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Moisture Dependent of Mechanical Properties of Tabarzeh Apricot Pit

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Abstract: In this study Tabarzeh variety of apricot pit were loaded between two parallel plates to determine the rupture force, deformation and toughness. The tests were carried out at deformation rate of 50 mm/min and four moisture contents of 5.89, 11.21, 17.01 and 22.05% (w.b.). Samples were compressed along the length, width and thickness of apricot pits. Physical characteristics of pits such as dimensions, geometric mean diameter, volume and mass were determined. Results have shown that rupture force, deformation and toughness were decreased with increase in moisture content. The lowest and highest force, deformation and toughness in all moisture content levels for pit rupture were obtained through its width and length, respectively. Also experiments were indicated that for loading through thickness there was always the tendency of the kernel breakage.

Key words: Apricot pit · mechanical properties · moisture content · rupture force · deformation · toughness

INTRODUCTION

Apricot (*Prunus armeniaca L.*) is the third most widely grown stone fruit crop with a world production of 2.8 Mt in 2005. The production is mainly located in the Mediterranean countries which collectively account for 40% of global production. Apricot kernel is an important source of dietary protein as well as oil and fibre [1]. The kernel is added to bakery products as whole kernel or grounded and also consumed as appetizers. Both processes involve heat treatment which provides brown color and some desirable textural properties like fragility and crispness [2]. Although it is a known fact that heat treatments generally cause loss of some vitamins and other nutritional components that possess antioxidant properties, it has been proposed that some antioxidative Maillard reaction products arise during roasting [3]. In Iran, the most widely produced types are Tabarzeh, Kardi Damavandi, Nakhjavan [4]. Iran is the second apricot producer in the world with 275580 ton production per year and 8.2% share.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 [5].

There are many researches about physical and mechanical properties of stone fruits, kernels and pits such as Gezer *et al.* [6] for Hacýhaliloglu apricot pit and its kernel, Olaniyan and Oje [7] for Shea Nut, Aydin [8] for almond nut and kernel, Guner *et al.* [9] for Hazelnut, Vursavus and Ozguven [10] for apricot pit, Zhang *et al.* [11] for rice kernels and Pliestic *et al.* [12] for Filbert Nut and Kernel, but no detailed study concerning mechanical properties of Iranian apricot pit was found in the literature. Iran, in spite of being second great apricot producer in the world, has low exportation and weak process. It is clear that investigating on mechanical properties of apricot fruit, pit and kernel is very essential and practical for its process. So for achieving the aims referred to above, some important physical and mechanical properties of apricot pit such as axial dimensions, volume, mass, rupture force, deformation and toughness were determined in four level of moisture content.

Nomenclature

L	Length	F	Rupture force
W	Width	D	Deformation
T	Thickness	P	Toughness
Dg	Geometrical mean diameter	X	Effected on X-axis
M	Weight	Y	Effected on Y-axis
Mc	Moisture content	Z	Effected on Z-axis

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MATERIALS AND METHODS

The Tabarzeh variety of Apricot pit (Fig. 1) used for this study that is very desirable and well known in Azarbayejan and Iran, were collected from the orchard located in Salmas village in west Azarbayjan, Iran in august 2007 [4]. Broken pits and foreign matters such as dust, dirt, stones and chaff were removed from 7 kg apricot pit. All products were kept in the room temperature for two days. All of the experiments were carried out at a room temperature of 25± 3°C during the laboratory tests. All of the tests were made at the physical and mechanical properties Laboratory of Tehran University, Karaj, Iran. The pits were divided into four batches in order to obtain four moisture levels for the experiments. One of the batches was left at the initial moisture content of 22.05% (w.b.) while the remaining three batches were conditioned to moisture contents of 17.01, 10.98 and 5.89% (w.b.). To determine the average size of the pits, their three linear dimensions namely, length, width and thickness were measured using a digital micro meter having accuracy of 0.01 mm. Mass of apricot pit was measured with an electronic balance with accuracy of 0.001 g. The geometric mean diameter (D_g) was calculated using the following equations [13].

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

Where L is the length, W is the width and T is the thickness.

Volume (V) was determined by the amount of liquid displaced. We used toluene instead of water as liquid, because it is more advantageous. As we know toluene has less surface tension and degeneration [13]. Three mechanical properties determined in the study include Rupture force, Deformation and Toughness in three compression axes (X; Y; Z) (Fig. 2). The X-axis (force F_x) is the loading axis through the length dimension, while the Y-axis (force F_y) is the transverse axis containing the minor dimension (width) at right angles to the X-axis and the Z-axis (force F_z) is the transverse axis containing the minimum dimension (thickness).

