Determination of some physical properties of virgin olive fruits

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Abstract: Information on physical properties of virgin olive fruit, especially those grown in Iran,arenot available in literatures. Some physical properties of Mari variety of virgin olive fruits, namely: dimensional properties (length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, volume of the fruit, surface area and projected area), gravimetric properties (unit mass of fruit, 1,000 fruit mass, bulk density, true density and porosity), frictional properties (angle of repose and coefficient of friction), modeling dimensional properties and mass (using normal distribution) were studied. Also sphericity, volume, surface area and projected area were calculated using different theoretical equations. Length, width and thickness of fruits ranged from 18.46 mm to 27.63 mm, 15.80 mm to 21.99 mm and 14.77 mm to 20.33 mm, respectively. Bulk density of fruits increased from 590.78 kg m^{-3} to 646.51 kg m^{-3} as the volume container increased from 500 mL to 2,000 mL and true density of 1,059.14 kg m^{-3} were obtained. The highest value forangle of repose and coefficient of friction amongplywood, rubber, iron and galvanized surfaceswererecorded for iron surface and the lowest value was recorded for galvanized surface.

Keywords: normal distribution, dimensional properties, gravimetric properties, frictional properties, modeling

Citation: Mirzabe, A. H., J. Khazaei, G. R. Chegini, M. H. A. Pour, R. Nejad. Determination of some physical properties of virgin olive fruits. Agric Eng Int: CIGR Journal, 15(1): 201−210.

1 Introduction

Olive (*Olea europaea* L.) is one of the world's most important oil crops. Virgin olive oil is a unique product because it is extracted by gentle physical procedure only, which results in a genuine fruit juice having excellent organoleptic and nutritional properties. Its richness in oleate makes it appropriate for direct human consumption, as well as for use in diets designed to reduce cardiovascular diseases (Ranalli et al., 2002).

The physical and mechanical properties of virgin olive fruits, like those of other grains, seeds and fruits are required in the designation and construction of equipment and structures for harvesting and post harvesting operations such as handling, transportation, sorting, processing, oil extraction and storage of the fruits. They are also required in the assessment of the product quality (Bart-Plange and Baryeh, 2003). Various types of cleaning, grading, separation and conveying equipment are designed and constructed based on physical, mechanical and thermal properties of grains and seeds (Baryeh, 2001, 2002). While a lot of researchers have conducted studies on olive oil (Cabrini et al., 2001; Vierhuis et al., 2001; Ranalli et al., 2002; Servilia et al., 2004), available literatures are limited to physical and mechanical properties of virgin olive fruits. Drying and modeling of olive cake over a wide temperature range using mathematical models were studied and the effective diffusivities and activation energy were calculated by Akgun and Doymaz(2004). Physical properties and mechanical behavior such as rupture force, rupture energy and specific deformation under compression loading of olive fruits and their pits of Gemlik variety growing in Aydin province in Turkey were determined by Kilickan and Güner (2007).

Received date: 2012-10-29 **Accepted date:** 2013-02-17

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For a single seed, dimensions, mass and other physical properties can be determined. However, values of these properties differ for each single seed, but description of the frequency distribution of dimensions, mass and physical properties of the whole set of the seeds is required for designing agricultural machinery (Khazaei et al., 2008). There are many studies reported on modeling the properties of agricultural products based on statistical distributions. Frequency distribution curve for dimensions and mass of cocoa beans were fitted to empirical data (Bart-Plange and Baryeh, 2003). Frequency distribution curve for length, width and thickness of Sumac fruits were studied by Özcan and Haciseferogullari (2004). Log-normal, normal and Weibull distribution for modeling the mass and size distribution of two varieties of sunflower seeds and kernels were used by Khazaei et al. (2008). Frequency distribution curves for length, width, thickness and mass of sunflower seeds and kernels were studied by Jafari et al. (2011).

Informations on the physical properties of virgin olive fruit especially those grown in Iran are not available in literatures yet. The aim of this study was to determine the physical properties such as length, width, thickness, fruit mass, 1,000 fruit mass, arithmetic mean diameter, geometric mean diameter, sphericity, volume, surface area, projected area, bulk density, true density, porosity, angle of repose, coefficient of friction and modeling dimensional properties and mass (using normal distribution) of virgin olive fruit of Mari variety grown in Tehran province, Iran. Also sphericity, volume, surface area and projected area were calculated using different equations and the results of different equations were compared.

