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Mass modeling of two varieties of apricot *(prunus armenaica L.)* with some physical characteristics

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Abstract

In this study the mass of tow Iranian apricot varieties were predicted with using different physical characteristics in four models includes: Linear, Quadratic, S-curve, and Exponential. According to the results, the best and the worst models for prediction the mass of *Ghavami* cultivar were based on volume and length of the fruit with determination coefficients of 0.80 and 0.61, respectively. Also these results for *Rajabali* cultivar were based on criteria projected area and length of the fruit with determination coefficients of 0.97 and 0.63, respectively. Also observed that Exponential model was not suitable at all.

Key words: *Mass, apricot, physical characteristics, cultivar, fruit.*

Abbreviations: M- fruit mass, g; V-fruit Volume, cm^3; D_g- geometric mean diameter, mm; S-surface area,mm^2; L- length of fruits, mm; W-width of fruit, mm; T- thickness of fruit, mm; PA_1 - first projected area,mm^2; PA_2-second projected area,mm^2; PA_3- third projected area,mm^2; CPA-criteria projected area,mm^2; $b_{0,}b_1,b_2$-curve fitting parameters; T-independent parameter

Introduction

Apricot (*prunus armeniaca L.*) is classified under the *prunus* species of *prunoidae* sub –family of the *Rosaceae* family of the *Rosales* group. Apricot plays an important role in human nutrition, and can be used as a fresh, dried or processed fruit such as frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products etc. (Yildiz, 1994). Australia, France, Hungary, Iran, Italy, Morocco, Spain, Tunisia and Turkey are among the most important apricot producer countries. Turkey and Iran (having cultivated area with 20000 hectares and with average annual production of 275580 ton) were the largest producers of apricot in the world (USDA, 2004). Agricultural crops and food products have several unique characteristics which set them different from engineering materials. These properties determine the quality of the fruit and identification of correlation among in these properties makes quality control easier (Jannatizadeh et al., 2008). To design and optimization a machine for handling, cleaning, conveying, and storing, the physical attributes and

Table 1. Some physical properties of two Iranian apricot fruits.

properties	varieties		Significant level
	Ghavami	*Rajabali*	
L(mm)	41.21 ± 1.87	48.51 ± 3.72	**
W(mm)	34.11 ± 1.99	43.32 ± 3.12	**
T(mm)	31.65 ± 1.63	40.84 ± 2.72	**
M(g)	27.71 ± 3.19	53.69 ± 8.96	**
V(cm^3)	26.20 ± 3.24	45.60 ± 9.49	**
Dg(mm)	35.42 ± 1.52	44.09 ± 2.82	**
S(mm^2)	3884.62 ± 338.70	6109.42 ± 774.57	**
PA_1 (mm^2)	1206.77 ± 83.04	1868.23 ± 193.69	**
PA_2 (mm^2)	1144.70 ± 84.43	1797.11 ± 181.10	**
PA_3 (mm^2)	915.13 ± 82.49	1555.69 ± 159.20	**
CPA(mm^2)	1088.86 ± 79.97	1740.34 ± 174.24	**

** Significant (1% level)

their relationships must be known. As an instance, grading of fruits by their size can be replaced with grading by their weight because it may be more economical. Grading fruit based on weight is important in packing and handling. In nearly all cases raw product grades are based on weight (O'Brian and Floyd, 1978). Size and shape determine how many fruit can be placed in containers of a given size. Volume and surface area could be beneficial in proper prediction drying rates and hence drying time in the dryer. on the other hand, volume and is relationship with packing coefficient are very important because having any information about Packing coefficient of fruits could result in efficient control of fruit quality during storage. Physical characteristics of agricultural products are the most important parameters to determine the proper standards of design of grading, conveying, processing and packaging systems (Tabatabaeefar and Rajabipour, 2005).

