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Correlation the mass of grapefruit to some physical attributes

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Abstract

The aim of this research to present some physical properties of grapefruit. In addition, in this study the mass of grapefruit was correlated to different physical characteristics in four models including: Linear, Quadratic, S-curve, and Power as three different classifications: (1) Single variable regressions of grapefruit dimensional characteristics, (2) Single variable regressions of grapefruit mass based on projected areas and (3) estimating the grapefruit mass based on its volumes. The results showed that mass modeling of grapefruit based on width and second projected area were the most appropriate ones in the first and the second classifications, respectively. In third classification, the best model was obtained based on the oblate volume as $M=-15.693+0.001V_{osp}-1.219\times10^{-9}V_{osp}$ with R^2=0.953 whereas corresponding values were 0.924 and 0.897 for assumed grapefruit shapes (ellipsoid spheroid and actual), respectively. In the economical and agronomical point of view, suitable grading system of grapefruit mass was ascertained based on width as Quadratic form: $M=490.564-13.593W+0.313W^2$, R^2=0.919.

Keywords: Grapefruit; physical characteristics; mass prediction

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1. Introduction

Citrus fruits have stippled rinds that surround pulp that's tart, juicy, and rich in vitamin C and other nutrients. 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 [1-3]. 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 [4]. 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 [5-7].

A number of studies have been conducted on mass modeling of fruits based upon their physical properties. Tabatabaeefar *et al*. [8] found 11 models for the prediction of orange mass based upon dimensions, volume and surface areas. Al-Maiman and Ahmad [9] studied the physical properties of pomegranate and found models of predicting fruit mass while employing dimensions, volume and surface areas. Tabatabaeefar and Rajabipour, [10], determined a quadratic equation (M= 0.08c^2 + 4.74c + 5.14, R^2 = 0.89) to calculate apple mass based on its minor diameter. Lorestani and Tabatabaeefar [11] 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. Also Khanali *et al*. [12] achieved models for tangerine. Some researchers modeled the mass of pomegranate fruit [13-15]. Lorestani and Ghari [16] concluded that the best model for prediction the mass of Fava bean among the dimensional models was linear based on width and the best model for prediction the mass of Fava bean was based on third projected area which perpendicular to L direction of Fava bean and it was Power form.

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No detailed studies concerning mass modeling of grapefruit fruit have yet been performed. The aims of this study were to determine the most suitable model for predicting grapefruit mass by its physical attributes and study some physical properties of Iranian grapefruit fruit to form an important database for other investigators.

2. Materials and methods

Fresh harvested grapefruit (*Citrus paradise*) fruits in May 2012, obtained from Lorestan province Iran, were used in this study. In order to determine the physical properties, 150 grapefruits 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 hours then weight loss on drying to a final constant weight was recorded as moisture content. Grapefruit mass (M) was determined with an electronic balance with 0.01 g sensitivity. To determine the average size of the samples, three linear dimensions namely as length, width and thickness were measured by using a digital caliper with 0.01 mm sensitivity (Fig 1). Actual volume (V_m) was determined by the water displacement method [3]. The geometric mean diameter (D_g) and surface areas (S) were determined by using following equations, respectively [3]:

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

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

Where L is length (mm), W is width (mm) and T is thickness of grapefruit (mm), S is surface area (mm^2) and Dg is geometric mean diameter (mm). In addition, projected areas (PA_1, PA_2 and PA_3) in three perpendicular directions of the fruit were measured by a ΔT area-meter, MK2 model device with 0.1 cm^2 accuracy and then criteria projected area (CPA) calculated as follows [3]:

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

Where PA_1, PA_2 and PA_3 are first, second and third projected areas (mm^2), respectively.

In order to estimate mass models of grapefruits, the following models were considered:

1. Single variable regression of grapefruit mass based on grapefruit dimensional characteristics: length (L), width (W), thickness (T), and geometric mean diameter (D_g).
2. Single variable regressions of grapefruit mass based on projected areas (PA_1, PA_2 and PA_3), surface area (S) and criteria projected area (CPA).
3. Single regression of grapefruit mass based on measured (actual) volume (V_m), volume of the fruit assumed as oblate spheroid (V_{osp}) and ellipsoid shapes (V_{ellip}).

