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Study on some morphological and physical attributes of walnut used in mass models

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ABSTRACT

Physical properties of horticultural products are important in designing the sorting, transporting, processing and packaging systems. Among physical attributes, dimensions, weight, volume, projected areas and porosity are useful for designing grading systems. This study carried out on four superior walnut (*Juglands regia*) genotypes, which were selected from primary morphological screening of 608 genotypes in Neyriz city, Iran. G-570 with higher nut weight (12.46 g), kernel weight (8.25 g) and kernel ratio of 66.21% was a promising genotype among others. Regarding studied physical properties, G-570 was 44 mm in diameter significantly different from other genotype. In this research walnut mass was predicted by using different physical properties with linear and nonlinear models as three classifications (dimension, projected areas and volume). Results showed that the highest correlation was between models number three, two and one. Among grading system based on dimensions in walnut (first classification), minor diameter model with nonlinear relation was the best and could be considered as a good model for economical and horticultural designing systems.

1. Introduction

Persian walnut, *Juglans regia*, is one of the most important nutritive nut crops. Iran is considered as one of the walnut centers of diversity and cultivation in middle-eastern part of the world. The main benefits of walnut kernels include lowering cholesterol, increasing the ratio of high-density lipoprotein cholesterol to total cholesterol, reducing inflammation, and improving arterial function (Patel, 2005). Walnuts contribute nutrients that are essential to a healthful lifestyle. Eating walnuts is one of the easiest things a person can do to improve his or her health. Best of all, they taste great and are ideally suited for inclusion in any diet as part of meals or snacks.

Iran with the production of 150,000 tones of walnut was ranking as third producers in the world after China and United States. In spite of high production of walnuts, there is not a considerable world's market for Iranian walnut yet. In order to provide marketable crops, walnuts should be sorted, graded and packed properly. To achieve such operations, information about physical characteristics for walnut genotypes is required. A specific knowledge of the walnut physical properties such as linear dimensions, shapes, porosity, volume, density, terminal velocity, rupture force and coefficient of fraction is necessary to design walnut processing equipment. The functioning of many types of machines is influenced decisively by the size, shape and density characteristics of walnuts.

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 is needed (Stroshine and Hamann, 1994).

The regression analysis used by Chuma et al. (1982) to develop equations for predicting volume and surface area. They used logarithmic transformation to develop equations for wheat kernels at 15.7%. They suggested that the volume (V) was related to the surface area (S) by a linear regression relationship: $V = 1.10S + 17.2$. Frequently, the surface areas of fruit are determined on the basis of its diameter or weight. Knowing the diameter or weight of a fruit, its surface area may be calculated using empirical equations, or read from an appropriate plot (Sitkei, 1986; Frechette and Zahradnik, 1968).

Consumers prefer bright color nuts with even weight and uniform shape. Mass grading of nuts can reduce packaging and transportation costs, and also may provide an optimum packaging configuration (Peleg, 1985). Sizing by weighing mechanism is recommended for the irregular shape product (Stroshine and Hamann, 1994). Since electrical sizing mechanism is expensive and

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mechanical sizing mechanism reacts poorly; therefore, for walnut genotypes dimensional method (of length, area, and volume) can be used. Determining relationships between mass and dimensions and projected areas may be useful and applicable (Stroshine and Hamann, 1994; Marvin et al., 1987). In weight sizer machines, individual nuts 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 nut is constant, the weight sizer sorts by volume. The sizing error will depend upon the correlation between weight and volume (Stroshine and Hamann, 1994).

In the case of mass modeling, Tabatabaeefar et al. (2000) determined models for predicting mass of Iranian grown oranges from its dimensions and projected areas. They reported that among the system that sorted oranges based on one-dimension, system that applies intermediate diameter suited better with nonlinear relationship. Al-Maiman and Ahmad (2001) had analyzed pomegranate physical properties and obtained models to predict fruit weight from dimension, volume and surface pictures. Topuz et al. (2005) studied physical and nutritional properties of four mandarin genotypes. They reported dimension, volume, weight, surface picture, friction coefficient, porosity, and mass and fruit density in four mandarin genotypes.

No detailed studies concerning morphological characteristics of Iranian walnuts and mass modeling of walnut have been performed up to now. The objective of this research was to determine some morphological characteristics and an optimum walnut mass model based on its some physical attributes. This information is used to design and develop the sizing systems.