A	Angleof external static friction /deg	S_1	Surface area based on Equation (8)/mm^2
A_r	Angle of repose /deg	S_2	Surface area based on Equation (9)/mm^2
C_{SF}	Coefficientof external static friction	STD	Standard deviation
D_a	Arithmetic mean diameter, mm	T	Thickness of fruit /mm
D_b	Bulk density /kg m^{-3}	V_1	Volume of fruit based on Equation (6)/mm^3
D_g	Geometric mean diameter /mm	V_2	Volume of fruit based on Equation (7)/mm^3
D_t	True density/kg m^{-3}	W	Width of fruit /mm
H	Heightof the cone /mm	α	Location parameter in Normal distribution
L	Length of fruit /mm	β	scale parameter in Normal distribution
P_{a1}	Projected area based on Equation (10)/mm^2	ε	Porosity /%
P_{a2}	Projected area based on Equation (11)/mm^2	φ_1	Sphericity based on Equation (3)/%
PDF	Probability density function	φ_2	Sphericity based on Equation (4)/%
R	Radius of the cone /mm	φ_3	Sphericity based on Equation (5)/%

2 Materials and methods

2.1 Sample preparation

Samples used in this study were virgin olive fruits collected on 5 September 2012 from local farms of Ghezlagh located at Pakdasht, Tehran, Iran. Six kgof virgin olive fruits of Mari variety were harvested manually, cautiously and randomly. The fruits were immediately transported to laboratory and were stored at 5℃ prior to experiment.

Bulk samples were selected randomly. The length, width, thickness, unit mass, 1,000 fruit mass, bulkiness and true density, angle of repose and friction coefficient of olive fruit samples were measured.

2.2 Dimensional properties

To determine the dimensions of the virgin olive fruit squash seeds, 100 seeds were randomly selected from the bulk sample. For each single fruit, the three principal dimensions of length (L), width (W) and thickness (T) were measured. For all measurements, a digital caliper with an accuracy of 0.01 mm was used.

Some related dimensional properties of fruit samples were calculated based on the measured dimensions of the samples. Geometric mean diameter (D_g mm) and arithmetic mean diameter (D_a /mm) were determined using Equation (1) and Equation (2) as reported by Koochaki et al. (2007).

$$D_g = \sqrt[3]{LWT} \quad (1)$$

$$D_a = \frac{L+W+T}{3} \quad (2)$$

The sphericity (φ/%) of the grain is an index of its roundness. For non-spherical particles, the sphericity is calculated as the ratio of the surface area of equivalent sphere to the surface area of the grain (Jain and Bal, 1997). The sphericity of the seeds and fruit were determined using Equation (3) as reported by Khazaei et al. (2008).

$$\varphi_1 = \left(\frac{\sqrt[3]{LWT}}{L}\right) \times 100 \quad (3)$$

Sphericity of seeds or fruits can alsobe determined using Equation (4) (Jain and Ba, 1997; Baryeh, 2001; Baryeh, 2002; Kibar and Öztürk, 2008). In order to determine the sphericity of seeds or fruit, some researchers used Equation (5) (Razavi and Milani, 2006; Burubai et al., 2007; Milani et al., 2007; Koocheki et al., 2007).

$$\varphi_2 = \left[\frac{B(2L-B)}{L^2}\right]^{\frac{1}{3}} \times 100 \quad (4)$$

$$\varphi_3 = \left[\frac{B(2L-B)}{L}\right]^{\frac{1}{3}} \times 100 \quad (5)$$

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

Volume (V /mm^3) of the fruit samples were calculated using Equation (6) and Equation (7) (Baryeh, 2002; Kibar and Öztürk, 2008; Tabarsa et al., 2011):

$$V_1 = \left(\frac{\pi D_g^3}{6}\right) \quad (6)$$

$$V_2 = \frac{\pi B^2 L^2}{6(2L-B)} \quad (7)$$

Surface area (S/mm^2) of the fruit samples were calculated using Equation (8) and Equation (9) (Baryeh, 2001; Baryeh, 2002; Jafari et al., 2011):

$$S_1 = \pi D_g^2 \quad (8)$$

$$S_2 = \frac{\pi B L^2}{2L-B} \quad (9)$$

Projected area is an important parameter for determining aerodynamic properties (Mirzabe et al., 2012). This parameter was determined using Equation (10) and Equation (11) (Burubai et al., 2007; Kabas et al., 2007):

$$P_{a1} = \left(\frac{\pi WL}{4}\right) \quad (10)$$

$$P_{a2} = 1.21 V^{\frac{2}{3}} \quad (11)$$

2.3 Modeling dimensional properties and mass

Normal distribution was used to model dimensional properties and mass of fruit sample. Normal probability density functions were fitted to the empirical probability density to estimate the parameter values by nonlinear least-squares method. The probability density function ($f(x)$) and cumulative frequency function ($F(x)$) for the Normal distribution are defined as in Equation (12) and Equation (13), respectively (Khazaei et al., 2008).

$$f(x) = \left(\frac{1}{\beta\sqrt{2\pi}}\right) \exp\left(-\frac{1}{2}\left(\frac{x-\alpha}{\beta}\right)^2\right) \quad (12)$$

$$F(x) = \left(Z\left(\frac{x-\alpha}{\beta}\right)\right), \quad Z(x) = \left(\frac{1}{\sqrt{2\pi}}\right)\int_0^x e^{-t_2/2} dt \quad (13)$$

where, β = mean or location parameter; α = standard deviation or scale parameter.