Fig. 1: Tabarzeh apricot pit

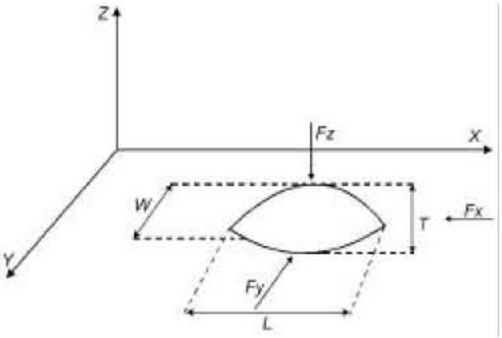

Fig. 2: Three axes and three perpendicular dimensions of apricot pits

Fig. 3: Universal testing machine (Model santam SMT-5)

Quasi-static compression tests were performed with an Instron Universal Testing Machine (Model Santam SMT-5) equipped with a 25-kg compression load cell and integrator [14]. The measurement accuracy was 0.001N in force and 0.001 mm in deformation. For each treatment 30 apricot pits were randomly selected and the average values of all the 30 tests were reported (Fig. 3). Experiment was conducted at a loading velocity of 50 mm/min [6]. The individual pit was loaded between two parallel plates of the machine and compressed at the preset condition until rupture occurred as is denoted by a bio-yield point in the force-deformation curve. The bio-yield point was detected by a break in the force deformation curve. Once the bio-yield was detected, the loading was stopped. The mechanical properties of apricot pit were expressed in terms of rupture, deformation and toughness required for initial rupture. The deformation (strain) was taken as a change in original dimension of the pit. Note that load cell deflection under load was found too negligible for loads used in this study. The energy (E) was determined by calculating area under the force-deformation curve up to grain rupture. Toughness (P) is expressed as the energy absorbed by the apricot pit up to rupture point per unit volume of the pit. This was calculated using the following formula [7].

$$P = E / V \quad (2)$$

Variance analysis was carried out on the four moisture contents of apricot pits and the difference between the mean values was investigated by using the Duncan's multiple range tests (SPSS 13.0). Mean values were reported with the standard deviation.

RESULTS AND DISCUSSION

The average dimensions and masses of the apricot pits tested in the laboratory are brought in Table 1. As it is perceived from Table 1, the length, width, thickness, geometric mean diameter and mass values of apricot pits, all had an increasing trend with an increase in moisture content. This may be attributed to the water absorption phenomenon of the pit.

The average values of rupture force, deformation and toughness obtained from the experiments at different moisture contents and compression direction are presented in Table 2. The standard deviations for the respective mean values are also shown in parentheses.

Rupture force: Initiation of the pit rupture at different moisture contents and along three different compression direction required forces presented in Fig. 4. Based on Fig. 4 the force required to bring about the pit rupture was decreased more considerably along the length as the moisture content increased from 5.98 to 22.05% (w.b.) and also at the same moisture contents this force was higher compared to other two direction and may be taken into account for designing a cracking machine. Apricot pit compressed along the length required 617.95, 505.26, 432.75 and 399.38N at the moisture contents of 5.98, 11.21, 17.01 and 22.05% (w.b.) respectively. Mathematical correlation between moisture content and rupture force of apricot pit compressed along the length can be expressed as follows:

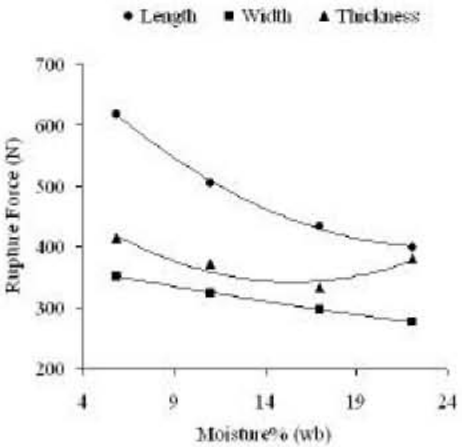

Fig. 4: Moisture content and compression axis effect on rupture force

$$F_x = 0.7002Mc^2 - 32.909Mc + 786.06 \ (R^2 = 0.9988)$$

The rupture force had a descending trend from 351.96 to 276.28 N along the width by moisture increase from 5.89 to 22.05% (w.b.). It seems that the force changes through the width orientation are more linear in comparison with other two directions. The relationship between moisture content and rupture force of apricot pit compressed along the width can be represented as follows:

$$F_y = 0.0512M^2 - 6.1013M + 386.01 \ (R^2 = 0.9999)$$

As we see in Fig. 4, rupture force decreased to a minimum value at a moisture content of 17.01% (w.b.) and later increased as moisture content was increased further from 17.01 to 22.05% (w.b.). This may be related to the fact that compression of the apricot pit samples along the thickness led to further absorption of water by the pit and made kernel inside to swell up and fill the clearance between the kernel (shell turgiding) and this resulted in an increase in rupture force again. Similar findings were also observed By Gezer *et al*. [6] for Hacýhaliloglu apricot pit and its kernel, Olaniyan and Oje [7] for shea nut, Aydýn [8] for almond nut, Guner *et al*.[9] for Hazelnut, Vursavus

