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# Some physical characteristics of pomegranate, seeds and arils

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The physical properties of pomegranate fruits, arils and seeds were investigated. Results of mass modeling indicated that the best models for predicating fruit mass and aril mass based on physical characteristic were projected area and volume of ellipsoid with $R^2$ of .98 and 0.78, respectively. Physical properties of fruit were determined and average value of length, width, thickness, geometric mean diameter, sphericity, surface area, criteria project area and porosity were 88.12 mm, 82.61 mm, 79.65 mm, 83.33 mm, 0.95 percent, 219.91 $cm^2$, 57.90 $cm^2$, 29.402, respectively. Coefficient of friction of fruit on wood, glass and galvanized Iron surface were 0.45, 0.72 and 0.84, respectively. Mean values of coefficient of friction on these surfaces were 0.53, 0.31, 0.50 and 0.58, 0.30 and 0.49 for arils and seeds, respectively. Weight ratio different parts of samples were determined and average value were o.73 for arils respect to fruit and 0.25 for peels respect to fruit.

**Key words**: mass modeling, frictional properties, pomegranate fruits, arils and seeds.

## Introduction

Pomegranate (*Punica granatum* L.) belongs to punicacia family and is one of the most popular fruits native to Iran (Akbarpour *et al.,* 2009). There are about 70,000 hectares of pomegranate orchards in Iran, with about 700,000 tones annual production and more than 150,000 tones is exported to other countries (Khoshnam *et al.,* 2007). The edible part of the fruit (57.51% of total fruit wt.) comprised 63.58% of juice and 36.21% of seeds also contains considerable amounts of acids, sugar, vitamins, polysaccharides, polyphonies and important mineral (Al-Maiman and Ahmad, 2002).

Physical characteristics of agricultural products are the most important parameters in design of grading, conveying, processing and packaging systems. Among these physical characteristics, mass, volume, projected areas and center of gravity are the most important ones in sizing systems (Mirzaee *et al.,* 2008). Fruits with the similar weight and uniform shape are desirable in terms of

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marketing value. Therefore, grading fruit based on weight reduces packing and handling costs and also provides suitable packing patterns (Khoshnam *et al.,* 2007). Shape and physical dimensions are important in screen solids to separate foreign materials and in sorting and sizing of fruits and vegetables. Quality differences in fruit can often be detected by difference in density. When fruits are transported hydraulically the design fluid velocities are related to both density and shape (Stroshine and Hamann, 1994).

One commonly used technique for quantifying differences in shape of fruits, vegetables and seeds are to calculate sphericity. The porosity, which is the percentage of airspace in particular solids, affect the resistance to airflow through bulk solids and air flow resistance, in turn , affects the performance of aeration systems used to control the temperature of stored bulk solid (Stroshine and Hamann, 1994). Sizing by weighing mechanism is recommended for the irregular shape product. Since electrical sizing mechanism is expensive and mechanical sizing mechanism reacts poorly; therefore, for pomegranate, dimensional method (of length, area and volume) can be used. Determining relationships between mass and dimensions and projected areas may be useful and applicable (Marvin *et al.,* 1987). The physical properties of different fruits and vegetables were determined by other researcher; caper fruit (Sessiz *et al.,* 2007), potato (Singh *et al.,* 2006; Sadowska *et al.,* 2004), gumbo fruit (Akar and Aydin, 2005), wheat (Tabatabaeefar, 2003), pear (Wang, 2004), onion (Abhayawick *et al.,* 2002), apple (Meisami-asl *et al.,* 2009), date (Keramat Jahromi *et al.,* 2008).

In the case of mass modeling, Tabatabaeefar and Rajabipour (2005) determined models for predicting mass of Iranian apple from its volumes, dimensions, and projected areas. Mirzaee *et al.* (2008) predicated models for mass modeling of apricot cultivars. The model investigated many kind of model for predication mass of pomegranates based on dimensions and project areas. They recommended that suitable grading system of pomegranate mass was ascertained based on minor diameter as nonlinear relation (Khoshnam *et al.,* 2007). Also, some physical properties of pomegranate have been investigated and reported by several researchers (Kingsly *et al.,* 2006; Fadavi *et al.,* 2005; Al-Maiman and Ahmad, 2002; Safa and Khazaei, 2003).

Some studies were performed on physical property of pomegranate but there is not comprehensive study on pomegranate and its seeds and arils. In this study, the physical properties of seeds, arils and fruits of pomegranate were investigated.

