface area (S1 and S2) obtained from fallow equations (Mohsenin, 1970; Jain and Bal, 1997).

$$D_g = (LWT)^{0.333} \quad (1)$$

$$\Phi = (Dg/L)*100 \quad (2)$$

$$S1 = \pi Dg^2 \quad (3)$$

$$S2 = \frac{\pi BL^2}{2L - B} \quad (4)$$

where B = $(WT)^{0.5}$

In order to determine thousand grain mass (M_{1000}) in gram, randomly 100 kernel selected and weighted. True density (T_d) in kg/m^3 and volume (V) determined by using displacement liquid method. Toluene has used instead of water as liquid, because it is more advantages (Mohsenin, 1970; Ogut, 1998). The bulk density (B_d) is in kg/m^3 the ratio of the mass sample of the kernels to its total volume. It was determined by filling a 1000 ml container with kernels from a height of about 15 cm, striking the top level and then weighing the contents (Desphande et al. 1993). Also porosity (P) calculated by using following equation (Thompson and Isaacs, 1967; Mohsenin, 1970):

$$P = 1 - (\frac{B_d}{T_d}) \quad (5)$$

The angle of static friction (θ) of apricot kernels on four surfaces including wood, glass, and fiberglass and galvanize plate was determined. For determining Angle of friction, the product was put on the surface with adjustable slope (Fig.2). The angle at which the kernels started to slip, was indicated as angle of static friction.

Figure 2. The device for determining the angle of static friction

3. RESULTS AND DISCUSSION

The average values of physical properties of apricot kernels in different moisture content were compared by Duncan's multiple tests. Comparing average data by Duncan method related to geometrical, Gravimetrical and frictional properties are shown in tables 1, 2 and 3 respectively.

3.1 Geometrical Properties

Table1. Effect of moisture content on geometrical properties of apricot kernel

Geometrical properties	Replications	Moisture content 2.86%	4.1%	8.81%	13.03%
Length (mm)	100	15.21^{a}(1.217)	15.25^{a}(1.142)	15.34^{a}(1.213)	15.43^{a}(1.184)*
Width (mm)	100	10.34^{a}(0.916)	10.36^{a}(0.918)	10.42^{a}(0.885)	10.49^{a}(0.877)
Thickness (mm)	100	5.49^{a}(0.759)	5.52^{a}(0.813)	5.62^{a}(0.648)	5.75^{a}(0.742)
Geometric mean diameter (mm)	100	9.45^{a}(0.761)	9.48^{a}(0.715)	9.58^{ab}(0.697)	9.7^{b}(0.699)
Sphericity (%)	100	62.2^{a}(4.513)	62.25^{a}(4.479)	62.49^{ab}(3.729)	62.9^{b}(3.385)
Surface area 1 (mm^2)	100	282.35^{a}(41.513)	284.23^{a}(43.649)	289.88^{a}(57.647)	297.25^{a}(60.001)
Surface area 2 (mm^2)	100	238.9^{a}(35.121)	140.48^{ab}(35.487)	245.23^{b}(35.294)	251.45^{b}(35.319)

tests (at 5% level)
*standard deviation values in parentheses

3.1.1 Dimensions and Geometric Mean Diameter

Effects of moisture content on geometry dimension, such as length, width and thickness of apricot kernels, was shown on table1 and figure 3.

It is clear that there is much correlation between them. Reason for these phenomena is cellules inflation and penetration water in the porous area. Also by increasing humidity content, Geometrical mean diameter was increased. The positive linear relationship of dimension and geometric mean diameter with moisture content were also observed by other research works such as Gezer et al. (2002) and Kashaninejad et al. (2005) for apricot kernel and pistachio nut, respectively.

