Development of 11 Mass Models for Iranian Apricot fruits based on some physical attributes (cv. Shahroud-8 and Gheysi-2)

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Among physical characteristics, dimensions, mass, volume and projected areas are important parameters in sizing and grading machines. Fruits with the similar weight and uniform shape are desirable in terms of marketing value. This research was conducted on 150 observations of two Iranian cultivars (Shahroud-8 and Gheysi-2) of apricot fruits. Apricot mass was predicted by applying different physical characteristics with linear and nonlinear models. Results showed that mass modeling of apricot based on intermediate diameter and three projected areas gave the most appropriate models in the first and second classifications, respectively. In third classification, the highest determination coefficient was obtained for mass modeling based on the actual volume as $R^2 = 0.94$ whereas corresponding values were 0.85 and 0.90, respectively for assumed apricot shapes (oblate spheroid and ellipsoid). In economical and agronomical point of view, suitable grading system of apricot mass was based on intermediate diameter as nonlinear relation: $M = 2.147 b - 51.95, R^2 = 0.83$.

Key words: Apricot, Mass modelling, Physical characteristics, Iranian cultivars, Grading

Introduction

Apricot (*Prunus armeniaca* L.) is classified under the *Prunus* species of *Prunodae* sub-family of the *Rosaceae* family of the Rosales group. Apricot has an important place in human nutrition, and can be used as fresh, dried or processed fruit. As known, the fruit of apricot is not only consumed fresh but also used to produce dried apricot, frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products etc. Moreover, apricot kernels are used in the production of oils, benzaldehyde, cosmetics, active carbon, and aroma perfume (Yildiz, 1994). Apricot has an important place in terms of human health.

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Apricot is rich in minerals such as potassium and vitamins such as β-carotene. β-carotene, which is the pioneer substance of mineral A, is necessary for ephithelia tissues covering our bodies and organs, eye-health, bone and teeth development and working of endocrine glades (Haciseferogullari *et al*., 2006). Apricot trees can grow over the five continents of the world and production level exceeds 2 millions tons. Australia, France, Hungary, Iran, Italy, Morocco, Spain, Tunisia, Turkey can be regarded as important apricot producer countries. While some of countries such as Hungary, Morocco, Iran and Tunisia are important fresh apricot exporters, the others such as Australia and Turkey are major and famous dried apricot producers and exporters. Dried apricots which are in extensive demand in several parts of the world, i.e., USA, UK, Germany, Australia, etc., occupy an important place in the world trade (Hacisefrogullari *et al*., 2006).

In 2005, Turkey and Iran which cultivated area covered 20,000 hectares and averaged annual production of 275,580 tones were the largest producers of apricot in the world (USDA, 2004). However, in comparison to this production the export of apricot is very small in Iran. Physical characteristics of agricultural products are the most important parameters in design of grading, conveying, processing and packaging systems (Khoshnam *et al*., 2007). Among these physical characteristics, mass, volume, projected areas and center of gravity are the most important ones in sizing systems (Malcolm *et al*., 1986; Safwat, 1971). Other important parameters are width, length, and thickness (Mohsenin, 1968). There are some situations in which it is desirable to determine relationships among physical characteristics, for example fruits are often graded by size but it may be more economical to develop a machine which grades by weight. Therefore, the relationship between weight and the major minor and intermediate diameters are needed (Stroshine and Hamann, 1995; Khoshnam *et al*., 2007). Determining relationships between mass and dimensions and projected areas may be useful and applicable (Stroshine and Hamann, 1995; Marvin *et al*., 1987). In weight sizer machines, individual fruits are carried by cups or trays that may be linked together in a conveyor and are individually supported by spring-loaded mechanism. As the cups travel along the conveyor, the supports are engaged by triggering mechanisms which allow the tray to dump if there is sufficient weight. Successive triggering mechanisms are set to dump the tray at lower weight. If the density of the fruit is constant, the weight sizer sorts by volume. The sizing error will depend upon the correlation between weight and volume (Stroshine and Hamann, 1995; Khoshnam *et al*., 2007). Many studies have reported on the physical properties of fruits, such as wild plum (Calisir *et al*., 2005), cornelian cherry (Demir and Kalyoncu, 2003; Guleryuz *et al*., 1998), rose fruit (Demir and Ozcan, 2001), fresh okra fruit (Owalarafe and Shotonde, 2004), cherry laurel (Calisir and Aydin, 2004; Islam, 2002), orange (Topuz *et al*., 2005), berries (Khazaei and Mann, 2004), Juniperus drupacea fruit (Akinci *et al*., 2004).

