MASS AND VOLUME MODELING OF LOQUAT (*Eriobotrya japonica* LINDL.) FRUIT BASED ON PHYSICAL CHARACTERISTICS

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A B S T R A C T

There are instances in which it is desirable to determine the relationships between various physical attributes of fruit. For example, fruits are often graded on the basis of size and projected area, but it may be more economical to develop a machine which would grade by mass or volume. Therefore, the relationships between mass/volume (either mass or volume) and other physical attributes of fruit are needed. In this study, three Iranian local varieties of loquat fruits were selected and the various models for predicting mass/volume of loquat fruit from its dimensions, projected area and volume/mass were established. The models were divided into three classes: 1. single and multiple variable regressions of loquat fruit dimensions, 2. single and multiple variable regressions of projected areas, 3. estimating loquat fruit mass/volume based on its volume/mass. The results revealed that mass and volume modeling on the basis of intermediate diameter, on any projected area, and the measured volume are the best models. Based on the results, mass and volume modeling, respectively on the basis of the actual volume and one projected area, were identified as the best models. The highest determination coefficient in all the models was obtained for mass modeling based on measured volume as R^2 = 0.99. Finally, volume modeling from an economical standpoint was recommended as the most reliable modeling.

Key words: loquat fruit, physical characteristics, mass/volume, modeling, grading

Nomenclature:
A – major diameter (mm)
B – intermediate diameter (mm)
C – minor diameter (mm)
CPA – criteria projected area (mm^2)
GMD – geometric mean diameter (mm)
K_i – regression coefficient
M – mass (g)
M_m – measured mass (g)
PA_1 – first projected area (mm^2)
PA_2 – second projected area (mm^2)
PA_3 – third projected area (mm^2)
R^2 – coefficient of determination
S – surface area of fruit (cm^2)
V – volume (cm^3)
V_m – measured volume (cm^3)
V_{ellip} – volume of ellipsoid (cm^3)
V_{osp} – volume of oblate spheroid (cm^3)
π – constant (3.142)

INTRODUCTION

The loquat is an edible fruit (*Eriobotrya japonica* Lindl.) that belongs to the Rosaceae family (Badenes et al., 2000). Its reported composition (fresh weight basis) is: water 78.0%, carbohydrates 10.6%, fiber 10.2%, fat 0.5%, protein 0.4% and other components 0.3%. The world production of loquat in 2006 is estimated at 550 000 t (Lin, 2007; Soler et al., 2007). In Iran, loquat is mainly cultivated in Guilan, Mazandaran, Golestan, Zanjan, Qom and Fars provinces, and the annual production was about 1200 t of fruits in 2006)anonymous, 2006(.

Physical properties of fruit are important in designing and fabriccating equipment and structures for handling, transporting, processing and storage, and also for assessing quality. (Khoshnam et al. 2007). Fruits are often graded by size, but it may be more economical to develop a machine which grades by weight and density. In recent years, there has been interest in video-based dimensional sizing of agricultural products (Miller, 1990). Sizing by a weighing mechanism is recommended for the irregular shaped products (Khoshnam et al. 2007). Since mechanical sizing mechanisms react poorly, the video-based dimensional sizing method (of length, area and volume) can be used instead with loquat fruit.

In weight sorter machines, individual fruits are carried by cups or trays that may be linked together on a conveyor and are individually supported by a 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 a lower weight. If the density of the fruit is constant, the weight sizer sorts by volume. The sizing error will depend upon the correlation between weight and volume (Khoshnam et al. 2007).

Since there are density variations among loquat fruit varieties and within lots of a given variety, a critical concern is how to establish breakpoints in automatic density separation. The technique was applied to density sorting based on optical dimensional sizing for volume measuring, coupled with real-time weight measurement. Predicting the mass and volume of loquat fruit by geometrical attributes reduces costs and increases reliability and performance of both weight and density sorting techniques.

In the case of both mass and volume modeling, Khanali et al. (2007) determined models for predicting mass and volume of the Iranian grown tangerine with some geometrical attributes. They reported that among the systems that stored oranges based on one dimension, the system that applies intermediate diameter is suitable with nonlinear relationship. Also mass and volume modeling, respectively on the basis of the actual volume and one projected area, were identified as the best models.

Tabatabaeefar et al. (2000) modeled mass of the Iranian grown orange for its volumes, dimensions, and projected areas. They reported that among the systems that stored oranges based on one dimension, the system that applies intermediate diameter is suitable with nonlinear relationship. Also, Naderi-Boldaji et al. (2008), Khoshnam et al. (2007), Lorestani and Tabatabaeefar (2006), Keramat Jahromi et al. (2007) and Tabatabaeefar and Rajabipour (2005) used this method for predicting the mass of the apricot, pomegranate and kiwi, bergamot and apple fruits, respectively.

No detailed studies concerning mass and volume modeling of the loquat have yet been performed. The aim of this study was to determine the most suitable model for predicting loquat fruit mass and volume by its geometrical attributes.