Among these physical characteristics, mass, volume, projected area are the most important ones in determining sizing systems (Peleg and Ramraz, 1975; Khodabandehloo, 1999).Many researches have been conducted to find physical properties of various types of agricultural products. Tabatabaeefar *et al*. (2000) in a study found 11 models for the prediction of orange mass based upon dimensions, volume and surface areas. The regression analysis was used by Chuma et al. (1982) to develop equations for predicting volume and surface area. Determining relationships between mass and dimensions and projected areas may be useful and applicable (Stroshine, 1998; Marvin, et al., 1987). Tabatabaeefar and Rajabipour (2005) predicted apple mass through models that were based upon apple physical properties. Al-Maiman and Ahmad (2002) studied the physical properties of pomegranate and found models of predicting fruit mass while employing dimensions, volume and surface areas. Keramat Jahromi et al. (2007) investigated some physical properties of date (cv. Lasht). They determined dimensions and projected areas by using image processing technique. Mass grading of fruit can reduce packaging and transportation costs, and also may provide an optimum packaging configuration (Peleg, 1985). Most of the apricot fruit processing methods are still traditional. Hence, it is necessary to make a comprehensive study of the physical properties and their relationships of apricot fruit to develop appropriate technologies for its processing.

The main aim of this research is to determine the best models for mass of apricot based on apricot physical properties. This information could be used to design and to optimize sizing mechanism.

Material and Methods

The Iranian apricot cultivars consisted of *Ghavami* and *Rajabali* were obtained from orchard located in shahroud, Iran (170 km far from Semnan Province) in July 2008.

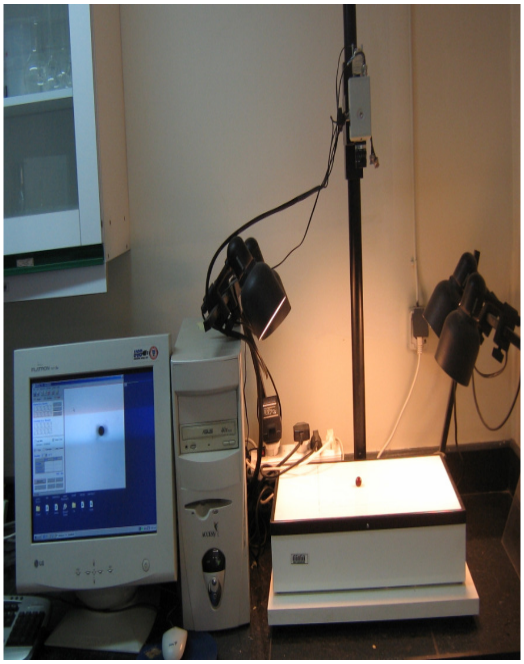

Fig 1. Apparatus for measuring projected area. Fruit is positioned in the center of horizontal plate, directionally, under the vision of camera**.**

The 100 fruits of each variety were tested in the Biophysical laboratory and Biological laboratory of University of Tehran, Karaj, Iran. The samples of the fruits were weighted and dried in an oven at a temperature of 78 ° c for 48 h and then weight loss on drying to final content weight was recorded as moisture content (AOAC, 1984). The remaining material was kept in cold storage at 4 ºC until use. Fruit mass (M) was determined with an electronic balance with 0.1 g sensitivity. To determine the average size of the fruits, three linear dimensions namely as length, width and thickness were measured by using a digital caliber with 0.1 mm sensitivity. Volume (V) was determined by the water displacement method (Mohsenin, 1986). The geometric mean diameter (D_g) and surface areas (S) were determined by using following formula (Mohsenin, 1986), respectively:

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

$$S = \pi (D_g)^2 \qquad (2)$$

Where: L is length of apricot fruit (mm), W is width of apricot fruit (mm); T is thickness of apricot fruit (mm), S is surface area (mm^2) and D_g is geometric mean diameter (mm). Also, Apricots' picture was taken by Area Measurement System Delta T-England apparatus shown in Fig 1. Then, projected areas (PA_1, PA_2 and PA_3) in three perpendicular directions of the fruits were calculated by applying the software written in Visual Basic. And criteria projected area (CPA) is defined as (Mohsenin, 1986):

$$CPA = (PA_1+PA_2+PA_3)/3 \qquad (4)$$

Where PA_1, PA_2 and $PA_3$are first, second and third projected area (mm^2).
In order to estimate mass models of apricot, the following models were considered:
1. Single variable regression of apricot mass based on apricot dimensional characteristics: length (L), width (W), thickness (T), and geometric mean diameter (D_g).
2. Single variable regressions of apricot mass based on apricot projected areas and criteria projected area.
3. Single variable regression of apricot mass based on measured volume.
4. Single variable regression of apricot mass based on surface area.