## Material and methods

### *Abbreviations*

| | | | |
|---|---|---|---|
| L | major diameter with calyx (mm) | $\rho_b$ | bulk density(gr/cm$^3$) |
| W | intermediate diameter (mm) | $\rho_t$ | true density(gr/cm$^3$) |
| T | minor diameter (mm) | $\varepsilon$ | porsity |
| CPA | criteria projected area (mm$^2$) | $\Phi$ | sphirity |
| $L^*$ | major diameter without calyx (mm) | $\varphi$ | angle of repose(degree) |
| $D_g$ | geometric mean diameter (mm) | $\theta_f$ | filling angle of repose(degree) |
| M | mass (g) | | |
| PA1 | first projected area (mm$^2$) | $\theta_e$ | emptying angle of repose(degree) |
| PA2 | second projected area (mm$^2$) | | |
| PA3 | third projected area (mm$^2$) | $\mu_s$ | static coefficient of friction |
| $R^2$ | coefficient of determination | $w_{1000}$ | thousand seeds mass(g) |
| V | volume (cm$^3$) | a | constant factor |
| Vsp | volume of ellipsoid(cm$^3$) | b | constant factor |
| Vm | measured volume (cm$^3$) | c | constant factor |
| Vosp | volume of oblate spheroid (cm$^3$) | d | constant factor |

### *Physical characteristics*

Fresh pomegranate (c.v Malas Yazd) was considered for this study which was obtained from different regions of Yazd province located in middle of Iran. The physical properties of pomegranate such as mass, volume, bulk density, true density, dimensions, projected area, porosity, surface area and friction properties were measured. The mass (M) of each pomegranate was measured to 0.1 g accuracy on a digital balance. To determine the average size of the fruits, three linear dimensions namely as length (L), width (W) and thickness (T) were measured by using a digital caliber with 0.1 mm sensitivity. Fruit volume (V) was obtained from water displacement method (Mohsenin, 1986; Stroshine and Hamann, 1994). Then the bulk density of each fruit was calculated by dividing the mass by the measured volume.

Pomegranate' picture was taken by Area Measurement System Delta T-England apparatus. Average projected area as a criterion for the sizing machine was proposed Mohsenin (Mohsenin, 1986). Three mutually perpendicular areas, $PA_1$, $PA_2$, $PA_3$, were measured with an area meter. Average projected area (known as criteria area, CPA) was determined from (Mohsenin, 1986):

$$\mathrm{CPA} = \frac{\mathrm{PA_1} + \mathrm{PA_2} + \mathrm{PA_3}}{3} \tag{1}$$

Geometric mean diameter (Dg) and surface area (S) were determined by using following formula, respectively (Mohsenin, 1986):

$$\mathrm{Dg} = (\mathrm{LWT})^{1/3} \tag{2}$$

$$\mathrm{S} = \pi(\mathrm{Dg})^2 \tag{3}$$

Bulk density is determined by dividing the weight of samples by the container volume. True density is prescribed by dividing the weight of samples by the volume that obtained from water displacement method (Stroshine and Hamann, 1994). Seed and aril porosity were calculated from pycnometer method that is the ratio of the volume of air to the total volume of the chamber (Mohsenin, 1986) while fruit porosity was computed from (Eq. 4) as follow:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \tag{4}$$

Other parameters were calculated from equations as follows (Mohsenin, 1986):

$$\Phi = \frac{\mathrm{Dg}}{\mathrm{L}} \times 100 \tag{5}$$

$$\mathrm{Vosp} = \frac{\pi}{6} \times \mathrm{LW}^2 \tag{6}$$

$$\mathrm{Vsp} = \frac{\pi}{6} \times \mathrm{LWT} \tag{7}$$

Where Φ is sphericity, Vsp is volume of ellipsoid and Vosp is volume of the oblate spheroid.

***Frictional properties***

The static coefficient friction against different surfaces includes wood, glass and galvanized iron sheet was determined using a cylinder (Fig 1) of diameter 75 mm and depth 50 mm filled with samples. With the cylinder resting on the surface, the surface raised gradually until the filled cylinder just started to slide down (Ghasemi Varnamkhasti *et al.,* 2008) then coefficient friction computed from (Eq. 8):

$$\mu_s = \tan(\alpha) \tag{8}$$

Whereas α is angle that samples start to slide down.

