American-Eurasian J. Agric. & Environ. Sci., 3 (4): 513-520, 2008
ISSN 1818-6769

Some Physical Properties of Sweet Cherry (*Prunus avium* L.) Fruit

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Abstract: Information about physical properties of cherry fruit is very important for understanding the behavior of the product during the post harvest operations such as harvesting, transporting, sorting, grading, packaging and storage processes. This research was undertaken to study some physical properties of six Iranian sweet cherry cultivars (Mashad, Siah Mashad, Dorageh Karaj, Shabestar, Siah Daneshkadeh and Ghazvin). These properties include: linear dimensions, geometric mean diameter, projected area, criteria projected area, surface area, sphericity, volume, mass, bulk and fruit density, packaging coefficient, static coefficient of friction and ratio of length to width, length to thickness and length to mass. The peduncle length of cherry fruit varied from 27.04 to 72.1 mm with CV of 18%. The fruit length, width and thickness ranged from 17.92 to 26.78, from 16.50 to 24.57 and from 14.62 to 23.41 with CV of 8.38, 7.71 and 8.53%, respectively. The geometric mean diameter ranged from 16.55 to 24.46 with CV of 7.81%. The criteria projected area of each cherry cultivar resulted in different means, varying from 481.19 to 599.04 mm^2. The highest and the lowest volume and mass were found for Siah Mashad and Mashad cultivars with means of 6.68 cm^3, 7.40 g and 3.96 cm^3, 4.51 g, respectively. The greatest values of L/W, L/T and L/M were obtained for Shabestar, Siah Daneshkadeh and Mashad cultivars respectively. Three surfaces of iron, rubber and galvanized iron sheet were selected for measuring the static friction coefficient. Among six Iranian cherry cultivars, Ghazvin showed the greatest friction coefficients on all surfaces.

Key words: Sweet cherry · physical properties · Iranian cultivars · fruit

INTRODUCTION

Many of the stone fruits like sweet cherry (*Prunus avium* L.) have been cultivated since ancient times. Cherries occupy the *Cerasus* subgenus within *Prunus* genous of *Rosaceae* family. The edible portion consists of the outer layer of the mature ovary wall, the flesh (mesocarp) and the skin (exocarp). The pit (endocarp) encloses the seed. Sweet cherry is a vigorous tree with strong apical control with an erect pyrimidal canopy shape; grows to 18 m in wild but in cultivation, sweet cherries are maintained <4 m in height. Leaves are relatively large, elliptic with acute tips, petiole and strongly veined [1].

In 2004, United States, Iran (having cultivated area with 25700 hectares and with average annual production of 218584 tones) and Turkey were the largest producers of cherries in the world, accounting for with 14, 13 and 12% of world production, respectively [2]. Cherries have been a popular fruit crop for consumption in Iran for many years and more recent attention on the health benefits of cherries has helped their boost consumption. Cherries in particular have been found to offer a good source of antioxidants and contain compounds believed to aid in pain relief of arthritis, gout and headaches.

Agricultural crops and food products have several unique characteristics that set them apart from engineering materials. These properties determine the quality of the fruit and identification of correlations between changes in these properties makes quality control easier [3]. Proper design of machines and processes to harvest, handle and store agricultural materials and to convert these materials into food and feed requires an understanding of their physical

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properties [4]. Information regarding dimensional attributes is used in describing fruit shape which is often necessary in horticultural research for a range of differing purpose including cultivar descriptions in applications for plant variety rights or cultivar registers [5], evaluation of consumer preference, investigating heritability of fruit shape traits [6], or analyzing stress distribution in the fruit skin [7]. Knowledge of shape and physical dimensions are important in screening solids to separate foreign materials and in sorting and sizing of cherry fruit. Quality differences in cherry fruits can often be detected by differences in density. When cherry fruits are transported hydraulically, design of fluid velocities are related to both density and shape. Volumes and projected area of cherries must be known for accurate modeling of heat and mass transfer during cooling and drying. Porosity of cherries can be used for controlling temperature of stored cherry fruits. An awareness of sweet cherry fruit surface area would be useful in determination of mass of Cuticular membrane per unit fruit surface area emphasized by Peschel *et al*. [8]. The Cuticular Membrane (CM) covers fruit and forms the interface between plant and its environment. The CM serves as a protective barrier against water loss, nutrient leaching, mechanical damage and invasion by pathogens [9]. In addition, there is a relationship between surface area value of fruit and its cracking in wet conditions because the fruit surface of sweet cherry is stomata's [10, 11] and stomata may be relevant in the process of fruit cracking.