In all cases, the results which were obtained from experiments were fitted to Linear, Quadratic, S-curve, and Exponential models which are presented as following equations, respectively:

$$M=b_0+b_1T \qquad (5)$$
$$M=b_0+b_1T+b_2T^2 \qquad (6)$$
$$Ln\ (M) =b_0+b_1/T \qquad (7)$$
$$M=b_0\ (e^{b1*T}) \qquad (8)$$

Where M is mass (g), T is the value of a parameter that we want to find its relationship with mass (in depended parameter), b_0, b_1, and b_2 are curve fitting parameters which are different in each equation.
One evaluation of the goodness of fit is the value of the coefficient of determination. For regression equations in general, the nearer R^2 is to 1.00, the better the fit (Stroshine, 1998). SPSS, 15, software was used to analyze data and determine regression models among the physical attributes.

Table 2. The best models and their constant values for mass based on the selected attributes for *Ghavami* variety.

Depended parameter	In depended parameter	The best model	Constant values			R^2
			b_0	b_1	b_2	
M(g)	L(mm)	Quadratic	-200.72	9.79	-0.10	0.61
M(g)	W(mm)	Quadratic	-178.75	7.34	-0.70	0.65
M(g)	T(mm)	Quadratic	-135.62	8.76	-0.11	0.64
M(g)	V(cm^3)	Linear	4.58	0.88	-	0.80
M(g)	Dg(mm)	Quadratic	-119.18	6.48	-0.06	0.78
M(g)	S(mm^2)	Quadratic	-35.10	0.02	$-2*10^{-6}$	0.78
M(g)	PA_1(mm^2)	Linear	-1.97	0.02	-	0.70
M(g)	PA_2(mm^2)	Quadratic	-121.82	0.23	$-9.3*10^{-5}$	0.69
M(g)	PA_3(mm^2)	Quadratic	-32.04	0.08	$-2.6*10^{-8}$	0.68
M(g)	CPA(mm^2)	Quadratic	-93.93	0.20	$-8*10^{-5}$	0.74

Results and Discussion

A summary of the physical properties of *Ghavami* and *Rajabali* cultivars is shown in Table1.These properties were found at specific fruit moisture contents of cultivars (*Ghavami* and *Rajabali*) at 79.84 and 84.17%wd, respectively. As seen in Table 1, all properties which were considered in the current study were found to be statistically significant at 1% probability level. According to the results, the mean values of properties which were studied in this research (length, width, thickness, geometric mean diameter, Volume, surface area, mass and projected area) for *Rajabali* cultivar were significantly grater than that of the *Ghavami* cultivar

The best models and their constant values for mass based on the selected attributes for *Ghavami* and *Rajabali* apricot cultivars are presented in Tables 2 and 3.

For *Ghavami* variety, for mass modeling based on dimensional characteristic including length, width and thickness, the best attribute was width and the best model was Quadratic with R^2 as: 0.65.

$$M= -178.75+7.34W-0.7\,W^2 \qquad R^2=0.65$$

whereas this model can predict the relationships between mass with length and mass with thickness with R^2 of 0.61 and 0.64, respectively. 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. For prediction of the mass of *Ghavami* cultivar based on volume the best model was Linear with R^2 as: 0.80.

$$M= 4.58+0.88V \qquad R^2=0.80$$

A corroding to the results, for prediction of the mass of the *Ghavami* cultivar based on geometric mean diameter, Quadratic model was the best model with R^2 as: 0.78.

$$M= -119.18+6.48\,Dg -0.06\,Dg^2 \qquad R^2=0.78$$

For mass modeling of *Ghavami apricot* variety based on projected areas including PA_1, PA_2 , PA_3 and CPA, the best attribute was CPA and the best model was Quadratic with R^2 as: 0.74.

$$M= -93.93+0.20CPA-8*10^{-5}\,CPA^2 \qquad R^2=0.74$$

whereas this model can predict the relationships between mass with mass with PA_2 and mass with PA_3 with R^2 of 0.69 and 0.68, respectively. One the other hand the best model for prediction of mass based on PA_1 was linear model with R^2 of 0.70.