**Fig 1.** Apparatus for measuring the static coefficient of friction

The filling or static angle of repose is the angle with the horizontal at which samples (seeds or arils) will stand when piled. This was determined using a topless and bottomless cylinder of 0.15 m diameter and 0.25 m height. The cylinder was placed at the centre of a raised circular plate having a diameter of 0.35 m and was filled with pomegranate aril. The cylinder was raised slowly until it formed a cone on a circular plane. The height of the cone was measured and the filling angle of repose ($\theta_f$) was calculated by the following relationship (Ozguven and Kubilay, 2005; Razavi *et al.,* 2007):

$$\tan(\theta_f) = \frac{2H}{D} \quad (9)$$

whereas H and D are the height and diameter of the cone, respectively.

In order to determine the emptying or dynamic angle of repose, a fiberglass box of 0.2 ×0.2 ×0.2 m, having a removable front panel was used. The box was filled with seeds and arils, and then the front panel quickly slid upwards allowing the samples to flow out and assume a natural heap. The emptying angle of repose ($\theta_e$) was obtained from measurements of height of samples at two points ($h_1$ and $h_2$) in the sloping sample heap and the horizontal distance between two points ($x_1$ and $x_2$) using the following equation (Bart-Plange and Baryeh, 2003; Jain and Bal, 1997; Paksoy and Aydin, 2004):

$$\tan(\theta_e) = \frac{h_2 - h_1}{X_2 - X_1} \quad (10)$$

### *Mass modelling*

Spreadsheet software, Microsoft EXCEL and SPSS were used to analyze the data and determine regression models between the parameters of either linear or polynomial form. In order to estimate a pomegranate mass from measured dimensions (length, projected area, and volume), the following two categories of models were suggested.

1- Regression models with linear variable for pomegranate fruit and its arils.

2- Regression models with nonlinear variable for pomegranate fruit and its arils.

## Results and discussion

### *Evaluation of models for fruit and its arils*

In this study, 18 regression models were classified in two categories for pomegranate fruit and also 12 regression models were classified in two categories for its arils.

### *Linear regression models category*

Results of 6 linear models for predicting mass of pomegranate fruit and 4 linear models for its arils based on geometrical attributes were indicated in Table 1. For pomegranate fruit, mass modeling based on dimensional characteristic including length, width and thickness, the best option was based on all of them and the model was as follows:

$$M=-447.46+2.05L+5.14W+1.71T \quad , \quad R^2=0.92$$

Result indicated that the best linear model for predicting mass of fruit was based on the projected areas with this equation:

$$M=-70.84-0.60\,PA_1+3.70PA_2+3.50PA_3 \quad , \quad R^2=0.98$$

The overall mass model of pomegranate based on the one projected area as shown in Fig. 2 was given as linear form in following equation:

$$M=-74.48+6.50\,PA_2 \quad , \quad R^2=0.97$$

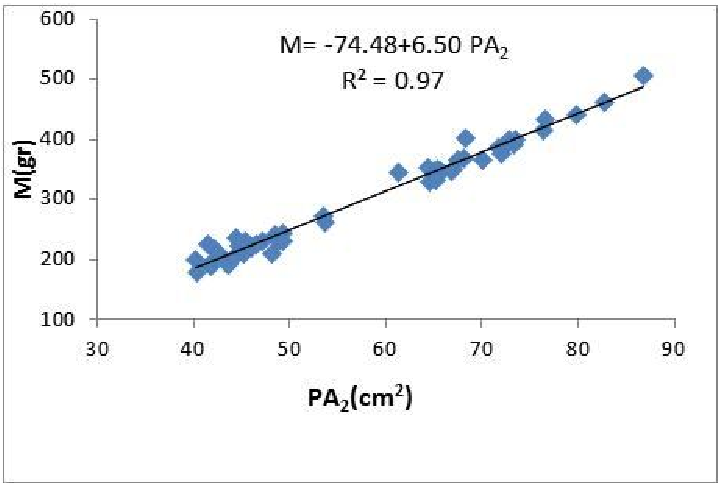


**Fig 2.** Pomegranate mass model based on PA2

In a study was conducted by khanali *et al.* (2007), Recommendation equation for mass modeling of tangerine fruit based on projected area was based on second projected area with following equation: $M=0.64\ (PA_2)1.47$, $R^2 = 0.89$
For mass modeling based on volume of oblate spheroid, following model was recommended: $M=39.87+1.04\ Vosp$ , $R^2=0.94$
In an experiment conducted by Khoshnam *et al.* (2007), the mass model of overall pomegranates based on measured volume was reported:

$M=0.96V + 4.20$ , $R^2=0.99$.