2.4 Gravimetric properties

2.4.1 Mass properties

To determine the mass of a single fruit sample, 100 fruits from the bulk sample were randomly selected. Mass of the fruit samples were measured by a digital balance with an accuracy of 0.0001 g. To determine 1,000 fruit mass, 500 seeds were selected; then the samples were divided randomly into 5 bins so that each bin contained 100 samples. The weight of each loaded bins were measured. Then the average weight of bins was calculated and multiplied by 10 to give one thousand fruits mass.

2.4.2 Density properties

The bulk material (samples) was put into 4 cylindrical containers with known weights and volumes of 500, 1,000, 1,500 and 2,000 mL with a constant height of 150 mm (Dash et al., 2008). Bulk density (D_b) was calculated from the mass of bulk material divided by volume containing the mass.

The fruits true density (D_t) was determined using the water displacement method. Toluene (C_7H_8) was used instead of water, because its absorption by seed is less compared to water. Also, its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Milani et al., 2007). The porosity (ε) of the fruit samples was calculated based onbulk density and true density, following the Equation (14) as reported by Nazari et al.(2008).

$$\varepsilon = \left(1 - \frac{D_b}{D_t}\right) \times 100 \tag{14}$$

where, ε is porosity; D_b is bulk density; D_t is true density.

2.5 Frictional properties

2.5.1 Angle of friction

The coefficient of external static friction was determined using plywood, rubber surface, iron sheet and galvanized iron sheet. A top and bottomless metallic box was put on the surface. The box was filled by virgin olive fruit samples. The surface was gradually raised by a screw. Both horizontal and vertical heights were measured using a ruler and digital caliper when the seeds started sliding over the surface and the coefficient of static frication was calculated using Equation (15) as reported by Burubai et al. (2007).

$$C_{SF} = \tan(A) \tag{15}$$

where, C_{SF} is coefficient of external static friction; A is angle of external static friction.

2.5.2 Angle of repose

Static angle of repose was measured by pouring method, because the sphericity of virgin olive fruit was very large (Fraczek et al., 2007). The angle of repose of fruit sample was determined by using a top and bottomless metallic cylinder of 250 mm height and 150 mm diameter. The cylinder was placed on horizontal surface and was filled with fruit samples. The cylinder was raised very slowly. The height and radius of the cone were measured using a digital caliper. The static angle of repose was determined using the following Equation (16) reported by Milani et al. (2007):

$$A_r = \tan^{-1}\left(\frac{H}{R}\right) \tag{16}$$

where, A_r is the angle of repose; H is the height of the cone; R is the radius of the cone.

2.6.2 Data analysis

2.6.2.1 Modeling

MATLAB R2009a was used to draw probability density function diagrams and calculate the parameters of the probability density function including location parameter and scale parameter.

2.6.2.2 Statistical indices

Statistical indices including maximum, minimum, average, standard deviation (STD), and variance for three principal dimensions, dimensional properties and mass of single fruit were calculated using Microsoft Office Excel 2010.

Skewness and kurtosis are two statistical indices which were calculated so that the reader would better understand the probability density distribution data. The skewness and kurtosis were calculated using the following Equation (17) and Equation (18) as reported by Lucian, (2006) and Khazaei et al. (2008), respectively.

$$Skewness = \frac{n}{(n-1)(n-2)} \sum_{i=1}^{n} \left(\frac{x_i - x_{avg}}{STD}\right)^3 \tag{17}$$

$$Kurtosis = \left\{\frac{n(n-1)}{(n-1)(n-2)(n-3)} \sum_{i=1}^{n} \left(\frac{x_i - x_{avg}}{STD}\right)^4\right\} - \frac{3(n-1)^2}{(n-2)(n-3)} \tag{18}$$

where, n = number of occurrence; STD = standard deviation; x_{avg} = mean seed size; x_i = midpoint of each class interval in metric.

