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Some Physical and Mechanical Properties of Crataegus Fruit

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ABSTRACT

The knowledge of physical properties of Crataegus fruit is necessary for the design of post-harvest equipment such as cleaning, sorting, grading, kernel removing, storage, packaging and processing of fresh fruits. This research was done to analyze some physical and mechanical properties of the Crataegus fruit in the moisture of 71.23% w.b. Other results showed that linear dimensions varied from 18.22 to 29.10 mm in length, 17.92 to 27.79 mm in width, 13.82 to 21.40 mm in thickness and 16.35 to 25.65 mm in geometric mean diameter. Mean values of fruit mass and volume were measured as 4.273 g and 4657.8 mm3, respectively. The mean values of sphericity, aspect ratio and surface area were calculated as 87.74%, 0.754 and 1316.42 mm2, respectively. The mean values of bulk density, true density and porosity were 660 g/m3, 1040 g/m3 and 31.44%, respectively. The friction coefficient over the surfaces of plywood, galvanized steel and glass were 0.39, 0.45 and 0.54, respectively.

Key words: Crataegus fruit, Mechanical, Moisture, Physical properties.

INTRODUCTION

Crataegus, is a large genus of shrubs and trees with small pome fruit and usually thorny branches in the family Rosaceae, native to temperate regions of the northern hemisphere in Asia, Europe and North America (Phipps et al., 2003). Common names for hawthorns may include, mayblossom, quick thorn, whitethorn, haw hazels, gazels, halves, hagthorn, and bread and cheese tree. They are usually multibranched 2–5m shrubby trees that can reach a height of up to 10m. The hawthorn tree prefers the forest margins of lower and warmer areas (Brown, 1995; Wichtl, 1996). The fruits of Crataegus are tart, and resemble small crabapple fruits. The fruits, which are eaten raw, are also used to produce jams, candies, jellies, juices, beverages and other drinks in many parts of the world (Wikipedia, 2014). Studies have confirmed the potential of hawthorn fruits as a good source of antioxidant constituents. The flower and fruit constituents responsible for free radical scavenging activity are epicatechin, hyperoside and chlorogenic acid (Zhang et al., 2001; Svedström, 2006; Liu et al., 2011). Traditionally, the fruits or the berries are used for their astringent properties in heavy menstrual bleeding and in diarrhoea. Hawthorn fruits and leaves have a curative effect on blood vessels of the heart which have been extensively reported (Pittler et al., 2003; Frishman et al., 2004; Long et al., 2006; Frishman et al., 2009). The extract of hawthorn has been shown to have many health benefits including being cardiovascular protective, hypotensive, hypocholesterolaemic and lowers serum cholesterol (Zhang et al., 2001, 2002; Yao et al., 2008).

In Iran, Crataegus fruits are known as zalzalak and are eaten raw as a snack, or used as in a jam known by the same name. Iranian Crataegus fruits are divided into two major groups according to the color. Those which have red fruit called the red Crataegus and those that are dark in color called black Crataegus. But apart from these two categories, there are some species that have yellow and orange fruit that are high quality as a food.

The major physical properties of biological materials are shape and size, bulk density, true density, porosity, mass and volume of fruits, friction against various surfaces and hardness. These properties have been

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studied for various crops such as terebinth fruits (Aydın and *Öğüt*, 2002); soybean (Kibar and Öztürk, 2008); and lentil seeds (Amin e al., 2004). Information regarding the study of physical properties of crataegus fruit is very important in the design of machines and analysis of the behavior of the product during agricultural operations such as harvesting, handling, cleaning, separating, packaging, storing and processing (Kabas et al., 2007). Literature review showed that a study was conducted on the physical properties of Crataegus fruits that on study were measured the mean pulp and seeds weight, length, diameter, mass, volume, geometric mean diameter, sphericity and projected area (Özcan et al., 2005). However, to the best of our knowledge, no detailed study is found in the literature on the physical and mechanical properties of crataegus fruit.

The object of this study was to investigate some physical and mechanical properties of the crataegus fruits, namely linear dimensions, geometric mean diameter, aspect ratio, surface area unit mass and volume, thousand weight, sphericity, densities, porosity, projected area, terminal velocity, rupture strength and coefficient of dynamic friction against to three surfaces.