2. Materials and methods

Initially fruit morphological characters of 608 walnut genotypes from Neyriz city, Iran were studied (Ebrahimi et al., in press). Among them, four promising genotypes (G-536, G-564, G-570, G-572) were selected for their quality and quantity and prepared for this study. Some morphological characteristics such as seed shape, nut width, nut length, shell color, shell texture, shell seal, kernel removal, nut weight, kernel weight, kernel fill, and kernel flashy were carefully determined according to Anon. (1994).

Linear dimensions, i.e. length, width and thickness and also projected areas, were determined by image processing method. In order to obtain dimensions and projected areas, Win-Area-Ut_06 system developed by Mirasheh (2006) was used.

WinArea-Ut_06 system comprises following components:

(1) Sony photograph camera Model CCD-TRV225E.
(2) Device for preparing media to taking a picture.
(3) Card capture named Winfast model DV 2000.
(4) Computer software programmed with visual basic 6.0.

Captured images from the camera are transmitted to the 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. Total errors for those objects were less than 2%. This method have been used and reported by several researchers (Keramat Jahromi et al., 2007; Khoshnam et al., 2006).

a, b, and c are designated as perpendicular dimensions of walnut namely length (major diameter), width (intermediate diameter) and thickness (minor diameter) and PA, PB, and PC are denoted as the first, second, and third projected areas taken along these three mutual perpendicular axes.

Mass (g) of individual nut was determined by using an electronic balance with an accuracy of 0.0l g. Actual volume was measured by the water displacement method (Mohsenin, 1986; Kabas et al., 2006; Karababa, 2006). The bulk density was determined using the mass–volume relationship by filling an empty plastic container of predetermined volume and weight, the nut was placed inside the container from a constant height, and weight (Fraser et al., 1978).

Geometric mean diameter (GMD) and sphericity (Sph) were calculated by using Eqs. (1) and (2) respectively as reported by Mohsenin (1986) and Kabas et al. (2006).

$$\mathrm{GMD} = (abc)^{1/3} \tag{1}$$

$$\mathrm{Sph} = \frac{\mathrm{GMD}}{a} \tag{2}$$

The coefficient of static friction of the nut was found with respect to four structural materials namely plywood, glass, fiberglass and galvanized steel sheet, using the inclined plane apparatus as described by Dutta et al. (1988). The table was gently raised and the angle of inclination to the horizontal at which the sample started sliding was read off the protractor attached to the apparatus. The tangent of the angle was reported as the coefficient of friction (Dutta et al., 1988).

In order to estimate the walnut mass from dimensions characteristics, projected area and volume, three classifications of models were considered as follows:

(1) Single or multiple variable regressions of nut dimension characteristics: length (a), width (b) and thickness.
(2) Single or multiple variable regressions of nut projected areas: PA, PB and PC.
(3) Single regression of nut volume: actual volume, volume of the nut assumed as oblate spheroid and ellipsoid shape.

In the case of first classification, mass modeling was accomplished with respect to length, width and thickness as following:

$$M = k_1 a + k_2 b + k_3 c + k_4 \tag{3}$$

In some instances only one or two diameters may adequately predict. The appropriateness of using one, two or three diameters can be compared by examining the R^2.

In second classification models, mass modeling of walnut was estimated based on mutually perpendicular projected areas as following:

$$M = k_1 \mathrm{PA}_1 + k_2 \mathrm{PA}_2 + k_3 \mathrm{PA}_3 + k_4 \tag{4}$$

In this classification, the mass can be estimated as a function of one, two or three projected area (s), too.

In the case of third classification, to achieve the models which can predict walnut mass on the basis of volumes, three volume values were measured or calculated. At first, actual volume (V_{m}) as stated earlier was measured then the nut shape was assumed as a regularly geometrical shape, i.e. prolate spheroid (V_{psp}) and ellipsoid (V_{ell}) shapes and thus their volume (cm^3) were calculated as:

$$V_{\mathrm{psp}} = \frac{4\pi}{3}\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)^2 \tag{5}$$

$$V_{\mathrm{ell}} = \frac{4\pi}{3}\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)\left(\frac{c}{2}\right) \tag{6}$$

In this classification, the mass (M) can be estimated as either a function of volume of supposed shape or the measured volume as

Table 1
Property means comparison between four walnut genotypes using Duncan's method.