3 Results and discussion

3.1 Dimensional and modeling results

Length, width and thickness of virgin olive fruit samples ranged from 18.46 mm to 27.63 mm, 15.80 mm to 21.99 mm and 14.77 mm to -20.33 mm, respectively. Kilickan and Güner (2007) reported that olive fruits (Gemlik variety) length, width and thickness ranged from 22.94 mm to 27.56 mm, 20.04 mm to 23.96 mm and 16.32 mm to 19.80 mm, respectively. A Comparison between the Mari and Gemlik varieties indicates that the range of dimensions of Mari variety was wider than the Gemlik variety. Statistical indices for dimensional properties and mass of the fruits are shown in Table 1. Table 1 shows that for olive fruits, in most cases, skewness had negative values and kurtosis values were positive.

Table 1 Statistical indices for dimensional properties of the virgin olive fruit

Parameter	Unit	Max/mm	Min/mm	Average	STD	Skewness	Kurtosis
L	mm	27.63	18.46	23.417	1.586	-0.342	0.814
W	mm	21.99	15.8	18.878	1.190	-0.196	-0.026
T	mm	20.33	14.77	17.749	1.097	-0.530	0.167
M	g	6.33	2.88	4.506	0.701	0.002	-0.015
D_g	mm	22.783	16.450	20.015	1.051	-0.447	0.924
D_a	mm	22.661	16.380	19.858	1.054	-0.394	0.720
φ_1	%	91.919	70.929	84.976	4.004	-1.358	2.663
φ_2	%	2.928	2.619	2.811	0.973	0.003	1.483
φ_3	%	292.841	261.893	281.074	5.257	-0.783	1.483
V_1	mm^3	6092.880	2301.246	4134.012	643.796	0.000	0.491
V_2	mm^3	5129.907	1976.802	3407.820	561.377	0.032	0.261
S_1	mm^2	1613.225	842.924	1242.248	130.251	-0.194	0.537
S_2	mm^2	1455.725	768.673	1110.222	119.562	-0.134	0.316
P_{a1}	mm^2	449.548	233.708	347.709	37.071	-0.209	0.712
P_{a2}	mm^2	403.646	210.908	310.823	32.590	-0.194	0.537

In probability theory and statistics, skewness is a measure of the asymmetry of the probability distribution of a real-valued random variable. The skewness value can be positive or negative, or even undefined. Qualitatively, a negative skewness indicates that the tail on the left side of the probability density function is longer than the right side and the bulk of the values (possibly including the median) lie to the right of the mean. A positive skewness indicates that the tail on the right side is longer than the left side and the bulk of the values lie to the left of the mean. A zero value indicates that the values are relatively evenly distributed on both sides of the mean, typically (but not necessarily) implying a symmetric distribution.

In a similar way to the concept of skewness, kurtosis describes the shape of a probability distribution. Kurtosis refers to the degree of peak in a distribution. More peak than normal (leptokurtic) means that a distribution also has fatter tails and that the probability of extreme outcomes is less compared to a normal distribution.

In ideal cases, value of skewness and kurtosis should be equal to zero for normal distribution of dimensions and mass of the seeds, grains and fruits. But in real case some factors such as irrigation period, fertilization period, weather conditions may cause changes in seeds, grains and fruit dimensions and mass, therefore value of skewnees and kurtosis cannot be equal to zero.

The dimensional distribution of virgin olive fruits were modeled using Normal probability density function distribution. Normal distribution parameters for modeling of dimensional properties and unit mass of the olive fruits are shown in Table 2.

Table 2 Calculated parameter values of probability density functions for dimensional properties and mass

Parameter	Units	Mean or location parameter	Standard deviation or scale parameter
L	mm	23.417	1.586
W	mm	18.878	1.190
T	mm	17.749	1.097
M	g	4.506	0.701
D_g	mm	19.858	1.054
D_a	mm	20.015	1.051
φ_1	%	84.975	4.004
φ_2	%	98.309	0.973
φ_3	%	281.074	5.257
V_1	mm^3	4134.01	643.796
V_2	mm^3	3407.82	561.377
S_1	mm^2	1242.25	130.251
S_2	mm^2	1110.22	119.562
P_{a1}	mm^2	347.709	37.071
P_{a2}	mm^2	310.823	32.590

Predicted dimensional distributions are illustrated in Figure 1. It can be seen in Figure 1 that three cases of skewness had negative values. Similarly, it can be seen in

Figure 1, that kurtosis value for length of fruit was more than the other dimensions. Figure1 shows that there is little overlap between the probability density function (PDF) of length and width, and even less overlap between the PDF of length and thickness.