Measuring of actual volume is time consuming task, therefore, mass modeling based on actual volume it is not reasonable; consequently it seems suitable to mass modeling of pomegranate be accomplished and based on volume of assumed oblate spheroid shape.

**Table 1.** Linear models for predicting mass of fruit and aril

| No | Independent | Model | Regression | $R^2$ |
|---|---|---|---|---|
| | L | M=a+bL | M=-342.94+7.23L | 0.72 |
| | W | M=a+bW | M=-418.49+8.63W | 0.82 |
| | T | M=a+bT | M=-362.06+8.24T | 0.86 |
| fruit | L,W | M=a+bL+cW | M=-457.92+2.14L+6.76W | 0.91 |
| | T,W | M=a+bT+cW | M=-413.06+6.35W+2.90T | 0.89 |
| | L,T | M=a+bT+cL | M=-417.20+2.56L+6.10T | 0.89 |
| | L,T,W | M=a+bL+cW+dT | M=-447.46+2.05L+5.14W+1.71T | 0.92 |
| | $L^*$,T,W | M=a+b$L^*$+cW+dT | M=-423.48+1.74$L^*$+5.30W+1.83T | 0.91 |
| | V | M=a+bV | M=5.013+.95V | 0.97 |

| | | | | |
|---|---|---|---|---|
| | Vsp | M=a+bVsp | M=44.59+1.02 Vsp | 0.93 |
| | Vosp | M=a+bVosp | M=39.87+1.04 Vosp | 0.94 |
| | $PA_1$,$PA_2$ ,$PA_3$ | M=a+b$PA_1$+c$PA_2$+d$PA_3$ | M=-70.84-0.60 $PA_1$+3.70$PA_2$ +3.50$PA_3$ | 0.98 |
| | CPA | M=a+b(CPA) | M=-76.61+6.50CPA | 0.97 |
| | $PA_1$ | M= a+b$PA_1$ | M=-76.26+6.30 $PA_1$ | 0.94 |
| | $PA_2$ | M= a+b$PA_2$ | M=-74.48+6.50 $PA_2$ | 0.97 |
| | $PA_3$ | M= a+b$PA_3$ | M=-66.77+6.60 $PA_3$ | 0.97 |
| | L | M=a+bL | M=-0.08+0.04L | 0.63 |
| | W | M=a+bW | M=-0.04+0.05W | 0.53 |
| | T | M=a+bT | M=0.02+0.05T | 0.56 |
| arils | L,W | M=a+bL+cW | M=-0.18+0.03L+0.03W | 0.74 |
| | T,W | M=a+bT+cW | M=-0.10+0.04W+0.03T | 0.63 |
| | L,T | M=a+bT+cL | M=-0.21+0.03L+0.03T | 0.72 |
| | L,T,W | M=a+bL+cW+dT | M=-0.23+0.03L+0.02W+0.2T | 0.77 |
| | V | M=a+bV | M=0.19+1.10V | 0.62 |
| | Vsp | M=a+bVsp | M=0.17+0.58Vsp | 0.78 |
| | Vosp | M=a+bVosp | M=0.19+0.91 Vosp | 0.63 |

Pomegranates arils mass can be estimated on the basis of volume of ellipsoid with linear model as indicated in Fig. 3 that recommended equation as follows: M=0.17+0.58Vsp , $R^2$=0.78

