Mass modeling of persimmon fruit with some physical characteristics

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Abstract: For proper design of grading systems of horticultural crops, important relationships between the mass and other properties of fruits such as length, width, thickness, volumes and projected areas must be known. The aim of this research was to measure and present some physical properties of persimmon fruits and correlating the mass of persimmon fruits to measured physical properties using linear, quadratic, S-curve and power models as three different classifications: (1) Single variable regressions of persimmon dimensional characteristics, (2) single variable regressions of persimmon mass based on projected areas and (3) estimating the persimmon mass based on its volumes. The results showed that mass modeling of persimmon based on length and the first projected area were the most appropriate ones in the first and the second classifications, respectively. In third classification, Linear Quadratic and models based on volume of the fruits assumed as ellipsoid shape (V_{ellip}) with R^2=0.880, were the best models for mass prediction of the persimmon based on volumes as: M =15.933+ 0.001V_{ellip} and M =15.933+ 0.001V_{ellip} + 5.569×10^{-10}. In the economical and agronomical point of view, suitable grading system of persimmon mass was ascertained based on length as Quadratic form: $M = 356.171-12.664L+ 0.136L^2$, $R^2 = 0.960$.

Keywords: persimmon fruit, physical characteristics, mass prediction

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1 Introduction

Persimmon (*Diospyros kaki Thunb.*) is rich in vitamin A, calcium, potassium, tannic acid and antioxidant phenolic compounds (Altuntas et al., 2011). China is ranked the first in the world with 1655000 t of persimmon production (Liu et al., 2007). Iran produces about 13,000 t of persimmons annually (FAOSTAT, 2009). Persimmon is successfully cultivated in the Northern regions of Iran. "Kaki" is the most common variety grown in Iran due to its taste and appeal.

Knowledge about physical properties of agricultural products and their relationships is necessary for the design of handling, sorting, processing and packaging systems. Among these properties, the dimensions, mass, volume and projected area are the most important ones in the design of grading system (Mohsenin, 1986). Consumers prefer fruits with equal weight and uniform shape. Mass grading of fruit can reduce packaging and transportation costs, and may provide an optimum packaging configuration. Fruits are often classified based on the size, mass, volume and projected areas. Electrical sizing mechanisms are more complex and expensive. Mechanical sizing mechanisms work slowly. Therefore, it may be more economical to develop a machine, which grades fruits by their mass. Besides, using mass as the classification parameter is the most accurate method of automatic classification for more fruits. Therefore, the relationships between mass and length, width and projected areas can be useful and applicable (Khoshnam et al., 2007; Lorestani et al., 2012).

A number of studies have been conducted on the mass modeling of fruits based upon their physical properties. Tabatabaeefar, Vefagh-Nematolahee, and Rajabipour

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(2000) developed 11 models based upon dimensions, volumes and surface areas for mass predication of orange fruits. Al-Maiman and Ahmad (2002) studied the physical properties of pomegranate and developed models for predicting fruit mass while employing dimensions, volume and surface areas. A Quadratic model ($M = 0.08c^2 + 4.74c + 5.14$, $R^2 = 0.89$), to calculate the apple mass based on its minor diameter, was determined by Tabatabaeefar and Rajabipour (2005). Lorestani and Tabatabaeefar (2006) determined models for predicting mass of Iranian kiwi fruit by its dimensions, volumes, and projected areas. They reported that the intermediate diameter was more appropriate to estimate the mass of kiwi fruit. Khanali et al. (2007) determined similar mass models for tangerine fruit. Naderi-Boldaji et al. (2008) also determined models for predicting the mass of apricot. They found a nonlinear equation ($M = 0.0019c^{2.693}$, $R^2 = 0.96$) between apricot mass and its minor diameter. Some researchers (Kingsly et al., 2006; Fadavi et al., 2005) reported mass models for pomegranate fruit. Lorestani and Ghari (2012) concluded that the best model for predicting the mass of Fava bean among the dimensional models was linear based on width and the best model for predicting the mass of Fava bean was based on the third projected area which perpendicular to L direction of Fava bean and it was Power form.