Nomenclature			
L	length of the fruit, mm	m	mass of the fruit, kg
W	width of the fruit, mm	ρ_t	true density of the fruit, kg/m^3
T	thickness of the fruit, mm	ρ_b	bulk density of the fruit, kg/m^3
D_g	geometric mean diameter, mm^3	D_r	density ratio, %
S_p	sphericity of the fruit, %	ε	Porosity, %
R_a	aspect ratio	µ	static friction coefficient
S	surface area, mm^2	V	volume of the fruit, m^3

MATERIALS AND METHODS

The crataegus fruits used in this study were obtained from a local market in Karaj, Iran in September 2013. The fruits were manually cleaned to remove all foreign matter such as dust, dirt, stones and chaff as well immature and broken fruits. The initial moisture content of the fruits was determined by using the standard hot air oven method at 105±1 ◦C for 24h (Brusewitz, 1975; Gupta and Das, 1997; Özarslan, 2002; Altuntas et al., 2005). The remaining material was packed in a hermetic vessel and kept in cold storage until use.

The physical properties that were considered in this study are size, shape, surface area, mass, true density, bulk density, density ratio, porosity and static friction coefficient. One hundred fruits were randomly selected from the samples. The three linear dimensions of each fruit namely length (L), width (W) and thickness (T) were measured using a digital caliper with a reading accuracy within 0.01 mm.

The geometric mean diameter of crataegus fruit was calculated by using the following formula (Mohsenin, 1986):

$$D_g = (LWT)^{\frac{1}{3}} \quad (1)$$

In this study, the fruit shape was expressed in terms of sphericity and aspect ratio. The sphericity and aspect ratio were calculated based on the three linear dimensions of the investigated fruits mentioned in section 2.1.1. According to Mohsenin (1986), the degree of sphericity can be expressed as:

$$S_p = \frac{(LWT)^{\frac{1}{3}}}{L} \times 100 \quad (2)$$

The aspect ratio (Ra) of fruit was calculated by using the following equation (Owolarafe et al., 2007):

$$R_a = \frac{W}{L} \quad (3)$$

The surface area (S) of hawthorn fruit was found by analogy with a sphere of the same geometric mean diameter using the expression by Sacilik et al., (2003):

$$S = \pi D_g^2 \tag{4}$$

The mass of each fruit mentioned in section 2.1.1. was determined by using a precision electronic balance with an accuracy of 0.0l g.

The true density of the crataegus fruit was determined by the water displacement technique (Dutta et al., 1988). Twenty randomly selected crataegus fruits were weighed and lowered into a graduated measuring cylinder containing 40 ml of water. It was ensured that the fruit was submerged during immersion in water. The net volumetric water displacement by each fruit was recorded. The true density ρ_t was then calculated as follows:

$$\rho_t = \frac{m}{v} \tag{5}$$

To determine the fruit bulk density, a cylindrical container of 300 cm3 was filled with fruits and the contents were weighted to a precision of 0.01 g. similar to true density, the bulk density (ρ_b) was then calculated using Eq. (5).

The density ratio Dr is the ratio of true density to bulk density expressed as a percentage as follows:

$$D_r = \frac{\rho_t}{\rho_b} \times 100 \tag{6}$$

The porosity was calculated using the following equation (Mohsenin, 1986):

$$\varepsilon = 100\left[1 - (\frac{\rho_b}{\rho_t})\right] \tag{7}$$

The coefficients of static friction were obtained with respect to three different surfaces namely galvanized steel, plywood and glass surfaces by using an inclined plane apparatus as described by Dutta et al., (1988). The inclined plane was gently raised and the angle of inclination at which the sample started sliding was read off the protractor with sensitivity of one degree. The tangent of the angle was reported as the coefficient of friction (Dutta et al., 1988):

$$\mu = tan\varphi \tag{8}$$

Where μ is the coefficient of friction and φ is the tilt angle of the friction device. All the friction experiments were conducted in three replications for each surface.

Hardness values or the cracking force of the fruits were measured by applying forces using a proprietary tension/compression testing machine (Instron Universal Testing Machine SMT-5, SANTAM Co., Iran). This machine has three main components, which are a stationary and moving platform, a drive unit and a data acquisition system. The fruit was placed on the moving lower platform and was pressed against the stationary platform. The applied force was measured by a strain-gauge load cell and a force-time record obtained up to the specimen failure. The probe used in the experiment had a 5 mm diameter and was connected to the dynamometer. Each experiment was conducted at a loading rate of 1 mm/min.

For the modeling of V, M ,S and dimensions we used the SPSS software because having three variable were more convenient for our study.

RESULTS AND DISCUSSION

A summary of the results of the determined physical parameters of the crataegus fruit is shown in Table 1.