In the case of mass modeling, Tabatabaeefar *et al*. (2000) determined models for predicting mass of Iranian grown orange for its volumes, dimensions, and projected areas. They reported that among the systems that stored oranges based on one dimension, the system that applies intermediate diameter is suitable with nonlinear relationship. Khoshnam *et al*. (2007) and Lorestani and Tabatabaeetar (2006) used this method for predicting the mass of pomegranate and kiwi fruits respectively.

No detailed studies concerning mass modeling of apricot have been performed up to now. The objective of this study was to determine the most suitable model for predicting apricot fruit mass by its geometrical attributes. This information can be used in the design and development of sizing mechanisms.

Materials and Methods

The Iranian apricot fruits used in this study, consisted of Shahroud-8 and Gheysi-2 cultivars which were obtained from agricultural research center of Shahroud-Iran (Longitude: 36^{o} 28'E and Latitude: 54^{o} 58'N). The number of fruits obtained from the aforementioned cultivars was 75 for each cultivar. The samples of the 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 content weight was recorded as moisture content. The mass of each apricot (M) was measured using a digital balance with accuracy 0.01 g. For each apricot fruit, three linear dimensions were measured, that are a major, (longest intercept), b intermediate (longest intercept normal to a) and c minor, (longest intercept normal to a, b). In addition, cross sectional areas (CSAs) in three perpendicular directions of the fruit, using area measurement system Delta-T England were determined (Fig. 1). Dimensional characteristics obtained from this device are based on image processing.

Captured images from a camera are transmitted to a computer card which works as an analog to digital converter. Digital images are then processed in the software and the desired user needs are determined. Through three normal images of the apricot fruit, this device is capable of determining the minor, intermediate and major 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 (Rafiee *et al*., 2006; Mirashe, 2006; Keramate Jahromi *et al*., 2007; Khoshnam *et al*., 2007). The average projected areas which known as criteria projected areas, geometric mean diameter and sphericity were calculated as suggested by Mohsenin (1986):-

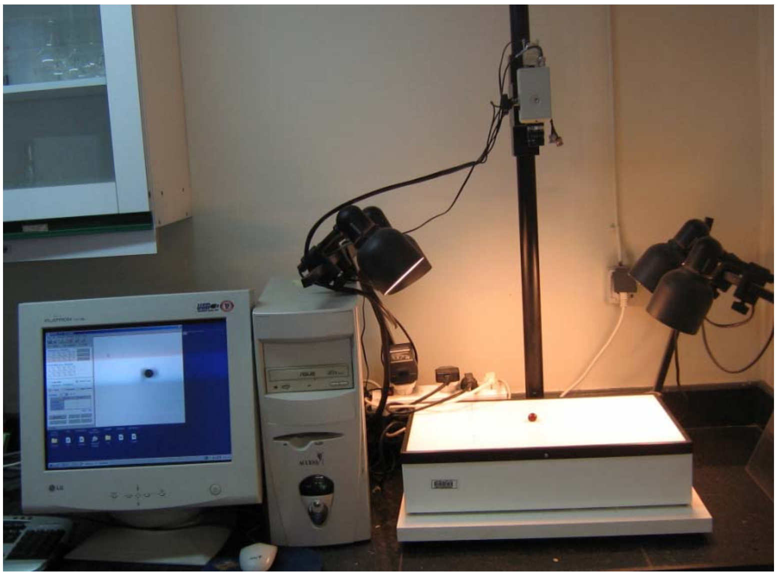

Fig. 1. Apparatus for measuring dimensional characteristics, area meter Delta T England