We found no detailed studies concerning mass modeling of persimmon fruit. The aims of this study were to determine the most suitable model for predicting persimmon mass by its physical attributes and specify some physical properties of persimmon fruit to form an important database for other researches.

2 Materials and methods

Freshly harvested persimmon fruits, of *Kaki* variety, were obtained from Lorestan province Iran. In order to determine the physical properties, 150 persimmon fruits were randomly selected. Selected samples were healthy and free from any injuries. Samples of fruits were weighed and dried in an oven at a temperature of 78°C for 48 h then weight loss on drying to a final constant weight was recorded as moisture content. The mass of each persimmon (M) was measured using a digital balance with accuracy of 0.01 g. For each persimmon fruit, three linear dimensions were measured by using a digital caliper with accuracy of 0.01mm, including Major diameter (Length, L), Intermediate diameter (Width, W) and Minor diameter (Thickness, T) (Figure 1). Water displacement method was used for determining the fruits measured volume (V_m). Fruits geometric mean diameter (D_g) and surface area (S) were determined by using the following Equation (1) and Equation (2) (Mohsenin, 1986; Shahbazi, 2013), respectively:

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

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

where, L is length (mm); W is width; T is thickness (mm); S is fruit surface are (mm^2) and D_g is geometric mean diameter (mm). In addition, fruit average projected areas perpendicular to dimensions (PA_1, PA_2 and PA_3) were measured by a ΔT are-meter, MK2 model, device with accuracy of 10 mm^2 and then the criteria projected area (CPA) was calculated as suggested by Mohsenin (1986) (Equation (3)):

$$CPA = \frac{(PA_1 + PA_2 + PA_3)}{3} \quad (3)$$

where, PA_1 (perpendicular to L direction of fruit); PA_2 (perpendicular to T direction of fruit) and PA_3 (perpendicular to W direction of fruit), are the first, the second and the third projected areas (mm^2), respectively.

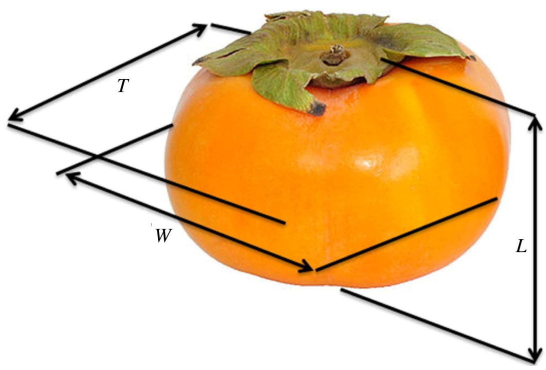

Figure1 Dimensional characteristics of persimmon fruit: L, length; W, width; T, thickness

The following models were considered in the estimation of mass models for persimmon fruits:

1) Single variable regression of persimmon mass based on fruits dimensional properties including length (L), width (W), thickness (T) and geometric mean

diameter (D_g).

2) Single or multiple variable regression of persimmon mass based on fruits projected areas (PA_1, PA_2 and PA_3), surface area (S) and criteria projected are (CPA).

3) Singe regression of persimmon mass based on measured volume (V_m), volume of the fruits assumed as oblate spheroid shape (V_{osp}) and volume of the fruits assumed as ellipsoid shape (V_{ellip}) (Lorestani et al., 2012).

In the case of the third classification, to achieve models, which can predict the persimmon mass, based on volumes, three volume values were either measured or calculated. At first, measured volume (V_m) as stated earlier was measured and then the persimmon shape was assumed as a regular geometric shape, i.e. oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes, and their volume was thus calculated as Equation (4) and Equation (5):

$$V_{osp} = \frac{4\pi}{3}(\frac{L}{2})(\frac{W}{2})^2 \quad (4)$$

$$V_{ellip} = \frac{4\pi}{3}(\frac{L}{2})(\frac{W}{2})(\frac{T}{2}) \quad (5)$$

Four models including: Linear, Quadratic, S-curve and Power models were used for mass predication of persimmon fruits based on measured physical properties, as are represented in the following Equation (6), Equation (7), Equation (8) and Equation (9), respectively (Shahbazi and Rahmati, 2013 a, b):

$$M = b_0 + b_1 X \quad (6)$$

$$M = b_0 + b_1 X + b_2 X^2 \quad (7)$$

$$M = b_0 + \frac{b_1}{X} \quad (8)$$

$$M = b_0 X^{b_1} \quad (9)$$

where, M is mass (g); X is the value of an independent (physical characteristics) parameter which want to find its relationship with mass, and 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 (R^2). 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 the data and determine regression models between the physical characteristics.