Property	Genotype				
	G-536	G-564	G-570	G-572	
Major diameter (a)	36.22^{a*}	41.9^{c}	40.68^{b}	44.02^{d}	
Intermediate diameter (b)	34.01^{a}	35.02^{b}	35.12^{b}	34.70^{ab}	
Minor diameter (c)	32.62^{a}	33.67^{b}	33.30^{ab}	33.60^{b}	
First projected area (PA)	837.2^{a}	877.11^{b}	872.28^{ab}	862.36^{ab}	
Second projected area (PB)	917.45^{a}	1087.58^{c}	1001.80^{b}	1101.09^{c}	
Third projected area (PC)	970.76^{a}	1124^{c}	1046.38^{c}	1163.18^{c}	
Mean mass (g)	14.90^{c}	10.79^{a}	11.30^{ab}	12.32^{b}	
Mean volume (mm^3)	25.34^{c}	16.60^{a}	19.38^{b}	19.65^{b}	
Nut bulk density (cm^3)	0.597^{ab}	0.592^{b}	0.611^{b}	0.564^{a}	
Kernel density (cm^3)	0.854^{a}	0.916^{b}	0.941^{c}	0.986^{d}	
Static friction coefficient of nuts	Galvanized steel sheet	14.67^{a}	19.33^{c}	18.00^{b}	15.00^{a}
	Glass sheet	14.33^{c}	10.67^{a}	12.00^{b}	17.33^{a}
	Plywood sheet	16.33^{a}	18.00^{a}	17.67^{a}	16.00^{a}
	Fiberglass sheet	26.00^{c}	21.67^{b}	20.00^{a}	21.33^{ab}
Static friction coefficient of kernel	Galvanized steel sheet	19.67^{ab}	b 20.33	20.00^{ab}	19.00^{a}
	Glass sheet	14.00^{c}	d 15.33	10.67^{a}	12.00^{b}
	Plywood sheet	20.33^{a}	b 22.33	21.67^{b}	19.67^{a}
	Fiberglass sheet	24.33^{c}	b 20.67	18.33^{a}	20.33^{b}
Geometric mean diameter (mm)	34.25^{a}	36.72^{bc}	36.23^{b}	37.16^{c}	
Sphericity	0.94^{a}	0.876^{b}	0.9^{c}	0.844^{b}	
Surface area (mm^2)	908.37^{a}	1032.68^{c}	979.49^{b}	1042.21^{c}	
Shell ratio	0.631^{c}	0.580^{b}	0.569^{b}	0.509^{a}	

*Numbers with similar letter in each row are not significant by DMRT at 5% level.

represented in following expressions:

$$M = k_1 V_{\rm m} + k_2 \quad (7)$$

$$M = k_1 V_{\rm psp} + k_2 \quad (8)$$

$$M = k_1 V_{\rm ell} + k_2 \quad (9)$$

Packages of statistical programs, available on both main frame and personal computers, can perform such regression analysis. Many spreadsheet programs also can perform multiple regressions. When evaluating the usefulness of such regression analyses, it is necessary to know how well the data fit the model. One measure of the goodness of fit is the value of the coefficient of determination which is usually designated as R^2. For regression equations in general, the nearer R^2 is to 1.00, the better the fit (Stroshine and Hamann, 1994). If values of k_i exactly predict the mass, then R^2 would be equal to 1.00. Win-Area-Ut_06 software was used to analyze data and determine regression models between the physical attributes.

3. Results and discussions

Data regarding mean values, standard deviation, and coefficient of variation for various nut and kernel characters in studied genotypes are presented in Table 1. A summary of some selected morphological and physical characteristics of the studied walnut genotype is presented in Table 2. Also, a total of 10 regression models in three different categories were classified. Coefficient of determination (R^2), regression standard error (R.S.E.), and models obtained from the data for the studied walnut genotypes are shown in Table 3.

3.1. First classification models, dimension

Among the model Nos. 1–3, model number 3 for walnut genotypes Nos. 536, 570, and 572 and model number 2 for genotype No. 564 had higher R^2 and lower R.S.E. than the other models.

11 models for predicting mass of apples based on geometrical attributes were recommended by Tabatabaeefar and Rajabipour (2005). They recommended an equation calculating apple mass on the basis of minor diameter as $M = 0.08c^2 - 4.74c + 5.14$, $R^2 = 0.89$.

Table 2
Descriptive analysis of examined traits in walnut genotypes.