Table 1. Summary of some properties of crataegus fruit

Property	Min	Max	Mean	SD
Length, mm	19.01	31.91	23.01	5.44
Width, mm	17.96	27.65	21.90	4.94
Thickness, mm	14.01	20.38	16.87	3.79
Geometric mean diameter, mm	16.35	25.65	20.40	4.54
Sphericity	82.98	92.41	87.74	5.82
Aspect ratio	0.632	0.902	0.754	0.042
Surface area	1121.67	1480.32	1316.42	605.06
True density	967	1101	1040	37
Bulk density	645	671	660	13
Volume of the fruit	3.69	5.36	4.65	0.43
Density ratio	66.98	70.15	68.56	3.12
Porosity	29.85	33.02	31.44	3.12
Static friction coefficient				
Galvanized steel	0.367	0.652	0.452	0.033
Plywood	0.331	0.432	0.398	0.061
Glass	0.512	0.621	0.545	0.064
Hardness	1.51	1.85	1.69	0.21

Some physical and mechanical properties of the hawthorn in this research were studied, such as length (L), width (W), thickness (T), mass, geometric mean diameter, sphericity, surface area, fruit density, volume, hardness were measured as 23.01 ± 5.44(mm), 21.90 ± 4.94(mm), 16.87 ± 3.79(mm), 4.27 ± 2.39(g), 20.40 ± 4.54(mm), 87.74 ± 5.82, 1316.42 ± 605.06(mm2), 1040 ± 37(kg/m3), 4.65 ± 0.43(cm3) and 1.6 ± 0.46(N) respectively. The importance of dimensions is in determining the aperture size of machines, particularly in separation of materials as discussed by Mohsenin (1986). These dimensions can be used in designing machine components and parameters. For example, it may be useful in estimating the number of fruits to be engaged at a time. The major axis has been found to be useful by indicating the natural rest position of the fruit. The following general expression can be used to describe the relationship between the average dimensions of fruits at 71.23% (w.b.) moisture content. Physical properties such as weight, length and diameter of fruit, mass, volume of fruit, geometric mean diameter, sphericity, fruit density, projected area, terminal velocity, hardness and static coefficient of friction were established at the 71.23% moisture content level. The moisture content is very important when determining the physical properties such as bulk density, fruit density, porosity, pulp mass, static and dynamic coefficient of friction of hawthorn fruit (Ajisegiri, 1987; Baryeh, 2001; Demir and O ¨zcan, 2001; Demir et al., 2002; Haciseferog ˇullari et al., 2003). Similar investigations were conducted to determine the projected area, volume, bulk density, fruit density and terminal velocity by Demir and O¨zcan (2001) for rose fruits. Eighty-eight percent of fruit were between 3 and 6 g at a moisture content of 71.23% in weight, 93% were between 17 and 23mm in Geometric mean diameter, 90% were between 19 and 25mm in length. To obtain the relationship between V and dimensions (L, W and T) and fruit mass (M) with dimensions, we have used the following model:

V=245.162 L + 153.843 W + 273.147 T - 8351.425	R^2=0.981
M=0.239 L + 0.178 W +0.101 T – 6.806	R^2=0.981
S= 36.795 L + 53.101 W +37.486 T – 1323.414	R^2=0.997
S= 233.562 M + 320.194	R^2=0.989

The dimensions obtained from the equation are close to actual value.

Grading fruit based on weight reduces packing and handling costs and also provides suitable packing patterns (Khoshnam et al., 2007). Also mean coefficient of static friction, on galvanized steel, plywood and glass surfaces, were obtained as 0.45, 0.39 and 0.54, respectively. Result of analysis showed that the surface materials had a significant difference on the static coefficient of friction. The static coefficient of friction on galvanized steel was higher than that on plywood and lower than that of glass surface. This is due to the frictional properties between the fruits and surface materials. These properties may be useful in the separation process and the transportation of the fruits.

CONCLUSION

1. The average mass and volume for Hawthorn were found to be 4.273g and 4657.8mm3, respectively.
2. The fruit density were measured as 1.04 ± 0.37(g/m3)
3. Linear dimensions ranged from 18.22 to 29.10 mm in length, 17.92 to 27.79 mm in width, and 13.82 to 21.40 mm in thickness.
4. The geometric mean diameter, sphericity and surface area were calculated as 20.40mm, 87.74% and 1316.42(mm2), respectively.
5. The mean coefficients of static friction, on galvanized steel, plywood and glass surfaces, were obtained as 0.45, 0.39 and 0.54, respectively.

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