$$\text{Criteria projected areas} = CPA = \frac{PA_1 + PA_2 + PA_3}{3} \quad (1)$$

$$\text{Geometric mean diameter} = D_g = (abc)^{1/3} \quad (2)$$

$$\text{Sphericity} = \Phi = D_g / a \quad (3)$$

Fruit actual volume and true density was determined by the water displacement technique (Dutta *et al*., 1988). Randomly selected apricot fruits were weighed on a digital balance with 0.01 g accuracy. The fruits were lower with a metal sponge sinker into a measuring cylinder containing water, such that the fruits did not float during immersion in water, weight of water displaced by the fruit was recorded.

The volume and in aftermath fruit density were calculated by following equations (Mohsenin, 1986).

$$V_w = \frac{W}{\rho_w} \quad (4)$$

$$\rho_t = \frac{m}{V_w} \quad (5)$$

where W and ρ_w were considered as weight of displaced water and weight density of water, respectively. The bulk density was determined using the mass and volume relationship (Fraser *et al.*, 1978) by filling an empty plastic container of predetermined volume and weight. The fruits were left to fall from a constant height, striking off the top level and weight. The fruit bulk density value is the ratio of mass to volume of the container.

Spreadsheet software, Microsoft Excel 2003 and SPSS 0.9 Software (1999) were used to analyze the data and to determine regression models between the parameters of either linear or nonlinear form. In order to estimate an apricot fruit's mass from measured dimensions, projected areas and volume, the following three categories of models were suggested as follows:-

1. Regression models of mass with major (a), intermediate (b), minor (c) and all three diameters were applied. A total of four models were determined. A model with the highest coefficient of determination, R^2, and the least R.S.E. was selected.

2. Regression models of mass with each projected area (PA_1, PA_2 and PA_3) and all three projected areas were determined. A total of four models were determined. A model with the highest coefficient of determination, R^2, and the least R.S.E. was presented.

3. Regression models of mass with apricot fruit volumes that are actual volumes, volume of the fruit assumed as oblate spheroid and ellipsoid shapes.

In the case of first classification, mass modeling was accomplished with respect to major, intermediate and minor diameters. Model obtained with three variables for predicting of apricot mass is as follows:-

$$M = k_1a + k_2b + k_3c + k_4 \quad (6)$$

In this classification, the mass can be estimated as a function of one, two and three dimensions. In second classification models, mass of apricot was estimated based on mutually perpendicular projected areas as following:

$$M = k_1PA_1 + k_2PA_2 + k_3PA_3 + k_4 \quad (7)$$

In this classification, the mass can be estimated as a function of one, two or three projected area(s). In the case of third classification, to achieve the models which can predict the apricot mass on the basis of volume, three volume values were measured and calculated. At first, actual volume V_m as stated earlier was measured then the apricot shape was assumed as a regularly geometrical shape, i.e. oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes and, thus, their volumes were calculated as:

$$V_{osp} = \frac{4}{3}\pi\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)^2 \qquad V_{ellip} = \frac{4}{3}\pi\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)\left(\frac{c}{2}\right) \tag{8,9}$$

In this classification, the mass can be estimated as either a function of volume of supposed shapes or the measured actual volume as represented in following expressions:

$$M = k_1 V_{osp} + k_2 \tag{10}$$
$$M = k_1 V_{ellip} + k_2 \tag{11}$$
$$M = k_3 V_m + k_2 \tag{12}$$

Results and discussion

A summery of some selected physical characteristics of the two Iranian cultivars of apricot and linear regression models based on the selected independent variables as seen in Table 1 and 2, respectively.