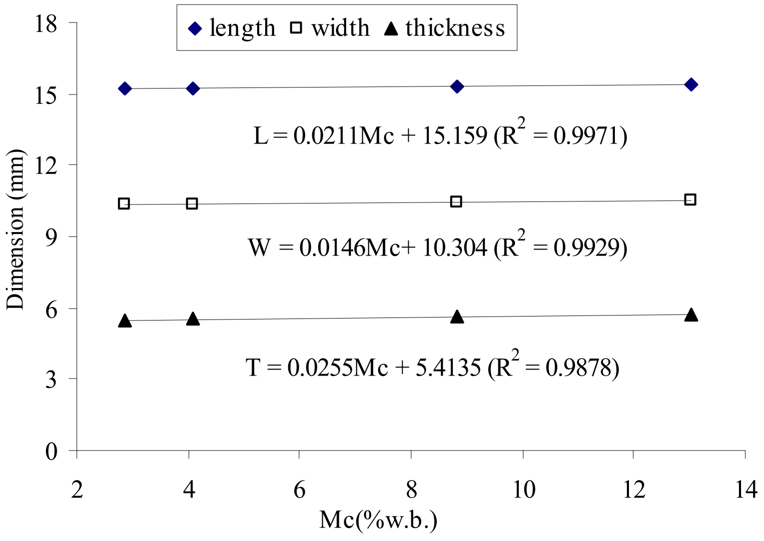

Figure 3. Effects of moisture content on symmetrical dimensions

3.1.2 Sphericity

Sphericity is a measure to determine shape of kernel which can describe figure of it. In the present study, change in spherically percentage with multi moisture content, were measured. Results show that spherically at 2.86%, 4.1%, 8.81% and 13.03% moisture content were 62.2%, 62.25%, 62.49% and 62.9%, respectively. Sphericity was increased with increasing in moisture content. (Fig. 4) Gezer *et al.* (2002) and Desphande *et al.* (1993) have found an increasing relationship between sphericity and moisture content in their experiments with apricot kernel and soybean, respectively.

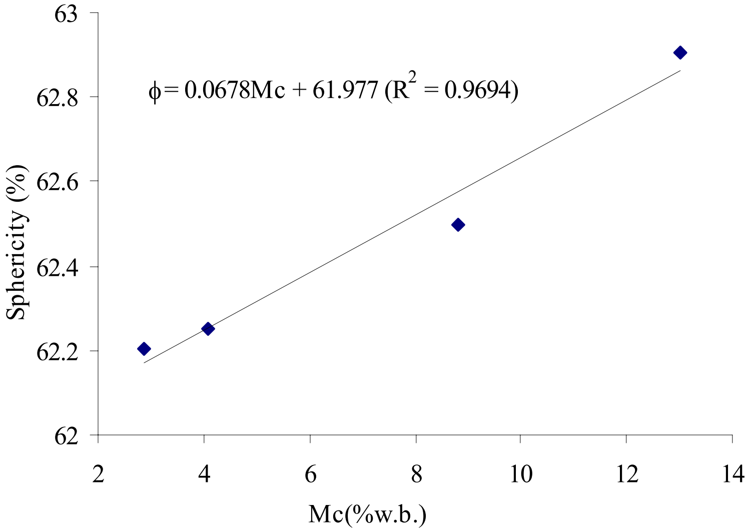

Figure 4. Effect of moisture content on Sphericity

3.1.3 Surface Area

In this study, effect of moisture content on surface area of apricot kernels investigated. According to figure 5, results show that equation S1 with moisture content 2.86%, 4.1%, 8.81% and 13.03% surface area were 282.35, 284.23, 289.88, and 297.25 mm^2 and with equation S2 it was 238.9, 140.48, 245.23 and 251.45 mm^2, respectively.

$$S1 = 1.4329Mc + 278.12 \ (R^2=0.9923) \quad (6)$$

$$S2 = 1.2068Mc + 235.33 \ (R^2=0.9922) \quad (7)$$

Equation S1 show more surface area than equation S2 which this difference related to change in data apparatus act on the equations. Similar trends were reported for many other seeds (Mohsenin, 1970). Desphande *et al.* (1993) found that the surface area of soybean grain increased from 0.813 to 0.952 cm^2, when the moisture content was increased from 8.7% to 25% db.