Trait	Unit	Min	Max	Mean	Standard deviation	Coefficient of variation%
Seed shape	(1–9)[a]	1	6	4	1.95	51.31
Fruit diameter	mm	34	38	36.16	8.08	8.94
Fruit length	mm	34.5	44	39.75	11.26	9.07
Shell thickness	mm	0.1	0.18	0.115	0.03	26
Tegument thickness	(1–9)[b]	1	5	2	1.8	90
Seed weight	g	12.46	16.72	13.97	1.17	8.37
Kernel weight	g	6.64	9.7	8.15	0.8	9.81
Kernel length	mm	29.5	36	32.37	1.88	5.8
Kernel width	mm	24	32	29.45	2.32	7.87
Shell weight	g	4.21	8.36	5.82	1	17
Kernel color	(1–4)[c]	1	3	2	1	50

[a] 1–9: globular to heart shape.
[b] 1–9: thin to thickness.
[c] 1: completely bright, 2: bright, 3: amber bright, 4: amber to brown.

Table 3
Models, coefficient of determination (R^2) values and regression standard error in studied walnut genotypes.

Model no.	Models	G-536		G-564		G-570		G-572	
		R^2	R.S.E.	R^2	R.S.E.	R^2	R.S.E.	R^2	R.S.E.
1	$k_1a + k_2$	0.575	30.34	0.474	30.85	0.402	32.79	0.466	32.57
2	$k_1b + k_2$	0.820	13.10	0.831	11.58	0.743	17.48	0.775	16.50
3	$k_1c + k_2$	0.800	14.61	0.805	13.97	0.823	11.62	0.810	13.73
4	$k_1\text{PA} + k_2$	0.879	5.33	0.861	8.19	0.869	6.64	0.866	7.60
5	$k_1\text{PB} + k_2$	0.860	7.68	0.860	8.32	0.864	7.23	0.861	8.30
6	$k_1\text{PC} + k_2$	0.850	7.99	0.847	9.85	0.869	6.60	0.861	8.28
7	$k_1\text{PA} + k_2\text{PB} + k_3\text{PC} + k_4$	0.882	3.24	0.873	6.72	0.892	2.59	0.984	4.74
8	$k_{1V} + k_2$	0.890	2.48	0.891	3.91	0.895	3.47	0.993	3.10
9	$k_{1V_{ell}} + k_2$	0.850	9.93	0.827	11.99	0.820	11.88	0.926	12.19
10	$k_{1V_{os}} + k_2$	0.762	19.07	0.698	21.28	0666	21.84	0.794	21.76

a: major diameter (mm), *c*: minor diameter, *d*: seed diameter mean (mm), PA: first projected area (mm^2), PC: third projected area (mm^2), *V*: volume (cm^3), V_{ell} (cm^3) ellipsoide volume, V_{os}: oblate volume (cm^3).

In another study, 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 $M = 2.93b - 64.15$, $R^2 = 0.78$.

3.2. Second classification models, projected areas

Among the linear regression projected area models (Nos. 4–7), model number 7, shown in Table 2, for all walnut genotypes had higher R^2, and lower R.S.E. than the other models.

The mass model recommended for sizing kiwi fruits based on any one projected area was reported by Lorestani and Tabatabaeefar (2006) as

$$M = 1.098(PC)^{1.273}, \quad R^2 = 0.97.$$

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 projection area; therefore, model using only one projection area, possibly model 4 can be used.

3.3. Third classification models, volume

Among the models in third classification (models 8–10), the R^2 for model 8 had maximum value and minimum R.S.E. Among the models 9 and 10, the model 9 for the walnut genotypes had the highest R^2 value and the lowest R.S.E. Therefore, model 9 was recommended for predicting walnut mass of the studied genotypes.

Tabatabaeefar (2002) determined physical properties of common varieties of Iranian grown potatoes. Relationships among physical attributes were determined and a high correlation was found between mass and volume of mixed potatoes with a high coefficient of determination as:

$$M = 0.93V - 0.6, \quad R^2 = 0.994.$$

In an experiment conducted by Khoshnam et al. (2006), the mass model of overall pomegranates based on measured volume was reported as:

$$M = 0.96V + 4.2, \quad R^2 = 0.99.$$

Measuring of actual volume is time consuming task, therefore mass modeling based on is not reasonable; consequently it seems suitable to mass modeling of studied walnut genotypes be accomplished based on volume of assumed prolate spheroid shape (model number 11).

In the end of this paper, it can be point out those morphological and physical properties of the studied walnut genotypes can be a subject of interest to horticultural scientist for breeding tasks and farm machinery engineers for efficiently equipment design for walnut postharvest operations. Also, the best models obtained are valuable information in sorting and sizing the tested walnut genotypes based on their weight. Finally, it is recommended that volume modeling and sorting based on image processing to be studied for walnut genotypes considered in this research and other genotypes most common in Iran that these researches significantly can help to better walnut export to other countries.

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