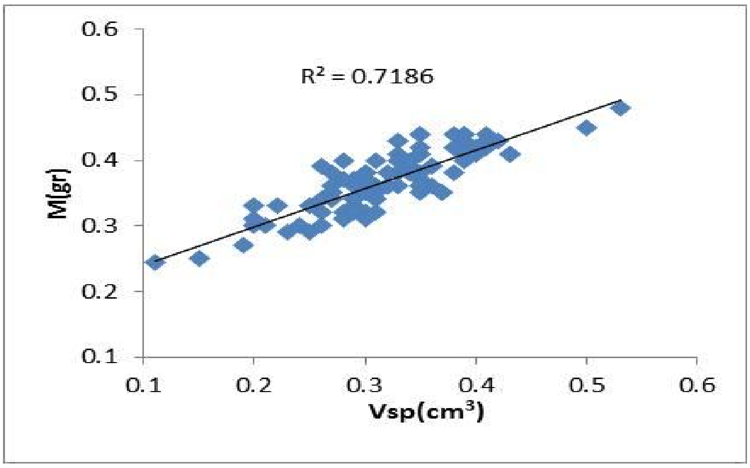


**Fig 3.** arils mass model based on Vsp.

### *Nonlinear regression models category*

For predicating mass of fruit 12 models including Quadratic and exponential models were investigated. For pomegranate fruit, mass modeling based on dimensional characteristic including length, width and thickness, the best attribute was thickness and the best nonlinear model was Quadratic as follows:

$$M= 0.20T^2- 24.24T+ 931.96 \quad , \quad R^2=0.79$$

Whereas, this model can predict the relationships between mass width and mass length with $R^2$ of 0.71 and 0.69, respectively. Results indicated that arils mass can be estimated on the basis of length as best attribute and the best nonlinear model was Quadratic with $R^2$ as: 0.62

$$M= -0.0410^{-1}\times L^2+ 0.149\times L - 0.497 \quad , \quad R^2=0.62$$

Tabatabaeefar *et al.* (2000) reported that among systems that sort oranges based on one dimension, the system that applies intermediate diameter is suited with nonlinear relationship. Lorestani and Tabatabaeefar, (2006) determined models for predicting mass of kiwi fruit based on physical attributes. They recommended an equation to calculate kiwi fruit mass based on intermediate diameter as: $M = 2.93W - 64.15$, $R^2=0.78$.

***Some dimensional and frictional attributes of pomegranate fruit***

The physical properties such as major, minor, and intermediate diameter, mass, volume, bulk density, true density, geometric mean, porosity, sphericity, and rolling frictional properties fruit were given in Table 2. The maximum, minimum and mean values of each property with its standard deviation were determined. Length of fruit was measured in two states. In the first state calyx over the fruit was considered and in the second was not considered. Length in first state was changed from 70.33 to 110.01 mm with mean value 88.12 mm and for second state from 60.03 to 95.55 mm with mean value 76.95 mm. Other dimensional properties such as width, thickness, mass, mean geometric diameter, volume, criteria project area, surface, sphericity and porosity showed the mean values of 82.61 mm, 79.64 mm, 194.25 g, 83.33 mm, 303.23 $cm^3$, 57.90 $cm^2$, 219.90 $cm^2$, 94 percent and 29.40 percent, respectively.

In a study conducted by Janatizadeh *et al.* (2008) stated that sphericity values of Iranian apricot was differed significantly among the tested cultivars and mean values were 0.971, 0.917, 0.973, 0.925, 0.923, and 0.875 for Shams, Nakhjavan, Djahangiri, Sefide damavand, Shahroud-8, and Gheysi-2 cultivars, respectively. Kheiralipour *et al.* (2003) also reported length, width, and thickness of apple fruit (cv. Redspar) as 57.13, 66.98, and 62.60 mm, respectively.

Among the frictional properties, coefficient of friction on glass surface gave the highest values with 0.82 and wood surface had lowest valve with 0.45. Sessiz *et al.* (2007) reported that the static and dynamic coefficients of friction on four different surfaces, namely, galvanized steel, plywood, rubber, and metal steel for caper fruit. On the all of mentioned surfaces, they were obtained value of the static coefficient of friction more than dynamic coefficient of friction (Sessiz *et al.,* 2007).

