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Mass modeling of two apple varieties by geometrical attributes

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Abstract

In this study mass of two Iranian apple varieties (*Golab Kohanz* and *Shafi Abadi*) were predicted using different physical characteristics in linear models as three different classifications: (1) single or multiple variable regressions of apple dimensional characteristics. (2), single or multiple variable regressions of apple projected areas and (3), estimating apple mass based on its volume. All properties considered in the current study were found to be statistically significant at the 1% probability level. The performance of the models was evaluated by a set of test data using three different measures including the root mean square error (*RMSE*), the coefficient of determination (R^2) and the mean error (*ME*) between predicted and measured values. In the first classification among single variable models the model based on width (M= 3.29W-116.25) had maximum coefficient of determination, R^2=0.91 for *Golab Kohanz* variety and the model based on thickness (M=3.29T-118.06) had maximum coefficient of determination, R^2=0.91 for *Shafi Abadi* variety, respectively. Among all of single variable models, the mass model based on actual volume was the best model for both varieties. For multiple variable regression models the best models were based on three dimension and three projected areas for all observation.

Keywords: *Golab Kohanz*; Mass modeling; physical properties; *Shafi Abadi*; stepwise method

Abbreviations: CPA_criteria projected area; Dg_geometric mean diameter; GK_Golab Kohanz; K_regression constant; k_1, k_2 and k_3_regression coefficients; L_length of fruits; M_fruit mass; ME_mean error; PA_L_projected area perpendicular to L; PA_T_ projected area perpendicular to T; PA_W_projected area perpendicular to W; RI_relative improvement (%); RMSE_root mean square error; S_surface area; SA_Shafi Abadi; T_thickness of fruit; V_{ellip}_volume of ellipsoid; V_m_fruit Volume; V_{osp}_volume of oblate spheroid; W_width of fruit; R^2_determining coefficient

Introduction

Apple is a tree and its pomaceous fruit, of species *Malus domestica* Borkh. in the rose family *Rosaceae*, is one of the most widely cultivated tree fruits. There are more than 7,500 known cultivars of apples (Kheiralipour *et al*., 2008). It is consumed in different forms, such as fresh fruit, concentrated juice or thin dried slices. Apples contain a high percentage of their fresh weight as water. *Golab Kohanz* and *Shafi abadi* are two Iranian apple varieties which are cultivated in northern regions of Iran (cities as *Damavand*, *Firooz Kooh*, *Karaj* and *Shahria*r). Annual apple production in Iran is 2.66 mln t, which is ranked as 3th in the world, next of China and United States of America countries (FAO, 2007). Iranian apple are not exported because of variance in size and shape and lack of proper packaging (Safwat, 1971). 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 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 their relationships must be known. For instance, fruits are often graded by size, but it may be more economical, which grades by weight (Peleg *et al*., 1985). Therefore, the relationship between weight and geometric attributes is needed (Khoshnam *et al*., 2007). In nearly all cases raw product grades are based on weight (O'Brian and Floyd, 1978). Size and shape determine the number of fruits that can be placed in containers with given size. Volume and surface area could be beneficial in proper prediction drying rates and hence drying time in the dryer. Physical characteristics of agricultural products are the most important parameters to determine the proper standards of design of grading, conveying, processing and packaging systems (Tabatab-aeefar and Rajabipour, 2005). Among these physical characteristics, mass, volume and 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.

Table 1. Selected physical properties of the two apple varieties (*Golab Kohanz*, *Shafi Abadi*)