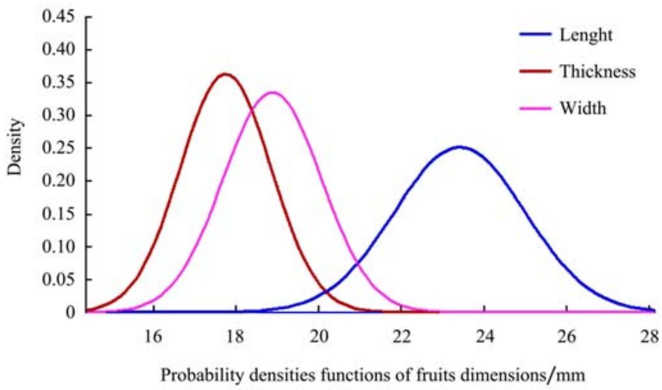

Figure 1 Probability densities functions of fruits dimensions

Geometric mean diameter and arithmetic mean diameter were calculated based on Equation (1) and Equation (2), respectively. The arithmetic mean diameter was small than the geometric mean diameter obtained in all cases. A comparison between the Mari and Gemlik (Kilickan and Güner, 2007) varieties indicates that the value of arithmetic mean diameter of Mari variety was more than the Gemlik variety and the value of geometric mean diameter of Gemlik variety was greater than the Mari variety.

The sphericity (Φ /%) of the olive fruits were calculated based on Equation (3), Equation (4) and Equation (5). Results indicated that average of sphericity of olive fruits based on Equation (5), was found to be 281.074%. Also Razavi and Milani (2006) calculated sphericity of three watermelon varieties seeds based on Equation (5). They found that average value of sphericity of Sarakhsi, Kolale and Red varieties were 206.6, 200.4 and 212.5%, respectively. Although it is impossible to have a spherecity more than 100%, Razavi obtained more than 100% because the equation (Equation (5)) he used was not correct.

Also results showed that values of the olive fruits sphericity calculated based on Equation (3) and Equation (4) were different; therefore a theoretical comparison between Equation (3) and Equation (4) was conducted. If for a single seed, grain or fruit W equals to aL and T equals to bL ($0 < a \leqslant 1$ and $0 < b \leqslant 1$) value of the sphericity can be calculated as Equation (19) and Equation (20):

$$\varphi_1 = \left(\frac{\sqrt[3]{LWT}}{L}\right) \times 100 = \left(\frac{\sqrt[3]{L(aL)(bL)}}{L}\right) \times 100 = \sqrt[3]{ab} \times 100 \tag{19}$$

$$\varphi_2 = \left[\frac{B(2L-B)}{L^2}\right]^{\frac{1}{3}} \times 100 = \left\{\frac{\sqrt{(aL)(bL)}(2L-\sqrt{(aL)(bL)}}{L^2}\right\}^{\frac{1}{3}} \times 100 = \sqrt[3]{(2\sqrt{ab}-ab)} \times 100 \tag{20}$$

When the value of ab ranged from 0.01 to 1, value of sphericity based on Equation (3) ranged from 21.5% to 100%. However, value of sphericity based on Equation (4) ranged from 57.5% to 100% as shown in Figure 2. According to Figure 2, in all cases, value of the sphericity based on Equation (4) was more than the value based on Equation (3). According to Figure 2, in the 70% of all cases, difference between the values obtained by Equation (3) and Equation (4) were more than 9.956%. Also, the result indicated that the variable range of sphericity based on Equation (3) was wider than the values obtained from Equation (4). Thus, calculating sphericity based on the Equation (2) had more valid results.

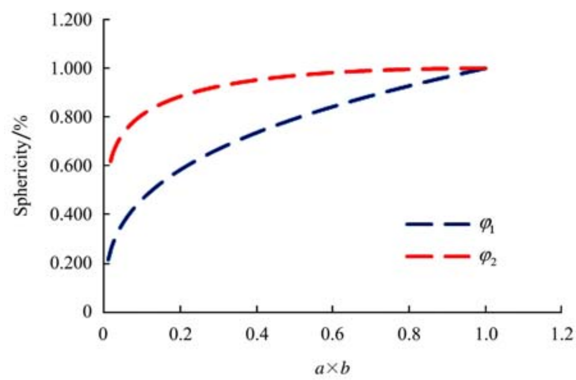

Figure 2 Effect of the value of ab onvalue of sphericity for Equation 3 and Equation (4)

Volume of the fruits basedon Equation (6) and Equation (7) were 7,413.4012 mm^3 and 3,407.820 mm^3, respectively. Results indicated that, in all cases, volume of the fruits based on the Equation (6) was more than that obtained using Equation (7).

Probability density function of volume of the fruit based on Equation (6) and Equation (7) are illustrated in Figure 3. From Figure 3, it can be seen that in both cases, kurtosis had positive values. The difference between volume based on Equation (6) and Equation (7) ranged from 324.444 mm^3 to 1,162.471 mm^3.