**Table 2.** Some physical attributes of pomegranate fruit

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| L(mm) | 70.33 | 110.01 | 88.12 | 8.19 |
| W(mm) | 67.17 | 97.36 | 82.61 | 7.61 |
| T(mm) | 64.97 | 96.12 | 79.64 | 7.84 |
| $L^*$(mm) | 60.03 | 95.55 | 76.95 | 7.95 |
| M(gr) | 180.03 | 506.80 | 294.25 | 69.65 |
| V($cm^3$) | 189.50 | 527.92 | 303.23 | 72.35 |
| $PA_1$($cm^2$) | 41.93 | 86.81 | 59.83 | 13.28 |
| $PA_2$($cm^2$) | 40.20 | 86.23 | 57.97 | 13.16 |
| $PA_3$($cm^2$) | 38.68 | 81.49 | 55.90 | 12.95 |
| Dg(mm) | 69.30 | 100.65 | 83.33 | 7.53 |
| S($cm^2$) | 150.81 | 318.09 | 219.90 | 39.50 |
| Vosp($cm^3$) | 176.15 | 539.20 | 321.73 | 84.87 |
| Vsp($cm^3$) | 174.19 | 533.59 | 310.38 | 83.44 |
| CPA($cm^2$) | 40.82 | 85.04 | 57.90 | 13.06 |
| Sph | 0.84 | 0.98 | 0.94 | 0.03 |
| $P_b$($kg/m^3$) | 612.43 | 765.12 | 686.78 | 40.34 |
| $P_t$($kg/m^3$) | 893.03 | 1131.57 | 971.26 | 75.32 |
| ε | 27.86 | 32.24 | 29.40 | 2.08 |
| Coef.of static friction | | | | |
| wood | 0.45 | 0.49 | 0.45 | 0.01 |
| Galvanized Iron | 0.75 | 0.73 | 0.74 | 0.01 |
| glass | 0.84 | 0.78 | 0.82 | 0.02 |

***Some dimensional and frictional attributes of pomegranate arils***

Selected properties of pomegranate arils, the maximum, minimum and mean values of each property with its standard deviation were reported in Table 3. These properties were found at specific fruit moisture content 78.70% wb. About arils thousand weights gave more importance respect to weight of each arils, thousand weights and weight of each arils gave mean values of 0.36 g and 391.00 g respectively. The bulk density, true density, porosity were changed as 673.05-681.12 $kg/m^3$, 1083.88-1096.81 $kg/m^3$ and 36.14-38.24, respectively.

**Table 3.** Selected physical properties of aril (78.70% wb).

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| L(mm) | 7.04 | 12.31 | 10.56 | 0.86 |
| W(mm) | 5.78 | 10.53 | 8.32 | 0.73 |
| T(mm) | 5.01 | 9.03 | 6.85 | 0.66 |
| Dg(mm) | 6.16 | 9.92 | 8.34 | 0.63 |
| M(gr) | 0.16 | 0.50 | 0.36 | 0.05 |
| V($cm^3$) | 0.12 | 0.51 | 0.30 | 0.07 |
| Vsp($cm^3$) | 0.11 | 0.53 | 0.32 | 0.07 |
| Vosp($cm^3$) | 0.12 | 0.66 | 0.39 | 0.09 |
| S($cm^2$) | 0.12 | 0.31 | 0.22 | 0.03 |
| Sph | 0.49 | 0.95 | 0.79 | 0.50 |
| $P_b$($kg/m^3$) | 673.05 | 681.12 | 678.87 | 3.21 |
| $P_t$($kg/m^3$) | 1083.88 | 1096.81 | 1088.93 | 3.14 |
| ε | 36.14 | 38.24 | 37.66 | 1.27 |
| $W_{1000}$(gr) | 368.40 | 398.50 | 391.00 | 8.51 |
| Coef.of static friction | | | | |
| wood | 0.53 | 0.54 | 0.53 | 0.01 |
| Galvanized Iron | 0.49 | 0.51 | 0.50 | 0.01 |
| glass | 0.29 | 0.32 | 0.31 | 0.01 |
| filling repose angle (degree) | 44 | 54 | 44.63 | 1.02 |
| emptying repose angle (degree) | 32.36 | 34.79 | 33.67 | 2.11 |

The range of friction coefficient on wood, galvanized iron and glass surface were 0.53-0.54, 0.49-0.51 and 0.29-0.32 respectively. Aydin (2003) investigated some physical properties of almond nut and kernel as functions of moisture content. The average length, width, thickness, the geometric mean diameter, unit mass and volume of nuts were 25.49, 17.03, 13.12, 18.13 mm, 2.64 g and 2.61 $cm^3$ respectively. Corresponding values for kernel were 21.19, 14.34, 6.38, 11.42 mm, 0.69 g and 0.71 $cm^3$ respectively.

***Some dimensional and frictional attributes of pomegranate seeds***

Physical properties pomegranate seeds were measured in moisture content 12% wb. The selected dimensional and frictional attributes of pomegranate seeds such as length, width, thousand weights, bulk density and true density that minimum, maximum and mean values of these attributes were reported as 5.54-8.09 mm, 6.97 mm, 1.05-3.81 mm, 2.77 mm, 28.90-29.70 g, 29.42 g, 512.16-531.48 $kg/m^3$, 519.46 $kg/m^3$, 823.00-870.67 $kg/m^3$,846.13 $kg/m^3$ (Table 4).