Properties	Number of observations	*Shafi Abadi*			*Golab Kohanz*			Significant level
		Max	Min	Mean±SD	Max	Min	Mean±SD	
Moisture , %w.b	3	84.7	83.5	83.9±0.7[b]	86	84.94	85.61±0.58[a]	*
Fruit mass, (g)	100	123.13	44.11	75.67±14.42[a]	97.33	46.61	64.22±13.2[b]	*
Fruit length, (mm)	100	62.77	43.05	53.09±3.86[a]	60.32	44.41	51.56±3.82[b]	*
Fruit width, (mm)	100	71.6	51.8	59.37±3.83[a]	64.28	48.85	54.86±3.83[b]	*
Fruit thickness, (mm)	100	67.6	46.36	57.02±3.97[a]	63.76	40.41	53.03±3.98[b]	*
Projected area, (mm^2)								
PA_L	100	4191	1969	2912±421.88[a]	3196	1509	2305.87±327.75[b]	*
PA_W	100	3975	1832	2798.74±425.17[a]	3035	1428	2232.77±297.55[b]	*
PA_T	100	4037	1982	2862.9±404.6[a]	3002	1648	2300.17±310.02[b]	
Surface area (mm^2)	100	14197	6920.1	10041.8±1321.2[a]	12121	7055.6	8902.1±1214.5[b]	*
Geometric mean diameter, (mm)	100	67.22	46.93	56.41±3.67[a]	62.11	47.4	53.11±3.58[b]	*
Fruit volume, cm^3	100	165.33	57.14	99.94±20.03[a]	128.34	58.93	82.8±17.62[b]	*

*Corresponding to 1% significance level; a and b: means followed by different letters are significantly different from others (P<0.01).

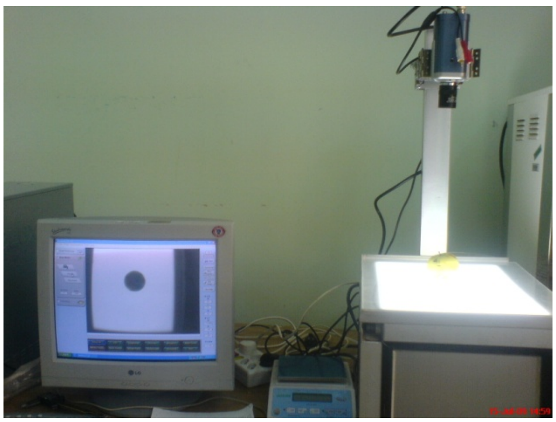

Fig 1. Apparatus used for determing projected areas

Based on the literature, the regression analysis was 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). Since electrical sizing mechanisms are expensive and mechanical sizing mechanisms react poorly (Tabatabaeefar and Rajabipour, 2005).

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. 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 potato with a high coefficient of determination. In another study, Tabatabaeefar and Rajabipour (2005) recommended 11 models for predicting mass of apples based on geometrical attributes, but the their suggestion models were non-linear (cubic or quadratic) and this problem makes difficult calculation of mass and complicates design of grading machine. For example, they suggested, the best equation to calculate mass is a quadratic equation based on the intermediate diameter (b) for all varieties ($M=0.08b^2-4.74b+5.14$). Mirzaee *et al* (2008) considered mass modeling of two varieties of apricot with some physical characteristics and suggested linear and nonlinear models for apricot mass. In the most of previous studies, because of only determination coefficient of linear models has been a little lesser than determination coefficient of non-linear models, therefore researchers have mostly reported non-linear models.

In previous studies, the equation used for modeling the fruit mass were nonlinear (Tabatabaeefar and Rajabipour, 2005) so it caused more complicated calculations. But the models used in this study are all simple linear models with high determination coefficient.

The objective of this research was to determine some morphological characteristics and presentation of Single or multiple variable regressions of apple mass based on its some physical attributes. This information is used to design and develop the sizing systems.

Materials and methods

The Iranian apple varieties consisted of *Golab Kohanz* and *Shafi Abadi* were obtained from orchard located in Karaj, Iran (30 km far from Tehran Province) in July 2009. The 100 fruits of each variety were tested in the Biophysical laboratory and Biological laboratory of University of Tehran, Karaj, Iran. The physical properties of apples such as mass, volume, dimensions and projected area were measured. The initial moisture contents of the fruits were determined using the oven dry method, at 77°C for 10 days (Kheiralipour *et al*., 2008). Fruit mass (M) was determined with an electronic balance with 0.1 g sensitivity. Its volume was measured by the water displacement method (Akar and Aydin, 2005; Aydin and Musa Ozcan, 2007). To determine the average size of the fruits, three linear dimensions, namely length (L); equivalent distance of the stem (top) to the calyx (bottom), width (W); the longest dimension perpendicular to L, and thickness (T); the longest dimension

Table 2. The get models for mass based on selected attributes for *Golab Kohanz* variety