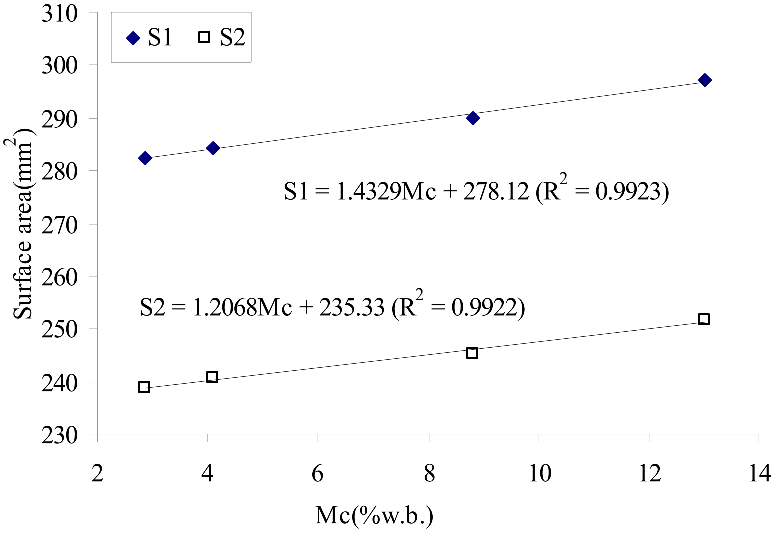

Figure 5. Effect of moisture content on surface area

3.2 Gravimetrical Properties

Table 2. Effect of moisture content on gravimetrical properties of apricot kernel

		Moisture content (%w.b.)			
Gravimetrical properties	Replication	2.86	4.1	8.81	13.03
Volume (cm^3)	100	0.431^a(0.102)	0.438^a(0.101)	0.454^a(0.105)	0.473^a(0.106)*
Mass (gr)	100	0.437^a(0.103)	0.444^a(0.105)	0.464^a(0.102)	0.484^a(0.109)
True density (kg/m^3)	100	1015.7^a(198.14)	1016.6^a(201.34)	1022.7^a(201.41)	1023.5^a(199.69)
Bulk density (kg/m^3)	3	580^a(12.324)	562.3^a(7.314)	543.2^{ab}(9.346)	540.1^b(10.049)
Porosity (%)	-	47.21	46.78	44.49	42.71
Thousand grain mass (gr)	-	437.4	444.1	464	484

tests (at 5% level)
*standard deviation values in parentheses

3.2.1 Volume and Mass

With increasing in moisture content volume and mass of kernels were increased (table2). Trend of change in volume of seed with multi moisture content, were shown on below (Fig 6). The volume was increased with increasing moisture content and its relation is as below:

$$V=0.004Mc + 0.4205 \quad (R^2 =0.9958) \tag{8}$$

Similar results have been reported by Desphande *et al*. (1993) for soybean, Ogut (1998) for white lupine, Gezer *et al.* (2002) for apricot kernel, and Karababa (2006) for popcorn kernels.

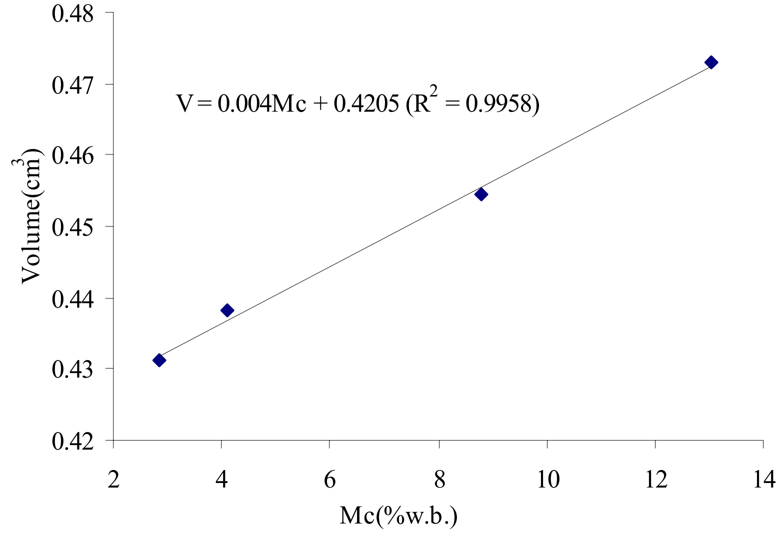

Figure 6. Effect of moisture content on grain volume of apricot kernel

3.2.2 True Density

As shown in figure 7, true density of apricot kernels at multi moisture contents was between 1015.7 till 1023.5 kg/m^3. Following equation can be used to for determining the relationship between density and moisture content. Desphande *et al*. (1993) also observed the linear increase in kernel density with increasing in grain moisture in the ranges of 8.7–25% db for JS-7244 soybean. Aydin (2003) reported that the effect of moisture content on true density of almond nut and kernel showed an increase with moisture content. The negative relationship was also observed by Desphande *et al*. (1993) for soybean, Sahoo and Srivastava (2002) for okra seed, Konak *et al.* (2002) for chickpea seeds, and Kaleemullah and Gunasekar (2002) for arecanut kernels, Karababa (2006) for popcorn kernels and Razavi *et al.* (2007) for pistachio nuts and their kernels.