**Table 4.** Selected physical properties of seeds (12%wb).

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| L(mm) | 5.54 | 8.09 | 6.97 | 0.50 |
| W(mm) | 1.05 | 3.81 | 2.77 | 0.48 |
| M(g) | 0.01 | 0.06 | 0.03 | 0.01 |
| V($mm^3$) | 35.00 | 51.00 | 39.33 | 6.21 |
| S($mm^2$) | 35.28 | 76.31 | 55.12 | 9.43 |
| $P_b$($kg/m^3$) | 512.16 | 531.48 | 519.46 | 8.47 |
| $P_t$($kg/m^3$) | 823.00 | 870.67 | 846.13 | 13.65 |
| $W_{1000}$(12% wb) | 28.90 | 29.70 | 29.42 | 0.16 |
| $W_{1000}$(39% wb) | 35.70 | 45.00 | 37.87 | 3.21 |
| ε | 36.16 | 41.20 | 38.60 | 1.42 |
| Coef.of static friction | | | | |
| wood | 0.55 | 0.60 | 0.58 | 0.01 |
| Galvanized Iron | 0.46 | 0.51 | 0.49 | 0.01 |
| glass | 0.29 | 0.31 | 0.30 | 0.01 |
| filling repose angle (degree) | 33 | 37.5 | 35.5 | 1.14 |
| emptying repose angle (degree) | 29.19 | 29.86 | 29.51 | 0.18 |

Filling repose angle and emptying repose angle for pomegranate seeds gave the mean values of 35.5° and 29.51°, respectively. As seen in filling repose angle that was greater than emptying repose angle for pomegranate seeds. With this, Dursan and Dursan (2005) reported bulk density, true density and porosity decreased from 438 to 399 kg /$m^3$, 806 to 678 kg/$m^3$ and 45.7 to 41.1%, respectively and thousand seed mass increased from 6.60 to 7.75 g when moisture content of caper seed increased from 6.03 to 16.35% d.b. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of material through the chute. In addition, it is important to design the conveyors because friction is necessary to hold the nuts and kernels to the conveying surface without slipping or sliding backward. If the handling of the crop is needed, the rougher surface like rubber must be used, and on the other hand, if it is necessary to discharge the product, the smoother surface like fiberglass might be useful as stated by Ravazi *et al.,* (2007).

***Weight ratio edible part of sample respect to non edible***

Maximum, minimum and mean value of weight ratio edible parts of fruit respect to non-edible parts were reported in Table 5. The weight ratio of arils respect to fruit and peels respect to fruit were changed from 0.39 to 0.82 and from 0.17 to 0.61 with mean values of 0.73 and 0.25, respectively.

**Table 5.** Weight ratio of edible and non-edible parts of samples.

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Fruit(g) | 155.87 | 345.51 | 251.51 | 41.73 |
| Arils of each fruit (g) | 92.04 | 265.00 | 184.88 | 34.38 |
| Peels of each fruit (g) | 26.33 | 143.94 | 64.74 | 18.63 |
| Arils respect to fruit | 0.39 | 0.82 | 0.73 | 0.06 |
| Peels respect to fruit | 0.17 | 0.61 | 0.25 | 0.06 |
| Fruit respect to arils | 1.21 | 2.57 | 1.37 | 0.19 |
| Fruit respect to peels | 1.64 | 5.92 | 4.05 | 0.75 |

## Conclusion

Some physical properties and their relationships of mass of pomegranate fruits and its arils are presented in this study. From this study, it can be concluded that the recommended equation to calculate pomegranate fruit mass based on physical attributes was as linear form: $M= -74.48+6.50\ PA_2$, $R^2=0.97$. The recommended equation to calculate pomegranate aril mass based on physical attributes was as linear form: $M=0.17+Vsp$, $R^2=0.78$. The nonlinear models including quadratic and exponential were not suitable for mass modeling based on physical characteristic of these pomegranate fruit, but linear models were more suitable. Highest coefficient of friction was on glass surface and lowest value was on wood surface for pomegranate fruit. Results indicated that filling repose angle had value greater than emptying repose angle for pomegranate seed and aril. Highest coefficient of friction was on wood surface and lowest value was on glass surface for pomegranate aril and seed.

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