No.	Models	R^2	RMSE	ME	RI (%)
1	$M = k_1 W + K$	0.91	3.86	0.00	34
2	$M = k_1 W + k_2 L + K$	0.93	3.31	0.00	43
3	$M = k_1 W + k_2 L + k_3 T + K$	0.94	3.13	0.01	47
4	$M = k_1 PA_T + K$	0.79	5.87	-0.19	0.6
5	$M = k_1 PA_T + k_2 PA_W + K$	0.81	5.73	0.91	3
6	$M = k_1 PA_T + k_2 PA_W + k_3 PA_L + K$	0.82	5.63	0.91	4
7	$M = k_1 S + K$	0.93	5.39	4.24	8
8	$M = k_1 CPA + K$	0.79	5.91	0.42	0
9	$M = k_1 D_g + K$	0.93	3.46	0.00	41
10	$M = k_1 V_m + K$	0.98	1.58	-0.03	73
11	$M = k_1 V_{ellip} + K$	0.94	3.15	0.02	46
12	$M = k_1 V_{osp} + K$	0.84	5.2	0.03	12

perpendicular to *L* and *W*, were measured by using a digital caliper with accuracy of 0.01 *mm*.
Geometric mean diameter (D_g) and surface (S) areas were calculated by using Eqs (1) and (2) respectively as reported by Mohsenin (1986) and Kabas *et al*. (2006).

$$D_g = \sqrt[3]{LWT} \quad (1)$$

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

Projected area PA_L, PA_W and PA_T of each apple which are perpendicular to *L*, *W* and *T*, respectively, were recorded with an accuracy of 0.05 *mm* using a device with Win Area-UT-06 soft ware (Mirasheh, 2006). The device (Fig. 1) is composed of the following:
1. Sony camera, model CCD-TRV225E.
2. Light chamber, an assembly constructed to provide an environment for taking photos of the desired quality.
3. Capture card Win Fast, model DV 2000.
4. Software, written in Visual Basic 6.0.
The basic operating principle of this equipment set is using ‘image processing’. Light emitting chamber is so designed as to emit light from behind the fruit. The equipment set is, as a whole, composed of the three different basic sections of light source, diffuser, and camera holding stand. The function of the light source (4, 20W lamps) is to emit light to the bottom section of the diffuser. The diffuser task is to diffuse light at its Owen level. The overall operation of the equipment set is as follows:

- The image coming from the camera is transferred to the capture card.
- The function of the card is to change the analogue image into a digital one.
- The digitized image is transmitted to the image processing window by computer software.

The equipment set, through the processing of 3 orthogonal images of the fruit, determines the large, medium, and small diameters together with the areas along these diameters. The outcome is presented in the display window. The equipment error for objects that occupy at least 5% of the viewing scope of the camera is below 2%.

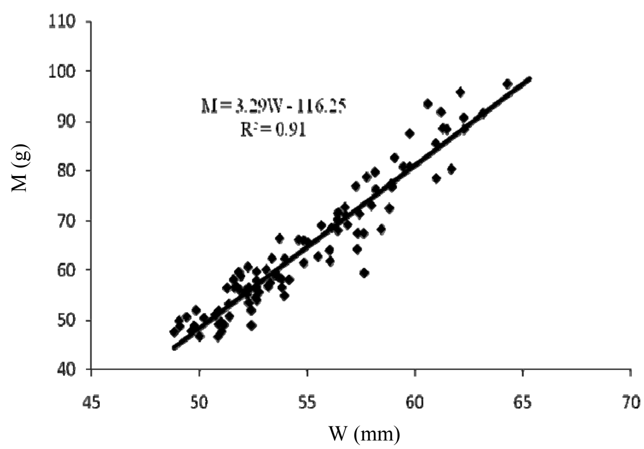

Fig 2. Mass model of apple based on width dimension for *Golab Kohanz* variety.