In the case of the third classification, to achieve models which can predict the fig fruit mass on the basis of volume, three volume values were either measured or calculated. At first, measured volume (V_m) as stated earlier was measured and then the fig fruit 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:

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

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

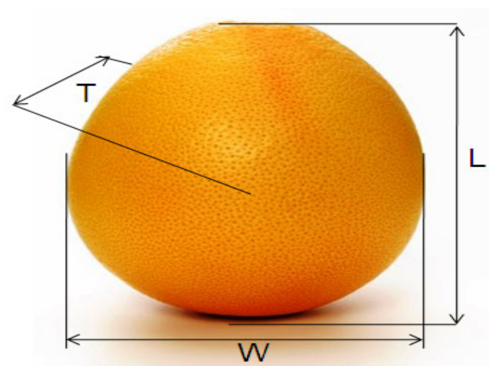

Figure 1. Dimensional characteristics of grapefruit: L, length; W, width; T, thickness.

In all cases, the results which were obtained from experiments were fitted to Linear, Quadratic, S-curve, and Power models which are presented as following equations, respectively [17]:

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

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

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

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

where M is mass (g), X is the value of a 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. On 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 [18, 19]. SPSS 15, software was used to analyze the data and determine regression models between the physical characteristics.

3. Results and discussion

Physical Properties of Grapefruits. A summary of the physical properties of studied grapefruits is shown in Table 1. These properties were found at specific moisture contents about 86.13% wet basis. 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, surface area, mass, first area, second, third area, criteria projected area, measured volume, oblate spheroid volume and ellipsoid shapes volume) were 67.518 mm, 70.072 mm, 70.57 mm, 69.356 mm, 15149.503 mm^2, 182.410 g, 4189.090 mm^2, 4172.727 mm^2, 4051.545 mm^2, 4138.787 mm^2, 295454.545 mm^3, 174916.454 mm^3 and 176174.580 mm^3, respectively.

Table 1. Some physical properties of grapefruit.

Properties	Value			Significant level
	Average	Maximum	Minimum	
L, mm	67.518	73.01	62.11	P <0.01
W, mm	70.072	78.13	64.61	P <0.01
T, mm	70.570	78.22	61.14	P <0.01
D_g, mm	69.356	75.93	64.23	P <0.01
S, mm^2	15149.503	18106.61	12957.36	P <0.01
M, g	182.410	228.31	152.83	P <0.01
PA_1, mm^2	4189.09	4750.02	3400.12	P <0.01
PA_2, mm^2	4172.72	5001.04	3500.03	P <0.01
PA_3, mm^2	40.54.548	4900.06	3400.11	P <0.01
CPA, mm^2	4138.78	4800.01	3500.13	P <0.01
V_m, mm^3	295454.54	450004.03	180000.09	P <0.01
V_{osp}, mm^3	174916.45	227685.75	145047.06	P <0.01
V_{ellip}, mm^3	176174.58	229160.43	138726.76	P <0.01

3.2. Mass Modeling

Mass models and their coefficient of determination (R^2) that obtained from the data for grapefruits are shown in Table 2. All of the models coefficients were analyzed with F-test and t-test in SPSS 15 Software. The results showed that all of them were significant at 1% probability level. As shown in Table 2 the best and the worst models were obtained based on the criteria projected area (*CPA*) and first projected area of the fruit with determination coefficients (R^2) of 0.948 and 0.665, respectively.

3.2.1. Modeling Based on Dimensions

The results of mass modeling of grapefruit based on dimensional characteristics including length (*L*), width (*W*) thickness (*T*) and geometric mean diameter (D_g), showed that Quadratic model to calculate mass of grapefruit based on geometric mean diameter, had the highest R^2 among the others as:

$$M = 599.782 - 17.663 D_g + 0.167 D_g^2 \quad R^2=0.927 \qquad (10)$$

However, measurement of three diameters of grapefruit is needed for calculating the geometric mean diameter (D_g) to use this model, which makes the sizing mechanism more tedious and expensive. Among three dimensions including length (*L*), width (*W*) and thickness (*T*), Quadratic model, which expresses the width (*W*) as independent variable, had the highest R^2 among the others (Table 2). Therefore, the mass model of grapefruit based on width is given as Quadratic form:

$$M = 490.564 - 13.593W + 0.131W^2 ;\ R^2=0.919 \qquad (11)$$

Whereas, this model can predict the relationships between the mass with length (*L*) and thickness (*T*) with R^2 values of 0.812 and 0.846, respectively. Therefore, sizing grapefruit based on width is recommended. Tabatabaeefar *et al*. [8] suggested a nonlinear model for orange mass based on fruit width too. Their recommended model was with the following values: $M= 0.069b^2 - 2.95b - 39.15$, $R^2=0.97$. Eleven models for predicting mass of apples based on geometrical attributes were recommended by Tabatabaeefar and Rajabipour [10]. They recommended an equation for calculating apple mass on the basis of minor diameter as: $M= 0.08c^2 - 4.74c + 5.14$, $R^2 = 0.89$. Ghabel *et al*. [20] recommended a nonlinear model for onion mass determination based on length as: $M = 0.035a^2 - 1.64a + 36.137$, $R^2 = 0.96$.