Researchers tried various, digital and mechanical methods to measure physical properties of Agricultural product for example Date Plum [12], Tangerine [13], Tomato [14], Watermelon [15] and Maize [16]. Also, some physical properties of sweet cherry fruit were determined and reported by several researchers [5, 17, 18].

Due to the lack of information about the physical properties of Iranian cherry cultivars, which are very important for understanding behavior of product during post harvesting operations such as harvesting, transporting, sorting, grading, packaging and storage processes and also, in processing operations such as cooling, drying and all heat and mass transfer processes, the main objective of this work was to study some physical properties to form an important database for six sweet cherry cultivars in Iran. These properties include: linear dimensions, geometric mean diameter, surface area, projected area, fruit volume, packing coefficient, mass, bulk and fruit density and static friction coefficient.

MATERIALS AND METHODS

The Iranian cherry fruits used in this study, shown in Fig. 1, consisted of Mashad, Siah Mashad, Dorageh Karaj, Shabestar, Siah Daneshkadeh and Ghazvin cultivars which were obtained from Experimental Orchard of University of Tehran located in Karaj (Longitude: 51°29'N and Latitude: 36°12'E). The number of fruits obtained from the aforementioned cultivars was 40 for each cultivar. Samples of fruits were weighed and dried in an oven at a temperature of 78°C for 48 hours then weight loss on drying to a final constant weight was recorded as moisture content [14].

For each cherry fruit, three linear dimensions were measured, that are length, width and thickness. In addition, Cross Sectional Areas (CSAs) in three perpendicular directions of the fruit, using area measurement system Delta-T England was determined (Fig. 2).

Dimensional characteristics obtained from this device are based on image processing. Captured images from acamera were transmitted to a computer card which works as an analog to digital converter. Digital images were then processed to the software and the desired parameters were determined. Through three normal images of cherry fruit, this device was capable of determining length, width and thickness diameters as well as projected areas perpendicular to these dimensions. Total error for these objects is less than 2%. This method have been used and reported by several researchers [15-17].

The geometric mean diameter, sphericity, criteria projected area and surface area were calculated [18-20]. PA_1, PA_2 and PA_3 are CSA perpendicular to length, width and thickness, respectively.

$$D_g = (LWT)^{1/3} \tag{1}$$

$$\Phi = D_g / L \tag{2}$$

$$CPA = \frac{PA_1 + PA_2 + PA_3}{3} \tag{3}$$

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

Spreadsheet software, Microsoft Excel 2003 and SPSS 9.0 Software (1999) were used to analyze the data.

Fruit density was determined by water displacement method/technique [21]. Randomly selected cherry fruits were weighed on a digital balance with 0.01 g accuracy. The fruits were lowered with a metal sponge sinker into a measuring cylinder containing of water such that the fruits did not float during immersion in water, weight of water displaced by the fruit was recorded.

Fig. 1: Six Iranian sweet cherry cultivars: A) Siah Daneshkadeh, B) Siah Mashad, C) Mashad, D) Shabestar, E) Dorageh Karaj, F) Ghazvin

Fig. 2: Apparatus for measuring dimensional characteristics, area meter Delta-T England

Fig. 3: Apparatus for measuring static coefficient of friction

The volume and in aftermath fruit density were calculated by following equations [18].

$$V_w = \frac{m_w}{\rho_w} \quad (3)$$

$$\rho_t = \frac{m}{V_w} \quad (4)$$

Bulk density was determined using mass and volume relationship [22] by filling an empty plastic container of predetermined volume. The fruits were left to fall from a constant height, striking off top level and weighting. The fruit density value was ratio of mass to volume values while porosity was computed [23] as:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (5)$$

Packing coefficient (λ) was defined by ratio of the volume of fruit (V) packed to the total volume (V_0) and calculated by the following equation:

$$\lambda = \frac{V}{V_0}$$

Coefficient of static friction of the fruit was found with respect to three structural materials namely iron, rubber and galvanized iron sheet, using the inclined plane apparatus as described by Dutta *et al.* [21], (Fig. 3). The table was gently raised and the angle of inclination to the horizontal at which the sample, arranged in a box of 10x10cm (avoiding fruit rolling phenomenon), started sliding was read off the protractor attached to the apparatus. The tangent of angle was reported as the coefficient of static friction. For this purpose, average of five experimental data was recorded for each parameter.