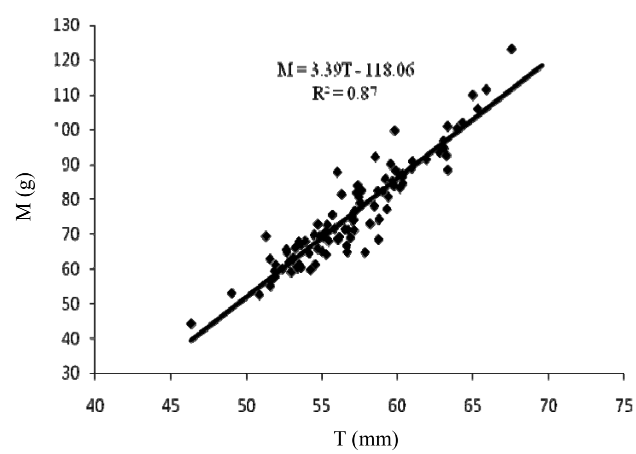

Fig 3. Mass model of apple based on thickness dimension for *Shafi Abadi* variety

Table 3. The get models for mass based on selected attributes for *Shafi Abadi* variety

No.	Models	R^2	RMSE	ME	RI (%)
1	$M = k_1 T + K$	0.87	5.08	0.01	5
2	$M = k_1 T + k_2 L + K$	0.91	4.11	-0.01	23
3	$M = k_1 T + k_2 L + k_3 W + K$	0.93	3.54	0.00	34
4	$M = k_1 PA_T + K$	0.93	3.83	1.36	28
5	$M = k_1 PA_T + k_2 PA_W + K$	0.94	3.33	-0.2	37
6	$M = k_1 PA_T + k_2 PA_W + k_3 PA_L + K$	0.94	3.3	-0.74	38
7	$M = k_1 S + K$	0.94	5.37	4.07	0
8	$M = k_1 CPA + K$	0.94	3.39	-0.7	36
9	$M = k_1 D_g + K$	0.93	3.58	-0.02	33
10	$M = k_1 V_m + K$	0.95	2.96	0.04	44
11	$M = k_1 V_{ellip} + K$	0.94	3.45	0.02	35
12	$M = k_1 V_{osp} + K$	0.88	4.86	-0.01	9

The criteria projected area (*CPA*) was determined from Eq. (3):

$$CPA = \frac{PA_L + PA_W + PA_T}{3} \qquad (3)$$

In order to estimate the apple mass from dimensions, projected areas and volume, the following three classifications of models were suggested.

1. Single or multiple variable regressions of apple mass based on apple dimensional characteristics: length (*L*), width (*W*), thickness (*T*) and geometric mean diameter (D_g), which the mass can be estimated as a function of one, two and three dimensions.
2. Single or multiple variable regressions of apple mass based on projected areas (PA_L, PA_W and PA_T), surface area (*S*) and criteria projected area (*CPA*).
3. Single regression of apple mass based on 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, at first, actual volume (V_m) as stated earlier was measured, but because of measuring of actual volume is time consuming task, therefore apple shape was assumed as a regular geometric shape *ie* oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes, and were calculated as:

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

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

The performance of the models was evaluated by a set of test data using three different measures including the root mean square error (*RMSE*), the coefficient of determination (R^2) and the mean error (*ME*) between predicted and measured values (Amini *et al*., 2005).

The *RMSE* is a measure of accuracy and reliability for calibration and test data sets, respectively (Cihan *et al*., 2007) and is defined as:

$$RMSE = \left[\frac{1}{n}\sum_{I=1}^{n}(M_{pre,i} - M_{\exp,i})^2\right]^{1/2} \qquad (6)$$

The *ME* is a measure of bias and reveals the overestimation or underestimation:

$$ME = \frac{1}{n}\sum_{I=1}^{n}(M_{pre,i} - M_{\exp,i}) \qquad (7)$$

where $M_{pre,i}$ is the *i*th predicted mass , $M_{exp,i}$ is the *i*th experimental mass, *n* is the number of observations.
To compare the performance of any two models M_i and M_j with respect to M_i, a relative improvement (*RI*) was calculated:

$$RI = \frac{RMSE_{Mi} - RMSE_{Mj}}{RMSE_{Mi}} \times 100 \qquad (8)$$

where $RMSE_{Mi}$ is highest root mean square error relative to *i*th model and $RMSE_{Mj}$ is the root mean square error relative to *j*th model.