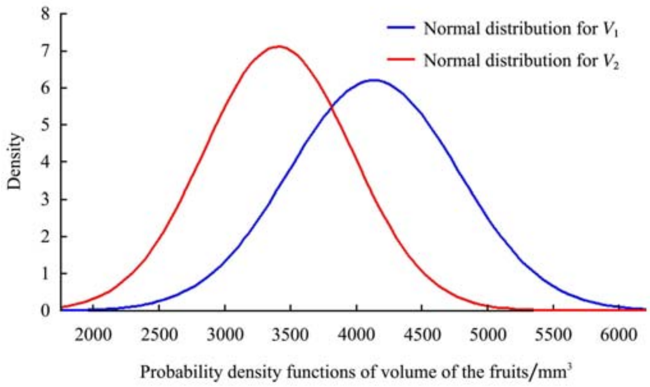

Figure 3 Probability density functions of volume of olive fruits based on Equation 6 and Equation (7)

If for a fruit, W equals to aL and T equals to bL ($0 < a \leqslant 1$ and $0 < b \leqslant 1$) the volume can be calculated as follows (Equation (21) and Equation (22)):

$$V = \left(\frac{\pi D_g^3}{6}\right) = \left(\frac{\pi LWT}{6}\right) = \left(\frac{\pi abL^3}{6}\right) \tag{21}$$

$$V = \frac{\pi B^2 L^2}{6(2L-B)} = \left(\frac{\pi WTL^2}{6(2L-\sqrt{WT})}\right) = \left(\frac{\pi abL^4}{6L(2-\sqrt{ab})}\right)\left(\frac{\pi abL^3}{6(2-\sqrt{ab})}\right) \tag{22}$$

When the value of ab ranged from 0.01 to 1, volume of fruit based on Equation (6) ranged from 0.005 L^3 to 0.524 L^3; but volume based on Equation (7) ranged from 0.003 L^3 to 0.524 L^3 as in Figure 4. In all cases, the calculated volume based on Equation (6) was more than the calculated volume based on Equation (7). Also calculation results showed that the difference between volume based on Equation (6) and Equation (7) ranged from 0 to 0.059 L^3.

Average of the surface area of the fruits based on Equation (8) and Equation (9) and projected area based on Equation (10) and Equation (11) was found to be 1,242.248 mm^2, 1,110.222 mm^2, 347.709 mm^2 and 310.823 mm^2, respectively. In all cases, values of the surface area based on Equation (8) were more than the values of the surface area based on Equation (9). Therefore average of the surface area of the olive fruits based on Equation (8) was found to be more than that based on Equation (9). Also, in all cases, values of the projected area based on Equation (10) were more than the values of the projected area based on Equation (11), therefore average of the projected area of the olive fruits based on Equation (10) was more than for Equation (11).

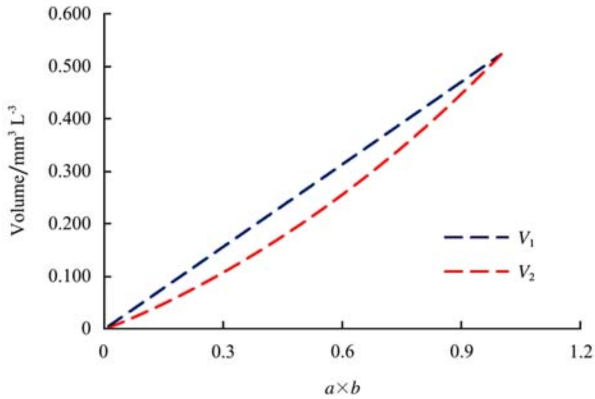

Figure 4 Theoretical comparison between Equation (6) and Equation (7)

Probability density functions (PDFs) of surface area of the fruit based on Equation (8) and Equation (9) using Normal distribution are shown in Figure 5. Skewness of calculated surface area based on Equation (8) and Equation (9) were negative and kurtosis had positive values. Also, in all cases, calculated value of the surface area of the fruits based on Equation (9) was less than calculated value based on Equation (8). Results of the calculations indicated that difference between surface areas of the olive fruits based on Equation (8) and Equation (9) ranged from 72.489 mm^2 to 189.535 mm^2.