3 Results and discussion

3.1 Physical properties of persimmon fruits

A summary of the physical properties of studied persimmon fruits are shown in Table 1. These properties were found at specific moisture contents of 80.33% wet basis. As seen in Table 1, the effects of all properties, on the mass of persimmon fruit, were found to be statistically significant at 1% probability level.

Table 1 Some physical properties of studied persimmon fruits

Properties	Value			Significant level
	Average	Maximum	Minimum	
L/mm	57.26	63.42	54.01	P<0.01
W/mm	53.92	59.61	45.65	P<0.01
T/mm	43.31	48.21	40.12	P<0.01
D_g/mm	51.09	56.69	45.65	P<0.01
S/mm^2	8212.94	10091.96	7238.32	P<0.01
M/g	79.21	102.03	67.45	P<0.01
AP_1/mm^2	1924.11	2230.01	1530.02	P<0.01
AP_2/mm^2	1824.44	2050.03	1620.06	P<0.01
AP_3/mm^2	1470.01	1870.11	1270.23	P<0.01
CPA/mm^2	1739.52	2043.33	1500.02	P<0.01
V_m/mm^3	86666.67	10200.05	80060.05	P<0.01
V_{osp}/mm^3	56570.07	77107.87	45216.87	P<0.01
V_{ellip}/mm^3	70229.89	93345.00	57921.96	P<0.01

3.2 Mass modeling

Table 2 shows the obtained the best models and their coefficient of determination (R^2) for mass predication of persimmon fruits based on the measured physical properties. The results of the F-test and T-test in SPSS 15 software showed that all the coefficients of the models were significant at the 1% probability level.

3.3 Modeling based on dimensions

The results of mass modeling of persimmon fruits based on the dimensional characteristics, including: length (L), width (W), thickness (T) and geometric mean diameter (D_g), showed that Quadratic model based on length (L), had the highest R^2 value among the others (Table 2) and we had Equation (10):

$$M = 356.171 - 12.664L + 0.136L^2 \quad R^2=0.960 \quad (10)$$

In addition, Quadratic model can predict the relationships between the mass with width (W), thickness (T) and geometric mean diameter (D_g) with R^2 values of 0.773, 0.266 and 0.880, respectively. Therefore, mass

Table 2 The models for mass prediction of persimmon with some physical characteristics

Dependent variable	Independent variable	The best fitted model	Constant parameters b_0	b_1	b_2	R^2
M/g	L/mm	Quadratic	356.171	-12.664	0.136	0.960
M/g	W/mm	Quadratic	745.147	-27.564	0.281	0.773
M/g	T/mm	Quadratic	811.253	-34.921	0.414	0.266
M/g	D_g/mm	Quadratic	102.987	-4.624	0.081	0.880
M/g	PA_1/mm^2	Quadratic	286.109	-0.255	7.571×10^{-5}	0.737
M/g	PA_2/mm^2	Quadratic	433.783	-0.440	0.001	0.619
M/g	PA_3/mm^2	Quadratic	253.435	-0.263	9.719×10^{-5}	0.667
M/g	CPA/mm^2	Quadratic	405.430	-0.426	0.001	0.880
M/g	S/mm^2	Quadratic	13.922	0.004	4.268×10^{-7}	0.880
M/g	V_m/mm^3	Quadratic	360.610	-0.007	4.60×10^{-8}	0.691
M/g	V_{osp}/mm^3	Quadratic	132.792	-0.003	2.683×10^{8}	0.596
M/g	V_{ellip}/mm^3	Linear	15.939	0.001	-	0.880
		Quadratic	19.184	0.001	5.569×10^{-10}	0.880