$$T_d = -0.0924Mc^2 + 2.2956Mc + 1009.5 \quad (R^2 = 0.9861) \qquad (9)$$

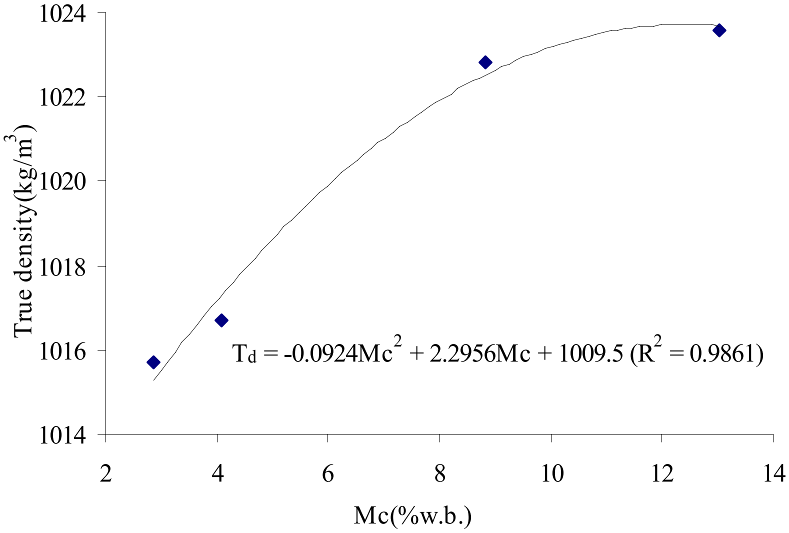

Figure 7. Effect of moisture content on actual density of apricot kernel

3.2.3 Bulk Density

According to figure 8, bulk density of apricot kernels at multi moisture content were 580 to 540.1 Kg/m^3 which its relation was as below:

B_d=0.5708Mc^2 – 12.661Mc + 608.73 ($R^2 = 0.9726$) (10)

The negative relationship of bulk density with moisture content was also observed by Aydin (2003), and Gupta and Das (1997) for almond nut and kernel, and sunflower seeds, respectively. The relationship between bulk density and moisture content was statistically significant ($p <$ 0:05). In contrast, the negative linear relationship of bulk density with moisture content was observed by various research workers (Konak et al., 2002; Nimkar and Chattopadhyay, 2001). Razavi et al. (2007) reported that there is a linear increase in bulk density of pistachio nut and its kernel with an increase in moisture content.

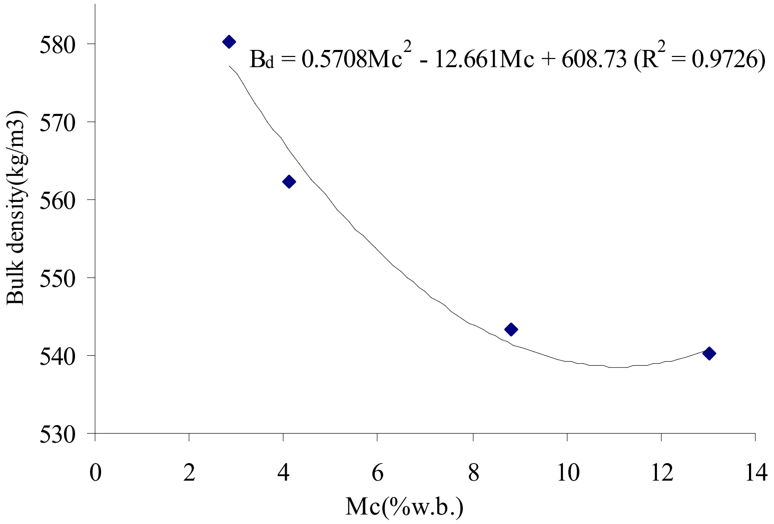

Figure 8. Effect of moisture content on bulk density

3.2.4 Porosity

Reverse relation between porosity and moisture content of apricot kernel (with value 47.21% to 42.71%) given in the below equation. Figure 9 shows trend of this variation.