Table 1: Dimensional properties and masses of apricot pits

Moisture % (w.b)	5.89	10.98	17.01	22.05
Length (mm)	27.400 (1.534)*	27.590 (1.629)	27.850 (1.624)	28.780 (1.314)
Width (mm)	15.810 (0.6514)	16.150 (0.8915)	16.329 (0.891)	16.980 (0579)
Thickness (mm)	9.900 (0.6214)	10.010 (0.455)	10.140 (0.456)	10.450 (0.945)
Geometric mean diameter (mm)	16.230 (0.632)	16.400 (0.737)	16.590 (0.738)	16.820 (0.568)
Volume (cm^3)	1.579 (0.341)	1.609 (0.212)	1.619 (0.213)	1.633 (0.167)
Mass (g)	1.399 (0.145)	1.410 (0.181)	1.430 (0.181)	1.981 (0.114)

*Standard deviation values in parentheses

Table 2: Effect of moisture content and compression axis on rupture force, deformation and toughness

		Moisture content (% w.b.)			
		5.89	11.21	17.01	22.05
Rupture force (N):	Length	617.95 (53.124)*	505.26 (50.014)	432.75 (43.152)	399.38 (47.128)
	Width	351.96 (23.528)	324.91 (32.948)	297.34 (41.746)	276.28 (22.001)
	Thickness	413.31 (25.468)	370.87 (33.555)	332.45 (51.114)	381.29 (22.415)
Deformation (mm):	Length	2.32 (0.241)	2.09 (0.289)	1.73 (0.262)	1.64 (0.199)
	Width	1.44 (0.184)	1.32 (0.201)	1.31 (0.184)	1.34 (0.179)
	Thickness	1.89 (0.147)	1.72 (0.211)	1.36 (0.165)	1.61 (0.183)
Toughness (mJ/mm^3):	Length	0.590 (0.034)	0.346 (0.031)	0.279 (0.026)	0.211 (0.022)
	Width	0.188 (0.011)	0.109 (0.012)	0.110 (0.018)	0.098 (0.009)
	Thickness	0.277 (0.021)	0.191 (0.014)	0.152(0.015)	0.204 (0.017)

*SStandard deviation values in parentheses

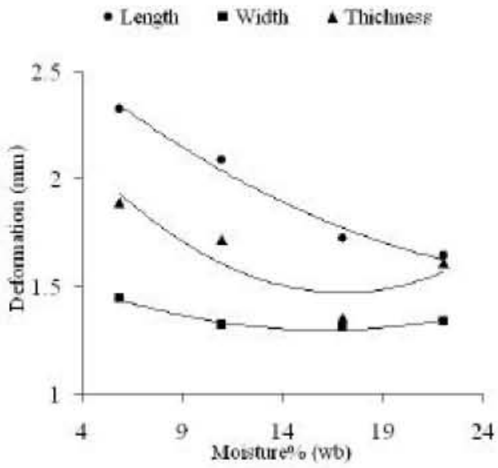

Fig. 5: Moisture content and compression axis effect on deformation for apricot pit

and Ozguven [10] for apricot pit and Pliestic *et al.* [12] for Filbert Nut and Kernel.

Apricot pit compressed along the thickness required 413.31N, 370.87 N, 332.45N and 381.29N at the moisture contents of 5.98, 11.21, 17.01 and 22.05% respectively. The relationship between moisture content and rupture force of apricot pit compressed along the X-axis is as follows:

$$F_z = 0.721M^2 - 22.125M + 493.56 \ (R^2 = 0.8457)$$

Deformation: As seen in Fig. 5 the deformation was decreased along the length as the moisture content increased from 5.98 to 22.05% (w.b.). The deformation values for apricot pit compressed along the length were always higher and this shows that the pit is stretchier and it resists more against the rupturing force along the length as compared to the other two directions.