First classification models and dimensions

Among the first classification models Nos. 1,2,3 and 4, a model number 4 had the highest R^2 and the lowest R.S.E., while for this model measurement of three diameters is needed, which made the sizing mechanism more tedious and expensive. Among the models Nos. 1,2,3, model number 2 for Shahroud-8 cultivar, model number 3 for Gheysi-2 cultivar and model number 2 for total of observation had the higher R^2 than the other models. Therefore, model number 2 based on the intermediate diameter (b) is recommended (Table 2). Thus, model number 2 that among the one dimensional-model was selected as the best apricot mass model with intermediate diameter as shown in Fig. 2. Eleven models for predicting mass of apples based on geometrical attributes were recommended by Tabatabaeefar and Rajabipour (2005). They recommended an equation calculating apple mass based on minor diameter as $M = 0.08c^2 - 4.74c + 5.14$, $R^2 = 0.89$. In another study, Lorestani and Tabatabaeefar (2006) determined models for predicting mass of kiwi which based on physical attributes. They recommended an equation to calculate kiwi fruit mass based on intermediate diameter as $M = 293b - 64.15, R^2 = 0.78$. Khoshnam *et al.*

(2007) recommended an equation based on minor diameter for predicting the mass of pomegranate as $M = 7.320c - 376.1, R^2 = 0.91$.

Table 1. Some physical characteristics of apricot fruit.

Characteristics	cultivars	
	Shahroud-8 (87.5%d.b.m.c.)	**Gheysi-2 (82.13% d.b.m.c.)**
Major diameter (mm)	46.63 ± 2.77	46.51 ± 1.95
Intermediate diameter(mm)	43.95 ± 2.57	39.93 ± 2.03
Minor diameter (mm)	38.93 ± 1.83	36.36 ± 2.29
Geometric mean diameter (mm)	43.04 ± 2.20	40.71 ± 1.85
Fruit mass(g)	42.97 ± 2.31	33.29 ± 1.55
Fruit volume(cm^3)	43.31 ± 2.4	36.04 ± 2.54
Sphericity	0.923 ± 0.001	0.875 ± 0.002
PA_1 (mm^2)	1353.36 ± 94.71	1192.46 ± 121.33
PA_2 (mm^2)	1489.79 ± 133.58	1384.83 ± 122.99
PA_3 (mm^2)	1668.18 ± 135.65	1523.86 ± 125.05
Criteria projected area (mm^2)	1503.78 ± 132.2	1367.05 ± 128.58
Bulk density (kg/m^3)	431.57 ± 12.35	455.27 ± 0.004
Fruit density (kg/m^3)	992.7 ± 28.83	924.1 ± 13.07

Table 2. Apricot mass models based on selected independent variables.

No.	Models	Parameter	Shahroud-8	Gheysi-2	Total of observations
		R^2	0.764	0.66	0.419
1	$\boldsymbol{M} = k_1a + k_2$	R.S.E.	3.114	2.51	5.54
		R^2	0.84	0.51	0.83
2	$\boldsymbol{M} = k_1b + k_2$	R.S.E.	2.58	3.03	2.99
		R^2	0.764	0.88	0.81
3	$\boldsymbol{M} = k_1c + k_2$	R.S.E.	3.115	1.5	3.2
		R^2	0.92	0.95	0.91
4	$\boldsymbol{M} = k_1a+k_2b+k_3c+k_4$	R.S.E.	1.91	1.04	2.2
		R^2	0.91	0.94	0.90
5	$\boldsymbol{M} = k_1PA_1 + k_2$	R.S.E.	1.93	1.05	2.25
		R^2	0.92	0.95	0.80
6	$\boldsymbol{M} = k_1PA_2 + k_2$	R.S.E.	1.79	0.97	3.26
		R^2	0.92	0.90	0.85
7	$\boldsymbol{M} = k_1PA_3 + k_3$	R.S.E.	1.8	1.36	2.86
		R^2	0.944	0.97	0.92
8	$\boldsymbol{M} = k_1PA_1+k_2PA_2+k_3PA_3+k_4$	R.S.E.	1.56	0.72	2.1
		R^2	0.95	0.97	0.94
9	$\boldsymbol{M} = k_1V + k_2$	R.S.E.	1.4	0.73	1.74
		R^2	0.88	0.64	0.85
10	$\boldsymbol{M} = k_1V_{osp} + k_2$	R.S.E.	2.2	2.6	2.82
		R^2	0.91	0.90	0.90
11	$\boldsymbol{M} = k_1V_{ellip} + k_2$	R.S.E.	1.93	1.31	2.36