modeling of persimmon fruits based on length is recommended. Similar model (nonlinear) suggested by Tabatabaeefar Vefagh-Nematolahee, and Rajabipour (2000) for mass predication of orange fruit mass based on fruit width, too. Their recommended model was: $M = 0.069b^2 - 2.95b - 39.15$, $R^2 = 0.97$. In addition, eleven models for predicting mass of apples based on geometrical attributes were recommended by Tabatabaeefar and Rajabipour (2005). They recommended an equation for calculating apple mass based on minor diameter as $M = 0.08c^2 - 4.74c + 5.14$, $R^2 = 0.89$. Ghabel et al. (2010) recommended a nonlinear model for onion mass determination based on length as $M = 0.035a^2 - 1.64a + 36.137$, $R^2 = 0.96$.

3.4 Modeling based on areas

Among the investigated mass models for persimmon fruits based on projected areas (PA_1, PA_2, PA_3 and CPA), Quadratic model of the criteria projected area (CPA), shown in Table 2, had the highest value of R^2 as Equation (11):

$$M = 405.43 - 0.426CPA + 0.001CPA^2 \quad R^2=0.880 \tag{11}$$

However, if this model use for grading of persimmon fruits, all the three projected areas of fruit will be required. Therefore, the speed of the processing will be decreased and the costs of sorting and grading will be increased. It is evident that one of the projected areas must be selected. Among the PA_1, PA_2 and PA_3 projected areas, Quadratic model of PA_1 was preferred because of the highest value of R^2 than other models as Equation (12):

$$M = 286.109 - 0.255PA_1 + 7.571\times10^{-5}PA_1^2 \quad R^2=0.737 \tag{12}$$

For mass prediction of the persimmon fruits based on surface area, the best model was Quadratic with $R^2 = 0.880$ as Equation (13):

$$M = 13.922 + 0.004S + 4.268\times10^{-7}S^2 \quad R^2 = 0.880 \tag{13}$$

However, measurement of three dimensions of fruits is needed for geometric mean diameter (D_g) and surface area (S) to use this model, which makes the grading mechanisms more tedious and expensive. Therefore, mass modeling of persimmon fruits based on the first projected area (PA_1) is recommended. Similar model (nonlinear) suggested by Shahbazi and Rahmati (2013a) for mass predication of sweet cherry fruit mass based on fruit first projected area (PA_1), too. Their recommended model was: $M = 6.521 - 0.017PA_1 + 5.196\times10^{-6}PA_1^2$, $R^2 = 0.805$.

3.5 Modeling based on volumes

According to the results, for mass prediction of the persimmon fruits based on volumes (V_m, V_{osp} and V_{ellip}), shown in Table 2, the Linear and Quadratic models based on volume of the fruits assumed as ellipsoid shape (V_{ellip}) with $R^2 = 0.880$, were the best models as Equation (14) and Equation (15):

$$M = 15.933 + 0.001V_{ellip} \quad R^2=0.965 \tag{14}$$

$$M = 19.184 + 0.001V_{ellip} + 5.569\times10^{-10}V^2_{ellip} \quad R^2 = 0.965 \tag{15}$$

According to the results obtained in this study, the Quadratic models could predict the relationships between the mass and some physical properties of persimmon fruits with proper values of coefficient of determination.

4 Conclusions

In this study, some physical properties of persimmon fruits, of *Kaki* variety and their relationships with fruits mass were presented. The effects of all considered properties, on the mass of persimmon fruit, were found to be statistically significant at 1% probability level. For mass predication of persimmon fruits, the best and the worst models were obtained based on length and thickness of the fruits with determination coefficients (R^2) of 0.960 and 0.266, respectively. At last, mass modeling of persimmon fruit based on length based on length (L) of fruit as: $M = 356.171 - 12.664L + 0.136L^2$, $R^2 = 0.960$, is recommended to design and development of grading systems.

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