SPSS-17 software and stepwise method (linear regression) was used to analyze the data and to determine regression models. The overall models are based on the following equation:

$$Y = K + k_1 X_1 + k_2 X_2 + ,...,+ k_n X_n \qquad (9)$$

where: Y is dependent variable, e.g. in this investigation, mass, *M (g); X_1, X_2,…, X_n* are independent variables, for example physical dimension (*L, W, T, PA_L, PA_W,…*); *k_1, k_2,…, k_n* are regression coefficients; *K* is constant of regression. In stepwise method, the independent variables, based upon their degree of dependency, are put in the equation one after one until the mass model is significant at 5% level or lower (Kalantari, 2004). The data relative to physical properties were analysed using the analysis of variance (ANOVA) test, and means were compared using Duncan's multiple range tests at 5% level of significance.

Results and discussion

A summary of the physical and properties of *Golab Kohanz* and *Shafi Abadi* varieties is shown in Table 1. These properties were found at specific fruit moisture contents of apples (*Golab Kohanz* and *Shafi Abadi*) at 86 and 84% (w.b), 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 *Shafi Abadi* variety were significantly greater than that of the *Golab Kohanz* variety. The models were derived through stepwise method and on the basis of the selected attribute together R^2, *RMSE*, *ME* and *RI* are presented in Table 2 and 3 for *Golab Kohanz* and *Shafi Abadi* varieties, respectively.

First classification models, dimensions

Among the model Nos. 1-3, shown in tables 2 and 3, Model 3 for any two varieties had higher R^2 and lower *RMSE* than Models 1 and 2 while for this model, measurement of three diameters is needed, which make the sizing mechanism more tedious and expensive. The apple mass models for GK and SA based on model 3 (using all three diameters) are given in Eqs.10 and 11, respectively:

$$M = 2.03W + 0.79L + 0.69T - 125.33 \quad (10)$$

$$M = 1.22T + 1.13L + 1.43W - 139.96 \quad (11)$$

Among mass models on basis dimensions with single variable, the models based on width (*W*) is best for GK variety and model based on thickness (*T*) is best for SA variety (as shown in Figs. 2 and 3), respectively, which are as following equations:

$$M = 3.29W - 116.25 \quad (12)$$

$$M = 3.39T - 118.06 \quad (13)$$

The mass models based on geometric mean diameter for GK and SA varieties are given in equations 14 and 15, respectively:

$$M = 3.55D_g - 124.37 \quad (14)$$

$$M = 3.79D_g - 138.68 \quad (15)$$

Tabatabaeefar and Rajabipour (2005) reported an equation calculating apple mass (mixed variety) on the basis of intermediate diameter (b) as $M = 0.08b^2 - 4.74b + 5.14$, which is quadratic while the recommended models in the form of Eqs. 12 and 13at above are single variable and linear.

Second classification models, projected areas

Among the second classification model Nos. 4– 6, shown in Tables 2 and 3, the Model 6 for GK and SA varieties had maximum R^2 value and minimum *RMSE*. The mass models

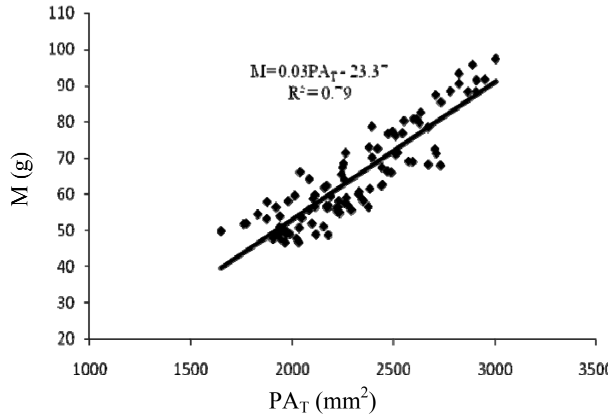

Fig 4. Mass model of apple based on projected area perpendicular to T (PA_T), for *Golab Kohanz* variety

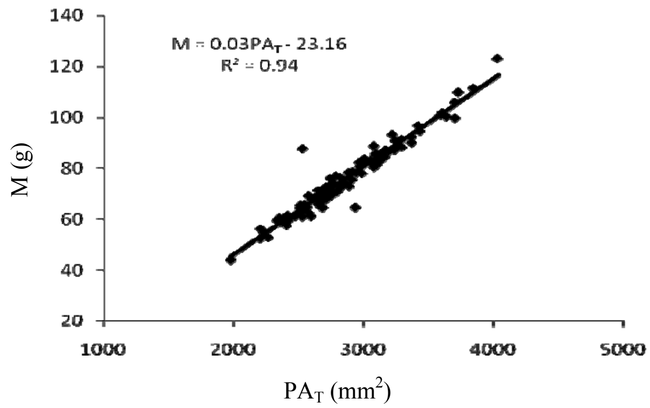

Fig 5. Mass model of apple based on projected area perpendicular to T (PA_T), for *Shafi Abadi* variety