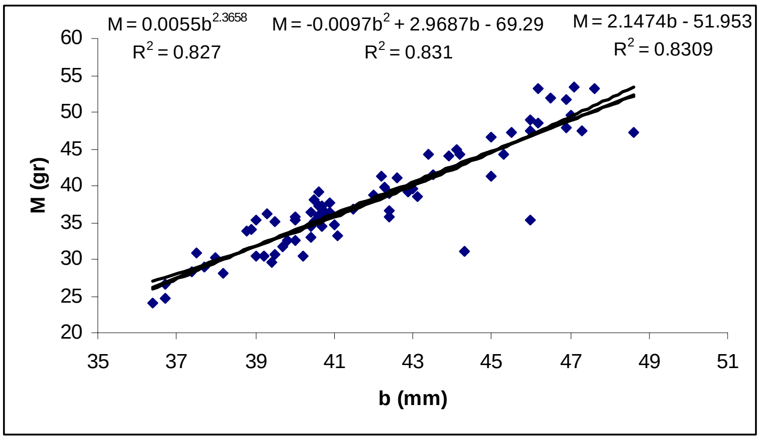

Fig. 2. Apricot mass model based on intermediate diameter.

The mass model of apricot for all the cultivars based on the model 4 of all three diameters is given in Eq. (13).

$$M = 0.346a + 1.184b + 1.25c - 74.71,\ R^2 = 0.91, R.S.E. = 2.2 \qquad (13)$$

For all the cultivars, the best equation to calculate mass of apricot based on the intermediate diameter was given in non-linear form of Eq. (14).

$$M = -0.0097b^2 + 2.96b - 69.3, R^2 = 0.831, R.S.E. = 3 \qquad (14)$$

Second classification model and projected areas

Among the second classification models Nos. 5,6,7 and 8 showed that the model 8 for all the cultivars had maximum R^2 value and minimum R.S.E. (Table 2). The overall mass model based on three projected areas of model 8 for total of observations was given in Eq. (15) as:

$$M = 0.0412PA_1 - 0.0152PA_2 + 0.01558PA_3 - 17.361 \qquad (15)$$
$$R^2 = 0.918, R.S.E. = 2.11$$

Among the models Nos. 5, 6 and 7 that based on the one projected area, the model 5 (based on PA_1) for all the cultivars had the highest R^2 and the lowest R.S.E. as shown in Fig. 3. The power model for apricot mass modeling based on the one projected area was given in Eq. (16) (Fig. 3).

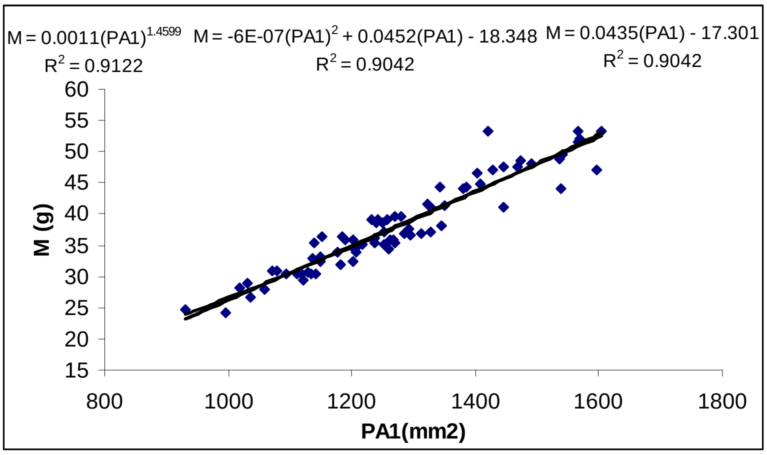

Fig. 3. Apricot mass model based on one projected area.

$$M = 0.0011(PA_1)^{1.46}, R^2 = 0.91 \quad (16)$$

The mass model recommended for sizing kiwi fruits based on the one projected area was reported by Lorestani and Tabatabaeefar (2006) as: $M = 1.098(PC)^{1.273}, R^2 = 0.97$ and by Khoshnam *et al*. (2007) for pomegranate as: $M = 1.29(PA_1)^{1.28}, R^2 = 096$ where PC is third projected area. Each one of the three projected areas can be used to estimate the mass. There is a need to have three cameras, in order to take all the projected areas and have one R^2 value close to unit or even lower than R^2 for just one projected area. Therefore, a model using only one projected area can possible be use model 5.