RESULTS AND DISCUSSION

Some dimensional and physical properties of the six cherry cultivars were shown in Table 1 and 2 respectively. The moisture contents of cultivars Mashad, Siah Mashad, Dorageh Karaj, Shabestar, Siah Daneshkadeh and Ghazvin at the time of experiment was 78.07, 78.32, 80.43, 82.34, 74.41 and 83.33% d.b respectively. Considering water which is an important component in most fruits and determines their perishability [24], hence knowledge of fruit moisture content and water activity is very useful to forecast the stability conditions in sweet cherry fruits in order to select formulations and storage conditions in new products and to improve drying processes and equipments [25].

From Table 1, it can be seen that the dimensional characteristics such as peduncle length and length of the fruit as well as geometric mean diameter of six Iranian cherry cultivars were found to be statistically significant at the 1 and 5% probability levels, respectively. The peduncle length of both 'Mashad' and 'Siah Daneshkadeh' fruits was significantly greater than that of the other cultivars, varying from 40.00 to 59.10 mm and from 48.1 to 72.1 mm, respectively. The width of the 'Siah Mashad' fruit (22.87 mm) was significantly greater than the other studied cultivars. The width of the 'Ghazvin' fruit

Table 1: Dimensional characteristics of sweet cherry fruits

	Cultivars					
Properties	Mashad	Siah Mashad	Dorageh karaj	Shabestar	Siah.Daneshkadeh	Ghazvin
Peduncle length[a](mm)	50.94±4.67	49.89±3.98	45.65±3.59	36.30±3.62	60.39±6.23	45.93±6.13
Fruit length[a] (mm)	20.18±1.28	24.72±1.08	20.99±0.92	23.48±1.2	21.99±1.11	23.10±0.93
Fruit width[a](mm)	18.93±1.13	22.87±1.14	20.21±1.05	21.40±0.73	20.76±1.29	21.78±0.83
Fruit thickness (mm)	17.04±1.08	20.54±1.17	18.13±1.06	19.69±0.96	18.15±1.29	19.69±0.94
Geo.Me.Dia.[b] (mm)	18.67±1.08	22.64±0.98	19.74±0.92	21.46±0.83	20.23±1.16	21.46±0.73
Fruit mass[b] (g)	4.51±0.73	7.40±0.99	4.87±0.65	5.99±0.71	5.46±0.84	6.11±0.6
Fruit volume[b] (cm^3)	3.96±0.64	6.68±0.86	4.24±0.63	5.36±0.62	4.76±0.78	5.65±0.54
Sphericity	0.93±0.002	0.92±0.003	0.94±0.003	0.91±0.002	0.92±0.001	0.93±0.002
Surface area[a] (mm^2)	1098.23±126.34	1612.90±138.8	1226.16±113.1	1449.48±112	1290.25±149.9	1447.87±98.45
PA_1[a] (mm^2)	458.03±29.78	566.24±42.65	476.94±27.65	518.84±2.51	492.74±34.71	513.39±21.33
PA_2[a] (mm^2)	480.54±32.6	593.64±36.94	488.33±26.37	549.39±29	504.76±33.58	535.91±22.99
PA_3[a] (mm^2)	504.97±34.47	637.23±37	517.66 ±27.65	573.62±32.14	544.13±35.65	571.12±25.05
Criteria projected area [b] (mm^2)	481.19±31.06	599.04±36.52	494.22±25.38	547.29±25.6	513.88±32.2	540.14±21.18