$$P = -0.0606Mc^2+1.3763Mc + 39.521 \quad (R^2 = 0.9839) \qquad (11)$$

Other researchers were reported for gram (Dutta *et al*., 1988), sunflower seeds (Gupta and Das, 1997), white lupin (Ogut, 1998), hazel nuts (Aydin, 2002), chickpea seeds (Konak *et al*., 2002), arecanut kernels (Kaleemullah and Gunasekar, 2002), okra seeds (Sahoo and Srivastava, 2002) and pigeon pea (Baryeh and Mangope, 2003).

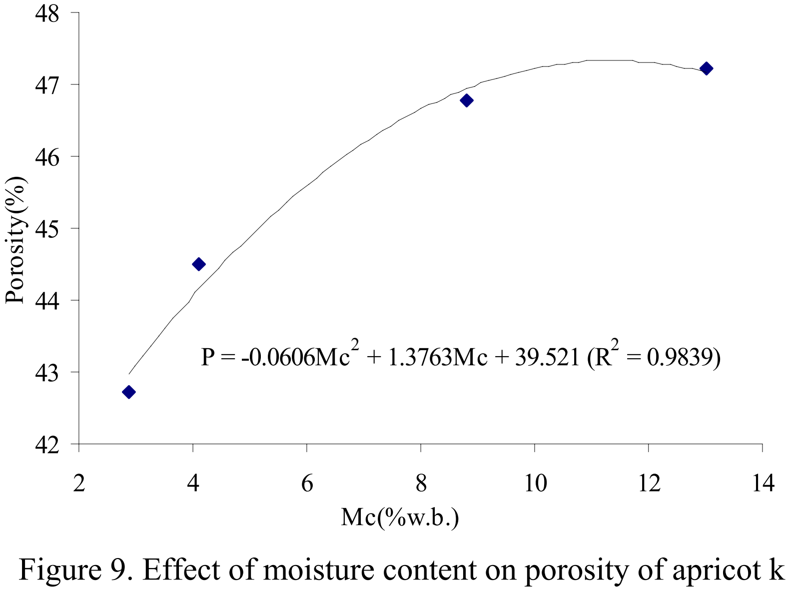

Figure 9. Effect of moisture content on porosity of apricot kernel

3.2.5 Thousand Grain Mass

Effect of moisture content from 2.86% to 13.03% on thousand grain mass of apricot kernels, were shown on the figure 10 and table 2. Thousand grain mass at this range of moisture content was between 437.4 to 484 gr. Its equation was:

$M_{1000} = 4.517Mc + 424.8$ ($R^2 = 0.9458$) (12)

Similar results have been reported by Desphande *et al.* (1993), Ogut (1998), Baryeh (2002), Baryeh and Mangope (2003) and Karababa (2006) for soybean, white lupine, millet, pigeon pea, and popcorn kernels, respectively.

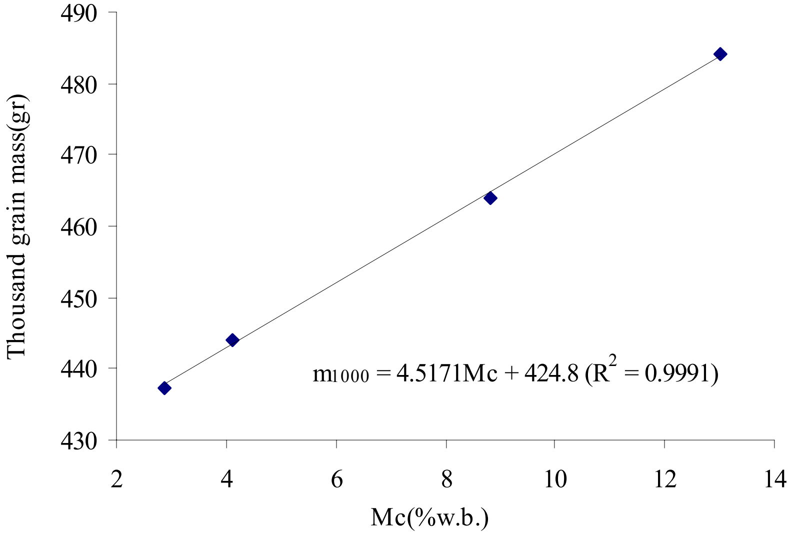

Figure 10. Effect of moisture content on thousand grain mass

3.3 Frictional Properties

Table 3. Effect of moisture content on angle of static friction of apricot kernel