Table 3. The best models and their constant values for mass based on the selected attributes for *Rajabali* variety

Depended parameter	In depended parameter	The best model	Constant values			R^2
			b_0	b_1	b_2	
M(g)	L(mm)	Linear	-39.10	1.91	-	0.63
M(g)	W(mm)	S-curve	6.01	-88.15	-	0.75
M(g)	T(mm)	Quadratic	450.06	-22.46	0.31	0.69
M(g)	V(cm^3)	Linear	12.90	0.89	-	0.90
M(g)	Dg(mm)	Linear	-73.17	2.87	-	0.82
M(g)	S(mm^2)	S-curve	5.16	-7188.03	-	0.83
M(g)	PA_1 (mm^2)	Linear	-19.78	0.04	-	0.96
M(g)	PA_2 (mm^2)	Linear	-21.59	0.04	-	0.95
M(g)	PA_3 (mm^2)	Linear	-16.98	0.04	-	0.87
M(g)	CPA(mm^2)	Linear	-22.92	0.04	-	.097

Keramat Jahromi et al., (2007), reported that the best models for perception of mass of Bergamot *(Citrus medica)* based on the projected area were M= 0.04 PA_2-5.12 with R^2 0.94 and M=0.03PA_3 With R^2 of 0.94. For prediction of the mass of the *Ghavami* cultivar based on surface area the best model was Quadratic with R^2 as: 0.78.

$$M= -35.10+0.02\,S-2*10^{-6}\,S^2 \qquad R^2=0.78$$

According to the results which are shown in Table. 3, For mass modeling of *Rajabali* variety based on dimensional characteristic including length, width and thickness, the best attribute was width and the best model was S-curve with R^2 as: 0.75.

$$Ln\,(M) =6.01-88.15/W \qquad R^2=0.75$$

Whereas, the best model for mass based on length and mass based on thickness were linear and Quadratic With R^2 of 0.63 and 0.69, respectively. Keramat Jahromi et al., (2007), reported that the best equations for single variables of mass modeling of Bergamot *(Citrus medica)* was determined as M=6.25T-283.53 with R^2 of 0 .90.
For prediction of the mass of the *Rajabali* cultivar based on geometric mean diameter, linear model was the best with R^2 as: 0.82

$$M=-73.17+2.87\,Dg \qquad R^2=0.82$$

Acorroding to the results, for prediction of the mass of the *Rajabali* cultivar based on volume, linear model was the best with R^2 as: 0.90.

$$M=12.90+0.89V \qquad R^2=0.90$$

Keramat Jahromi et al., (2007), proposed the M=0.52 V+ 44.72 with R^2 of 0.99 for mass modeling of Bergamot *(Citrus medica)*. For mass modeling of *Rajabali apricot* variety based on projected areas including PA_1, PA_2, PA_3 and CPA, the best attribute was CPA and the best model was Linear with R^2 as: 0.97.

$$M=-22.92+0.04CPA \qquad R^2=0.97$$

whereas this model can predict the relationships between mass with mass with PA_1 ,mass with PA_2 and mass with PA_3 with R^2 of 0.96 , 0.95,and .87, respectively.
Finally, for prediction of the mass of the *Rajabali* cultivar based on surface area the best model was S-curve with R^2 as: 0.83.

$$Ln\,(M) =5.16-7188.03/S \qquad R^2=0.83$$

Lorestani and Tabatabaeefar, (2006), concluded that the linear regression models of kiwi fruit have higher R^2 than nonlinear models for them, and are economical models for application. Among the linear regression dimensions models, the model that is based on width, and among the linear projected area models, the model that is based on third projected area, and among the other models, the model that is based on measured volume, had higher R^2, that are recommended for sizing of kiwi fruit. Also Tabatabaeefar and Rajabipour, (2005), determined a total of 11 regression models in the three different categories for two different varieties of apple fruits.

According to the results the Exponential model couldn't predict the relationships among the mass and physical properties of Ghavami and *Rajabali* apricot varieties with proper value for determination coefficients.

Conclusions

Some physical properties and their relationships of mass of *Ghavami* and *Rajabali* apricot varieties are presented in this study. From this study it can be concluded that:

1. The mean values of Properties such as length, width, thickness, geometric mean diameter, Volume, surface area, mass and projected area for *Rajabali* cultivar were significantly grater than that of the *Ghavami* cultivar.
2. The best model for prediction the mass of *Ghavami* cultivar was based on volume of fruit with determination coefficients of 0.8, and the worst was based on length of apricot fruit with determination coefficients of 0.61.
3. The best model for prediction the mass of *Rajabali* cultivar was based on criteria projected area of fruit with determination coefficients of 0.97, and the worst was based on length of apricot fruit with determination coefficients of 0.63.
4. The Exponential model was not suitable for mass modeling based on physical characteristic of these apricot varieties.

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