Third classification models and volume

Among the models in third classification of models 9, 10, 11, the R^2 for total of observations of model 9 showed maximum value and minimum R.S.E. Among the models 10 and 11, the model 11 for the all cultivars gave the highest R^2 value and the lowest R.S.E. Therefore, model 11 was recommended for predicting apricot mass. The mass model of overall apricots based on measured volume which was given as linear form of Eq. (17).

$$M = 1.033V_m - 2.88, R^2 = 0.94, R.S.E. = 1.74 \quad (17)$$

Tabatabaeefar (2002) determined physical properties of common varieties of Iranian grown potatoes. Relationships among physical attributes were determined. A high correlation was found between mass and volume of mixed potatoes with a high coefficient of determination as: $M = 0.93V_m - 0.6, R^2 = 0.994$.

Khoshnam *et al*. (2007) recommended $M = 0.96V_m + 4.25, R^2 = 0.99$ for predicting the mass of pomegranate by measured volume. Measuring of actual volume is time consuming task. Therefore, mass modeling based on it. It seems suitable to mass modeling of apricot be accomplished based on volume of assumed ellipsoid shape as shown in Fig. 4. The best mass model based on the volume of assumed ellipsoid is: $M = 0.0005(V_{ellip})^{1.068}, R^2 = 0.90$.

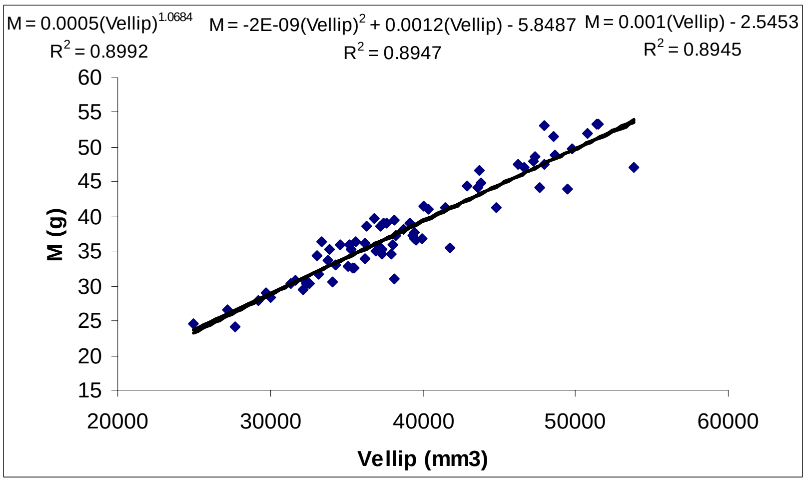

Fig. 4. Apricot mass models based on volume of assumed ellipsoid.

Conclusions

The recommended equation to calculate apricot mass based on intermediate diameter (model 2 was the best) was as nonlinear form: $M = -0.0097b^2 + 2.96b - 69.3, R^2 = 0.831, R.S.E. = 3$. The mass model recommended for sizing apricots based on one projected area (model 5 is suitable) was an nonlinear form: $M = 0.0011(PA_1)^{1.46}, R^2 = 0.91$. There was a very good relationship between mass and measured volume of apricots for all cultivars with R^2 as 0.94 (highest R^2 value among all the models). The model which predicts mass of apricot based on estimated volume, the shape of apricot considered as ellipsoid volume was found to be the most appropriate which model 11 is recommended. Finally, mass model No 2 from economical standpoint is recommended.

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