based on three projected areas (Model 6) for GK and SA varieties are given in equations 16 and 17, respectively:

$$M = 0.02PA_T + 0.01PA_W - 0.001PA_L - 25.78 \quad (16)$$

$$M = 0.01PA_T + 0.01PA_W + 0.006PA_L - 21.8 \quad (17)$$

According to stepwise method, among mass models on basis projected areas with single variable, the models base on PA_T were the best models for GK and SA varieties (as shown in Figs. 4 and 5), which are given in equations 18 and 19, respectively:

$$M = 0.03PA_T - 23.37 \quad (18)$$

$$M = 0.03PA_T - 23.16 \quad (19)$$

Tabatabaeefar and Rajabipour (2005) reported an equation calculating apple mass (mixed variety) on the basis of projected area of minor diameter as $M = 0.009(PA_3)^2 + 3.4PA_3 - 15.7$, which is quadratic while the recommended models in the form of Eqs. 18 and 19at are single variable and linear.

According the Model 7 and 8 in tables 2 and 3, two mass models were predicted based on surface area (*S*) and criteria projected area (*CPA*) for GK and SA varieties that are given in equations 20-23 (Eqs. 20 and 22 related to GK variety and 21 and 23 related to SA variety):

$$M = 0.01S - 29.45 \quad (20)$$
$$M = 0.01S - 30.7 \quad (21)$$
$$M = 0.03CPA - 24.25 \quad (22)$$
$$M = 0.03CPA - 22.19 \quad (23)$$

Each one of the three projected areas can be used to estimate the mass. However models with multiple variables make the sizing mechanism more complex and expensive in order to capture all the projected areas and have one R^2 value close to unity or even lower than R^2 for only one projection area. Therefore, a model using only one projection area, possibly Model 4 can be used.

Third classification models, volume

Among the models in third classification (Models 10–12, as shown in tables 2 and 3), the R^2 for Model 10 had maximum value and minimum *RMSE*. 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 apples be accomplished based on volume of assumed ellipsoid shape (Model 11). Among the Models 11 and 12, the Model 11 for the apple varieties had the highest R^2 value and the lowest *RMSE*. Therefore, Model 11 was recommended for predicting apple mass. The equations 24 and 25 were predicted for Gk and SA varieties, respectively:

$$M = 0.78V_{ellip} + 2.22 \quad (24)$$
$$M = 0.73V_{ellip} + 5.52 \quad (25)$$

The model 8 for GK variety and the model 7 for SA variety were assumed as base models for calculation of relative improvement (RI). The RI results are presented in tables 2 and 3. For example GK variety, the mass model based on width (model 1) is more improved (34%) than mass model based on criteria projected area (CPA).
By this study, it is possible to say that physical properties and the mass models for the apple could be useful for farm machinery engineers to design equipments efficiently for apple postharvest operations. Also, the obtained models have valuable application for sorting and grading of apple.

Conclusions

Some physical properties and their relationships of mass of *Golab Kohanz* and *Shafi Abadi* apple 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 *Shafi Abadi* variety were significantly greater than that of the *Golab Kohanz* variety.
2. The best single variable model for prediction the mass of *Golab Kohanz* variety based on dimension was predicted as: M=3.29W-116.25 with determination coefficients of 0.91 and corresponding model for *Shafi Abadi* variety was M=3.39T-118.06, R^2=0.87.
3. The best single variable model for prediction the mass of *Golab Kohanz* variety based on projected area was predicted as: M=0.03PA_T-23.37 with determination coefficients of 0.79 and corresponding model for *Shafi Abadi* variety was M=0.03PA_T -23.16, R^2=0.93.
4. The model which predicts mass of apples based on estimated volume, the shape of apples considered as ellipsoid volume was found to be the most appropriate (Model 11 is recommended for any two varieties).
5. At last, mass Model 1 from economical standpoint is recommended for any two varieties because of it is a single variable linear model.