[a]Corresponding to 1% probability, [b]Corresponding to 5% probability

Table 2: Some physical and frictional properties of sweet cherry fruits

	Cultivars					
Properties	Mashad	Siah Mashad	Dorageh karaj	Shabestar	Siah.Daneshkadeh	Ghazvin
Bulk density[a] (kg/cm^3)	631.400±9.29	574.00±10.14	630.100±13.54	661.200±10.13	657.100±13.89	637.500±8.35
Fruit density[a] (kg/cm^3)	1142.000±60	1113.20±99.5	1152.00±35.6	1120.300±74.5	1150.700±38.8	1080.000±64.5
Porosity[a] (%)	44.720±0.4	48.44±0.94	45.310±0.26	40.980±0.95	42.890±1.2	40.970±0.44
packaging coefficient[a]	0.553±0.004	0.52±0.009	0.547±0.002	0.590 ±.009	0.571±0.012	0.590±0.004
Static friction coefficient						
iron Sheet[a]	0.211±0.011	0.299±0.013	0.289±0.020	0.381 ±0.011	0.178±0.017	0.409±0.015
Galvanized iron sheet [a]	0.191±0.009	0.266±0.023	0.252±0.021	0.296 ±0.022	0.146±0.007	0.313±0.015
Rubber[a]	0.291±0.010	0.349±0.013	0.338±0.017	0.412 ±0.020	0.251±0.020	0.439±0.015

was found to be 21.78 mm, followed by the Shabestar, Siah Daneshkadeh, Dorageh Karaj and Mashad cultivars, which had a mean of 21.4, 20.76, 20.21 and 18.93 mm, February 7, 2008respectively. The importance of these axial dimensions in determining aperture size of machines, particularly in separation of materials has been discussed by Mohsenin [18] and Omobuwajo *et al*. [26]. These dimensions may be useful in estimating the size of machine components. For example, it may be useful in estimating the number of fruits to be engaged at a time, the spacing of slicing discs and number of slices expected from an average fruit. The major axis has been found to be useful by indicating the natural rest position of the material and hence in the application of compressive force to induce mechanical rupture [27]. As far as sweet cherry fruit was concerned, this dimension will be useful in applying shearing force during slicing.

The highest geometric mean diameter values were found for Siah Mashad and Shabestar cultivars with mean of 22.64 and 21.46 mm, respectively but the smallest ones belongs to Mashad and Dorageh Karaj cultivars, with average of 18.67 and 19.74 mm respectively.

Projected area perpendicular to fruit length (PA_1) was found to be statistically significant at 1% probability level. According to the results, the latter property values were 458.03, 566.24, 476.94, 518.54, 492.74 and 513.39 mm^2 for Mashad, Siah Mashad, Dorageh Karaj, Shabestar, Siah Daneshkadeh and Ghazvin cherry fruit cultivars, respectively. Based on statistical analyses, criteria projected area and fruit volumes were found to be significant at 5% probability level. The criteria projected area of each cherry cultivar resulted in different means, varying from 481.19 to 599.04 mm^2. The volume of the Siah mashad cultivar (6.68 cm^3) was significantly greater than that of the other ones. The volume values of the 'Ghazvin' and 'Shabestar' fruits were 5.65 and 5.36 cm^3, respectively, followed by the Siah Daneshkadeh (4.76 cm^3), Dorageh Karaj (4.24 cm^3) and Mashad (3.96 cm^3) cultivars. Considering the latter result, it was clear that the large number of 'Mashad' fruit could be packed in the predetermined volume compared with the other cultivars. The surface area values of the studied cultivars were found to be significant at 1% probability level. These properties could be beneficial in proper prediction of sweet cherry drying rates and hence drying times in the dryer. If in the drying equipment simulation models for sweet cherry, such as the changes of volume (that contains a characteristic dimension as the fruit radius) and surface area to volume ratio of individual fruit are not considered, the estimates could lead to important errors. Therefore, this requires the knowledge of the relation between the volume and surface area changes, on the operation conditions of the dryer and the average water content of the sweet cherry fruits. These volume and area changes also modify transport properties of individual fruits, as well as the thickness and porosity of the packed bed [28].

The sample mass of cherries was determined to have different means and these values varied from 4.51 to 7.39 g. In addition, 'Siah Mahsad' had more weight than other cultivars. The variation in those parameters was found to be significant at the 5% probability level. This property may be useful in the separation and transportation of the fruit by hydrodynamic means [29].