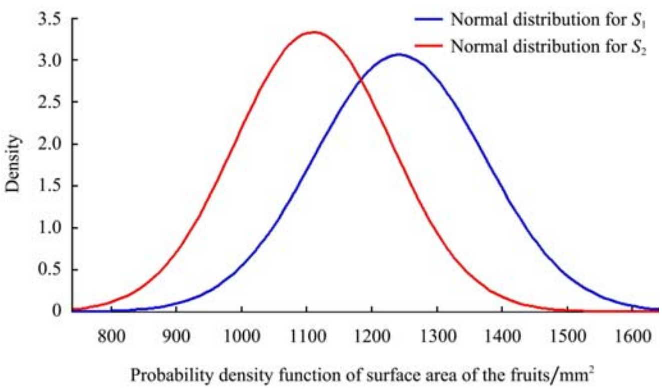

Figure 5 Probability density function of surface area of olive fruits based on Equation (8) and Equation (9)

When the value of *ab* ranged from 0.01 to 1, value of surface area of the fruit based on Equation (8) and Equation (9) ranged from 0.146 L^2 to 3.142 L^2 and 0.165 L^2 to 3.142 L^2, respectively (Figure 6). Results indicated that the difference between surface area (S_1 –S_2) based on Equation (8) and Equation (9), ranged from -0.020 L^2 to 0.261 L^2.

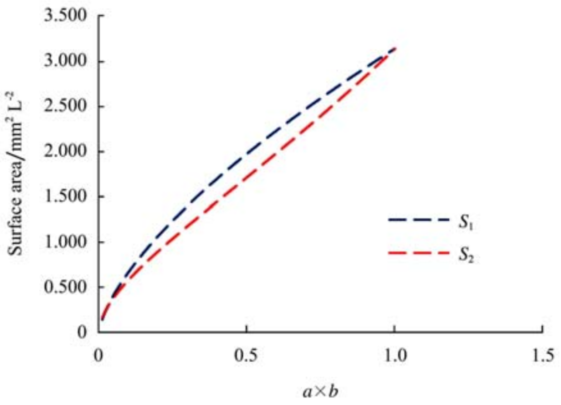

Figure 6 Theoretical comparison between calculated surface areas based on the Equation (8) and Equation (9)

Probability density functions (PDFs) of projected area of the fruit based on Equation (10) and Equation (11) using Normal distribution are shown in Figure 7. Value of skewness for calculated surface area based on Equation (8) and Equation (9) were negative and kurtosis had positive values. Normally, knowing the properties of each individual seed, grain or fruit is beyond the research interest but for designing the dehulling, separating, sizing, packing and planting machines the frequency distributions of the size and mass properties of whole sets of seeds, grains or fruits should be described (Khazaei et al., 2008, Mirzabe et al., 2012).

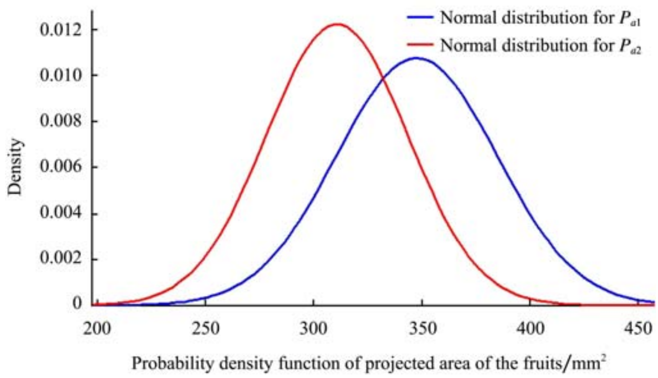

Figure 7 Probability density function of projected area of olive fruits based on Equation (10) and Equation (11)

3.2 Gravimetric results

3.2.1 Mass results

Mass of virgin olive fruits ranged from 2.88 g to 6.33 g. Kilickan and Güner (2007) reportedthat mass of olive fruits (Gemlik variety) ranged from 2.65 g to 5.65 g. A comparison between the Mari and Gemlik varieties indicated that the range of mass of Mari variety was wider than the Gemlik variety. Statistical indices for mass of the fruits are shown in Table 1. Table 1 shows that skewness had positive value and kurtosis value was negative. Thousand seeds mass of fruits was found to be 4,583.96 g.

3.2.2 Densities results

Bulk density of fruits increased from 590.784 kgm^{-3} to 646.508 kgm^{-3} as the volume container increased from 500 mL to 2,000 mL as shown in Figure 8. True density of the fruits was obtained to be 1,059.137 kgm^{-3}. Kilickan and Güner (2007) cited that the bulk and true density of olive fruit of Gemlik variety were found to be 556.00 kg m^{-3} and 1,062.00 kg m^{-3}, respectively. A comparison between the Mari and Gemlik varieties indicates that the value of bulk density of Mari variety was more than the Gemlik variety and true density of Mari variety was less than the Gemlik variety.