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References

Akar R, Aydin, C (2005) Some physical properties of Gumbo fruit varieties. Food Eng J 66: 387–393
Al-Maiman S, Ahmad D (2001) Changes in Physical and Chemical Properties during Pomegranate Fruit Maturation. Food Science & Nutrition Depart, King Saud University
Amini M, Abbaspour K.C, Khademi H, Fathianpour N, Afyuni M, Schulin R (2005) Neural network models to predict cation exchange capacity in arid regions of Iran. Soil Science Euro J 56: 551-559
Musa Ozcan M (2007) Determination of nutritional and physical properties of myrtle (*Myrtus Communis* L.) fruit growing wild in Turkey. Food Eng J 79: 453–458
Chuma Y, Uchida S, Shemsanga HH (ed) (1982) Simultaneous measurement of size, surface area, and volume of grains and soybean. Trans ASAE 25(6): 1752-1756
Cihan A, Kahveci K, Hacihafizoĝlu (2007) Modelling of intermittent drying of thin layer rough rice. Food Eng J 79: 293-298
FAO (2007) FAOSTAT database. Available at: http://faostat.fao.org/
Frechette R, Zahradnik J (1968) Thermal properties of Mc Intosh apple. Trans ASAE 11: 21–24
Janatizadeh A, Naderi Boldaji M, Fatahi R, Ghasemi Varnamkhasti M, Tbatabaeefar A (2008) Some Post harvest Physical Properties of Iranian apricot fruit. Int agrophysics 22: 356- 363
Kabas O, Ozmerzi A, Akinci I (ed) (2006) Physical properties of cactus pear (*Opuntia ficus India* L.) grown wild in Turkey. Food Eng J 73 (2): 198–202
Kalantari Kh (2004) Data analysis in social and economical searchs, 1rd edn. Sharif, Tehran
Kheiralipour K, Tabatabaeefar, Mobli H, Rafiee S, Sharifi M, Jafari A, Rajabipour A (2008) Some physical and hydrodynamic properties of two varieties of apple (Malus domestica Borkh L.). Int Agrophysics 22: 225-229
Khodabandehloo H (1999) Physical properties of Iranian export apples. M.Sc Thesis, University of Tehran, Karaj, Iran
Khoshnam F, Tabatabaeefar A, Ghasemi Varnamkhasti M, Borghei A (2007) Mass modeling of pomegranate

(*Punica granatum* L.) fruit with some physical characteristics. Sci Horticulture 114: 21–26

Meisami-asl E, Rafiee S, Keyhani A, Tabatabaeefar A (2009)

Mirasheh R (2006) Designing and Making Procedure for a Machine Determining Olive Image Dimensions. M.Sc Thesis, Faculty of Biosystems Engineering, University of Tehran, Karaj, Iran

Mirzaee E, Rafiee S, Keyhani A.R, Emam jom-eh Z, Kheiralipour.K (ed) (2008) Mass modeling of two varieties of apricot (*prunus armenaica* L.) with some physical Characteristics. Plant Omics J 1(1): 37-43

Mohsenin NN (1986) Physical Properties of Plant and Animal Materials. Gordon and Breach, New York

O'Brian M, Floyd S (1978) A micro computer controlled weighing and print out system for fruit and vegetable grading. Trans ASAE 16: 446-450

Peleg, K (1985) Produce Handling, Packaging and Distribution. The AVI Publishing Company. Inc, Westport, Connecticut, pp. 20–90

Peleg K, Ramraz Y (ed) (1975) Optimal sizing of citrus fruit. Trans ASAE 18 (6): 1035–1039

Safwat MA, Moustafa M (ed) (1971) Theoretical prediction of volume, surface area, and center of gravity for agricultural products. Trans ASAE 14(4): 549-553

Sitkei G (1986) Mechanics of Agricultural Materials. Elsevier Publisher, p 25

Tabatabaeefar A (ed) (2002) Sizeandshapeofpotatotubers. Int Agrophysics 16(4):301–305

Tabatabaeefar A, Rajabipour A (2005) Modeling the mass of apples by geometrical attributes. Sci Horticulture J 105: 373–382

Tabatabaeefar A, Vefagh-Nematolahee A, Rajabipour A (2000) Modeling of orange mass based on dimensions. Agric Sci Tech 2: 299–305