As shown in Table 2 the porosity and bulk density values were found to be statistically significant at 1% probability level. According to the results, the mean porosity values for 'Mashad', 'Siah Mashad', 'Dorage Karaj', 'Shabestar', 'Siah Daneshkadeh' and 'Ghazvin' fruits were found to be 44.72, 48.44, 45.31, 40.98, 42.89 and 40.97%, respectively. The Shabestar cultivar had a 661.2 kg/m^3 bulk density, followed by the Siah Daneshkadeh and Ghazvin cultivars with means of 657.1 and 637.5 kg/m^3, respectively. 'Mashad', 'Dorageh Karaj' and 'Siah Mashad' ranked at the next places with mean of 631.4, 630.1 and 574 kg/m^3, respectively.

Table 3: Some dimensional characteristics ratios of the studied sweet cherry cultivars

Varieties	Particulars	Ratio
Mashad	L/W	1.067
	L/T	1.185
	L/M	4.554
Siah.Mashad	L/W	1.082
	L/T	1.205
	L/M	3.389
Dorageh karaj	L/W	1.04
	L/T	1.16
	L/M	4.366
Shabestar	L/W	1.097
	L/T	1.193
	L/M	3.955
SiahDaneshkadeh	L/W	1.061
	L/T	1.214
	L/M	4.093
Ghazvin	L/W	1.059
	L/T	1.172
	L/M	3.797

The packaging coefficient of the cherry fruits resulted in different means, varying from 0.52 ('Siah. Mashad') to 0.590 ('Ghazvin'). Based on Topuz *et al*. [30], these results were probably due to volume and shape of the fruit. The packaging coefficient increased with decrease in fruit volume. For instance, 'Siah Mashad' fruit had the lowest packing coefficient, with the highest fruit volume (6.675 cm^3). Post harvest treatment with low O_2 and/or high CO_2 concentrations is an attractive alternative for controlling fungal decay, maintaining fruit quality and extending post harvest life of fruits [31]. Considering this fact, having any information on packaging coefficient of sweet cherry could result in efficient control of fruit quality during storage.

The static coefficient of friction on the examined surfaces was found to be statistically significant at the 1% probability level. On the iron sheet surface, the coefficient of static friction of the Siah Daneshkadeh and Ghazvin cultivars were found to be the lowest and the highest coefficients with means of 0.178 and 0.409, respectively. On the rubber surface, the coefficient of static friction of the 'Ghazvin' fruit, with mean of 0.439, was significantly greater than that of the other cultivars. This value for the 'Shabestar', 'Dorageh Karaj' and 'Siah Mashad' was found to be 0.412, 0.338 and 0.349, respectively and was followed by the 'Mashad' and 'Siah Daneshkadeh', with a mean of 0.291 and 0.251 respectively. Similar to the surfaces stated above, on the galvanized iron sheet, the highest coefficient of static friction was obtained for 'Ghazvin' fruit with a mean of 0.316 while the corresponding value was 0.146 for 'Siah Daneshkadeh' as the lowest coefficient.

The relational statistics such as L/W, L/T and L/M with respect to dimensional properties of all sweet cherry fruit types were found to be meaningful at 1% probability level (Table 3). The highest and the lowest of L/W value was found for Shabestar and Dorageh Karaj cultivars with means of 1.097 and 1.040, respectively. In the case of L/T value, The Siah Daneshkadeh cultivar had a 1.214 ratio, followed by the 'Siah Mashad' and 'Shabestar' with means of 1.205 and 1.193, respectively. 'Mashad', 'Ghazvin' and 'Dorageh Karaj' ranked at the next places with means 1.184, 1.172 and 1.160, respectively. Mashad cultivar showed the greatest L/M among the other cultivars with mean of 4.554 but 'Siah Mashad' had the minimum ratio as 3.389. Nearly similar results were found for hackberry, rose, medlar and wild plum fruits by Demir *et al*. [20], Demir and Ozcan [32], Haciseferogullari *et al*. [33] and Calisir *et al*.[34].

Data obtained in this research will have a potential for applying in harvest, transportation, classification, processing, storing, packaging and other processes related to sweet cherry fruits.

ACKNOWLEDGMENTS

The authors appreciate full support of Vice chancellor of research and technology of University of Tehran for conducting this research. In addition, the authors appreciate full support of Horticultural Science and Agricultural Machinery Engineering Departments of University of Tehran for their kind cooperation and technical assistances. It is necessary to gratefully acknowledge Mr. M. Karimi for kindly cooperation in analyzing the experimental data.

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