3.2.2. Modeling Based on Areas

Among the investigated classification models 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:

$$M = 360.818 - 0.141CPA + 1.33\times10^{-5} CPA^2 ;R^2=0.948 \quad (12)$$

However, if this model was used for the classification of fruits in grading system, all three projected areas will be required for grapefruit. Therefore, the costs of sorting and grading will be increased while the speed of system will be decreased.

Then it is evident that one of projected areas must be selected. Among the PA_1, PA_2 and PA_3 areas, Linear model of PA_3 was preferred because of the highest value of R^2 as:

$$M = -10.524 + 0.048 PA_3 \text{ ;} R^2=0.805 \quad (13)$$

For prediction of the mass of the grapefruit based on surface area, the best model was Quadratic with R^2 =0.924:

$$M = 130.147 - 0.006 S + 6.201 \times 10^{-7} S^2 \text{ ;} R^2=0.936 \quad (14)$$

However, measurement of three defamations of grapefruit is needed for calculating the geometric mean diameter (D_g) and then calculating surface areas (S) to use this model, which makes the sizing mechanism more tedious and expensive.

3.2.3. Modeling based on volumes

According to the results, for prediction of the mass of the grapefruit based on volumes (V_m, V_{osp} and V_{ellip}), shown in Table 2, Quadratic model based on volume of assumed oblate spheroid shape (V_{osp}) with R^2 =0.953, were the best models as:

$$M = -15.693 + 0.001 V_{osp} - 1.831 \times 10^{-8} V_{osp} \text{ ;} R^2=0.95 \quad (15)$$

According to the results obtained in this study, the Quadratic model could predict the relationships among the mass and some physical properties of grapefruit with proper value for determination coefficient. Therefore, we suggest the Quadratic model based on width (W) for prediction the mass of grapefruit.

4.Conclusions

Some physical properties and their relationships of mass of grapefruit are presented in this study. From this study it can be concluded that:

All properties considered in the current study were found to be statistically significant at the 1% probability level.

The best model for prediction the mass of grapefruit based on the fruit dimensional characteristics was Quadratic form based on width of fruit as:

$$M = 490.564 - 13.593 W + 0.131 W^2 \text{, } R^2=0.919.$$

The best model for prediction the mass of grapefruit was based on three projected areas was Linear form based on second projected area (AP_3) which is perpendicular to W direction of grapefruit as:

$$M = -10.524 + 0.048 PA_3 \text{, } R^2=0.917$$

Quadratic model based on volume of assumed oblate spheroid shape (V_{osp}) with R^2 =0.953, were the best models as: $M = -15.693 + 0.001 V_{osp} - 1.831 \times 10^{-8} V_{osp}$

Table 2. The best models for prediction the mass of grapefruit with some physical characteristics.

Dependent variable	Independent variable	The best fitted model	Constant parameters of model			R^2
			b_0	b_1	b_2	
M (g)	L (mm)	Quadratic	1126.122	-35.137	0.313	0.812
M (g)	W (mm)	Quadratic	490.564	-13.593	0.131	0.919
M (g)	T (mm)	Quadratic	1303.297	-36.397	0.289	0.846
M (g)	D_g (mm)	Quadratic	559.782	-17.663	0.167	0.927
M (g)	AP_1 (mm^2)	Quadratic	386.438	-0.151	2.425×10^{-5}	0.665
M (g)	AP_2 (mm^2)	Linear	401.213	-0.150	2.321×10^{-5}	0.891
M (g)	AP_3 (mm^2)	Quadratic	-10.524	0.048	-	0.917
M (g)	CPA (mm^2)	Quadratic	360.818	-0.141	2.33×10^{-5}	0.948
M (g)	S (mm^2)	Quadratic	130.147	-0.006	6.201×10^{-7}	0.924
M (g)	V_m (mm^3)	Quadratic	123.225	0.001	1.631×10^{-10}	0.897
M (g)	V_{osp} (mm^3)	Quadratic	-15.693	0.001	-1.831×10^{-9}	0.953
M (g)	V_{ellip} (mm^3)	Quadratic	89.922	0.001	1.219×10^{-9}	0.924

Compliance with Ethics Requirements

Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

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