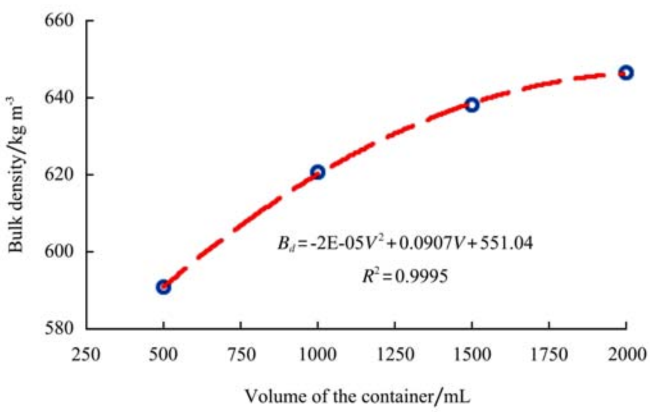

Figure 8 Effect of the volume of the container on bulk density

The porosity depends on the bulk and true density. Thus porosity of fruits decreased from 44.22% to 38.96% as the volume container increased from 500 mL to 2,000 mL as shown in Figure 9. According to the Kilickan and Güner (2007), the porosity of the Gemlik variety is more than the Mari variety.

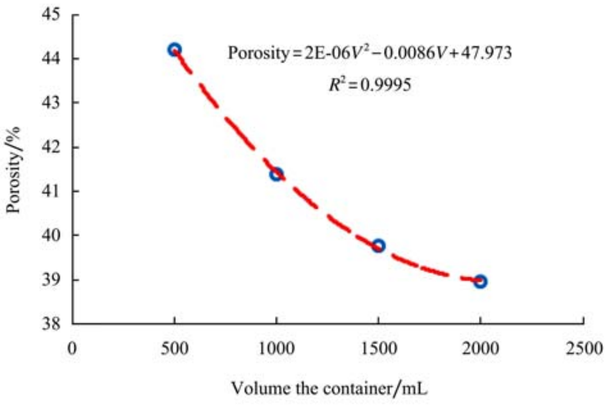

Figure 9 Effect of volume the container on porosity

3.3 Frictional results

3.3.1 Angle of friction

The coefficient of friction of olive fruit on plywood, rubber, iron and galvanized surface are shown in Table 3. Results indicate that the highest value for the static coefficient of friction (angle of friction) for olive fruits was obtained in iron surface and the lowest value was obtained in galvanized steel surface.

Table 3 Value of static coefficient of friction and angle of friction on different surfaces

Sheet material	A (deg)	C_{SF}
Plywood	19.26	0.35
Rubber	20.82	0.38
Iron	21.38	0.39
Galvanized	16.72	0.300

3.3.2 Angle of repose

The valuesobtained for pouring angle of repose on plywood, rubber, iron and galvanized surface were 22.51°, 25.72°, 26.05° and 24.15°, respectively. Angle of repose is one of the frictional parameters of fruits, grain, seeds, nuts and kernels of agricultural crops. Value of angle of repose of fruits on each surface was related to the value of the static coefficient of friction of fruits on the surface. Value of angle of repose on galvanized surface was lower than other surfaces because the value of coefficient of friction on galvanized surface was lower than the other surfaces. Value of angle of repose on iron surface was more compared to other surfaces because the value of coefficient of friction on iron surface was more than other surfaces.

5 Conclusions

In the present work, some physical properties of Mari variety of virgin olive fruits, namely, dimensional properties, gravimetric properties, frictional properties and modeling dimensional properties and mass using normal distribution were investigated. According to the measured and calculated properties:

1) Modeling result indicated that, in most cases, skewness had negative values and kurtosis values were positive.

2) Values of the calculated sphericity based on Equation (3) were higher than the values based on Equation (4). Values of the calculated volume of the fruits based on Equation (6) were higher than the values based on Equation (7). Values of the calculated surface area of the fruits based on Equation (8) were higher than the values based on Equation (9). Values of the calculated projected area of the fruits based on Equation (10) were higher than the values based on Equation (11).

3) Mass of virgin olive fruits ranged from 2.88 g to 6.33 g and 1,000 seeds mass of fruits was found to be 4,583.96 g.

4) When the value of the volume container increased from 500 mL to 2,000 mL, value of the bulk density also increased from 590.874 kg m^{-3} to 646.508 kg m^{-3}

5) True density of olive fruit was determined to be 1,059.137 kg m^{-3}.

6) The value of angle of repose and coefficient of friction on iron surface was more than that on other surfaces. Also values of angle of repose and coefficient of friction on galvanized surface were least compared to other surfaces.

Acknowledgement

The authors would like to thank the University of Tehran for providing technical support for this work. We would also like to thank Dear Mr. Mohammad Hassan Torabi Ziaratgahi, Mr. Rasool Sohrabi Khah, Mr. Ebrahim Sharifat, Mr. Mostafa Kabiri, Mr. Ali Mansouri, Hamed Ebrahimzadeh for their technical help and support while writing the paper.

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