Correlation between moisture content and deformation of apricot pit compressed along the length was as follows:

$$D_x = 0.0002M^2 - 0.0431M + 2.466 \ (R^2 = 0.9521)$$

For compression along the width, deformation was decreased from 1.44 to 1.31 mm with increase in moisture content from 5.89 to 17.01% (w.b.) and later was increased to 1.34 mm as moisture content was increased further from 17.01 to 22.05% (w.b.). The changes in deformation with moisture content for apricot pit compressed along the width can be shown by the following correlation:

$$D_y = 0.0014M^2 - 0.044M + 1.6509 \ (R^2 = 0.969)$$

The deformation of apricot pit compressed along the thickness was decreased from 1.89 to 1.36 mm as moisture content increased from 5.89 to 17.01% (w.b.) and later increase to 1.61mm as moisture content was increased from 17.01 to 22.05% (w.b.). The reason may come from the fact that compression along the thickness at higher moisture content makes apricot pit behaves like a structurally turgid material because there is not enough clearance between the shell and the kernel and it will increase the deformation at rupture point for loading along the thickness. The relationship between the deformation and moisture content for apricot pit compressed along the thickness was given as follows:

$$D_z = 0.003M^2 - 0.1026M + 2.3544 \ (R^2 = 0.6749)$$

Similar trends were observed by Vursavus and Ozguven [10] for apricot pit, whereas Guner *et al.* [9] for Hazelnut and Olaniyan and Oje [7] for Shea Nut were

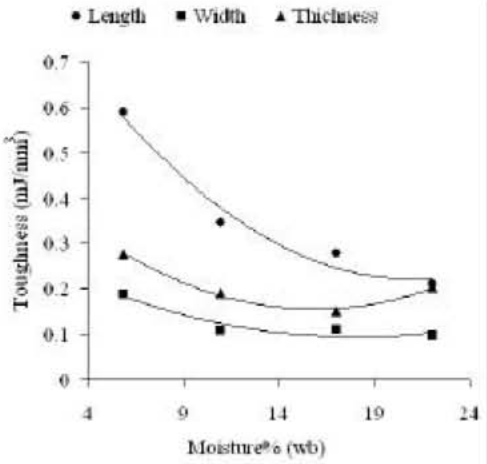

Fig.6: Effect of moisture content and compression axis on toughness for apricot pit

indicated that with increasing in moisture content deformation increased.

Toughness: From Table 2 and Fig. 6 it can be observed that toughness decreased from 0.59 to 0.21 (mJ/mm^3) with increase in moisture content from 5.89 to22.05% (w.b.) for apricot pits compressed along the length The reason for this trend could be attributed to the fact that rupture force decreased but volume of the apricot pit increased vise versa and it brought about the decrease in energy absorbed per unit volume called toughness. The toughness values of apricot pit compressed along the length resulted in following equation that relates those with moisture content:

$$P_x = 0.0016M^2\text{-}0.0655M + 0.9098\ (R^2 = 0.9707)$$

Toughness of the apricot pit decreased to a minimum value at a moisture content of 11.21% (w.b.) for loading along the width and later increased to a value of 0.110 (mJ/mm^3). However, further increase in moisture content from 17.01 to 22.05% (w.b.) resulted in a decrease in toughness. The reason for this trend can be explained with decreasing rupture force and increasing volume of the pit. This has similarities with the findings of Oloso and Clarke [15] for cashew nut, Olaniyan and Oje [7] for shea nut, Vursavus and Ozguven [10] for apricot pit. The toughness for apricot pit compressed along the width bears the following relationship with their corresponding moisture contents:

$$P_y = 0.0006M^2\text{-}0.0216M + 0.2892\ (R^2 = 0.8965)$$

For loading along the thickness, toughness decreased with increase in moisture content from 5.89 to 17.01% (w.b.) and later increased to 0.204 (mJ/mm^3) when moisture content was increased from 17.01 to 22.05% (w.b.). The reason may be explained that by increase in moisture content up to 22.05% (w.b.), rupture force for loading along the thickness increased again and it causes that the apricot pit absorbs more energy. This variation of toughness for compression along the thickness with moisture content can be represented by the following relationship:

$$P_z = 0.0012M^2\text{-}0.0392M + 0.4667\ (R^2 = 0.8128)$$

CONCLUSIONS

Results showed that the lowest rupture force, deformation and toughness were obtained for loading along the width. This study also revealed that apricot pit required higher rupture force and energy to crack apricot pits for compression along the length as compared to other two directions. Moreover, there was always the tendency of the kernel breakage for loading along the thickness. Since cracking operation is expected to be done with minimum energy and maximum kernel quality, it can be concluded that compression along the width is more suitable than the other two directions in forming a cracking principle for apricot pits.

According to the results of the analysis, the effect of moisture content, compression axis and moisture by compression axis interaction on rupture force, deformation and toughness was found to be statistically significant (P<0:01).

It can be concluded that a non-linear relationship with a good degree of fit between the moisture content and failure parameters can be obtained for the three compression direction.

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