		Moisture content			
Angel of static friction on	Replications	2.86%	4.1%	8.81%	13.03%
wood	3	19.01^{a}(2.361)	20.67^{a}(3.318)	21.02^{a}(3.609)	22.33^{a}(3.759)*
glass	3	9.01^{a}(1.064)	10.03^{b}(1.316)	10.47^{ab}(0.911)	10.67^{ab}(0.822)
galvanized sheet	3	10.67^{a}(1.362)	11.33^{a}(1.542)	11.67^{a}(1.616)	13^{a}(1.394)
fiberglass sheet	3	13.83^{a}(1.319)	14^{a}(1.229)	14.67^{a}(1.305)	14.67^{a}(1.716)

tests (at 5% level)
*standard deviation values in parentheses

3.3.1 Angle of Static Friction

Figure 11 shows that the relations between angle of static friction on 4 surfaces (wood, glass, galvanized steel and fiberglass). It is clear that, with increasing moisture content, this angle increased for all surfaces but with different levels. Relation between moisture content and angle of static friction of apricot kernels on different surface given as bellow:

$\theta_{wood} = 0.2689Mc + 18.814 \ (R^2=0.8339)$ (13)

$\theta_{fiberglass} = 0.0874Mc + 13.662 \ (R^2=0.8618)$ (14)

$\theta_{galvanize} = 0.2022Mc + 10.211 \ (R^2=0.92)$ (15)

$\theta_{glass} = 0.1183Mc + 8.9819 \ (R^2=0.6296)$ (16)

Gezer *et al.* (2002) stated that as the moisture content increased so the coefficient of static friction increased.

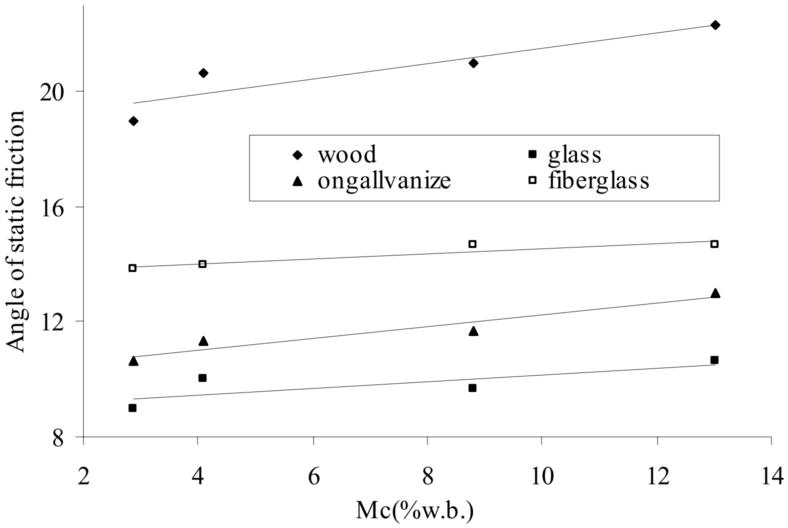

Figure 11. Effect of moisture content on angle of static friction of apricot kernel

4. CONCLUSIONS

The dimensions and geometric mean diameter of apricot kernel increased depending on moisture content. This situation stems from water absorption of kernel. Measured surface area from equation 3 and 4 and sphericity value of apricot kernel increased with increasing moisture content. In apricot kernels, thousand grain mass, volume, mass and grain density increased with increasing in moisture content. The bulk density value decreased with moisture content in apricot kernels. There was a negative relationship between them. Porosity value decreased with increase moisture content. It was maybe due to decreasing sphericity in lesser moistures content. In apricot kernel, the angle of static friction was found to be higher on a wood than on a fiberglass sheet, galvanize sheet and glass, respectively. The value of angle of static friction on all surfaces increased with increase moisture content.

5. ACKNOWLEDGMENTS

The authors wish to thank the Department of Agricultural Machinery Engineering Faculty of Biosystems Engineering, University of Tehran for its support.

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