MATERIAL AND METHODS

Three important varieties of the Iranian loquat (*Eriobotrya japonica* Lindl., Rosaceae, Maloideae) were considered for this study. About 300 samples of loquat fruit were obtained from the loquat orchards of the Mazandaran and Guilan provinces in the North of Iran. Three different popular varieties sampled were: ‘Anboo’ (n = 100), ‘Biva’ (n = 100) and ‘Azgel’ (n = 100). The mass of each loquat fruit was measured on a digital balance with an accuracy of 0.01 g. Its volume was measured by the water displacement method (Akar and Aydin, 2005; Aydin and Musa Ozcan, 2007). For this purpose, a loquat fruit was submerged into a known volume of water, and the volume of water displaced was measured. Water temperature was kept at 25°C. The specific gravity of each loquat fruit was calculated by the mass of loquat fruit in air divided by the mass of displaced water. Three mutually perpendicular axes: a – major (the longest intercept), b – intermediate (the longest intercept normal to a), and c – minor, (the longest intercept normal to a, b) of loquat fruit were measured by using the area measurement system Delta-T, England (Fig. 1). Dimensional characteristics obtained from this device are based on image processing. Captured images from a camera are transmitted to a computer card which works as an analogue to the digital converter. Digital images are then processed in the software and the desired user needs are determined. Through three

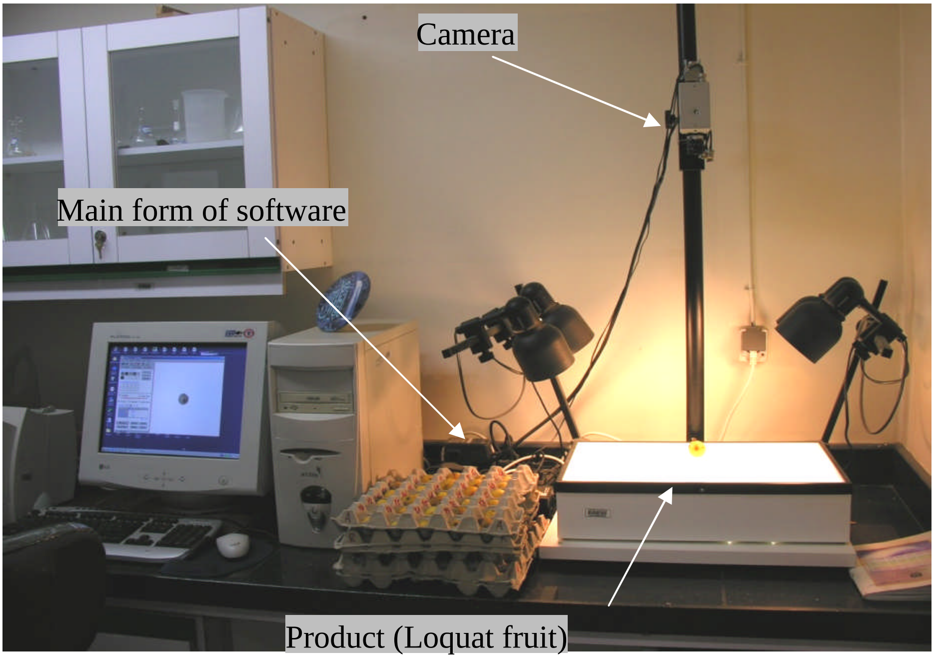

Figure 1. Apparatus for measuring dimensional characteristics (areameter Delta T, England)

normal images of the fruit, this device is capable of determining the required diameters as well as projected areas perpendicular to these dimensions. Total error for those objects that take up 5% of the camera field is less than 2%. This method has been used and reported by several researchers (Rafiee et al., 2006; Keramat Jahromi et al., 2007; Khanali et al., 2007; Khoshnam et al., 2007).

Geometric mean diameter, GMD, and sphericity were determined using the following equations (Mohsenin, 1986):

$$GMD = \sqrt[3]{abc} \quad (1)$$

$$\text{sphericity} = GMD/a \quad (2)$$

Three mutually perpendicular areas, PA1, PA2, PA3, were computed using the measurement system Delta-T, England as stated above. The average projected area (known as the criterion area, Ac, cm^2) was determined from equation:

$$\text{Criteria areas (CPA)} = (PA1 + PA2 + PA3)/3 \quad (3)$$

Spreadsheet software, Microsoft EXCEL 2003, was used to analyze the data and to determine regression models between the parameters. A typical linear multiple regression model is shown in equation:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + ,..., + b_n X_n, \quad (4)$$

where: Y – a dependent variable, for example mass, M; or volume (V); X_1, X_2, X_3,..., X_n – independent variables, for example physical dimensions; b_1, b_2,..., b_n – regression coefficients; a – constant of regression.

For example, mass is related to volume and can be estimated as a function of the actual volume V_m as shown in equation:

$M = a + b_1 V_m$ (5)

In order to estimate the loquat fruit mass/volume from its dimensions (length, area, and volume/mass), the following three classifications of models were suggested:

1. Single or multiple variable regressions of loquat fruit dimension characteristics: major (a), intermediate (b) and minor diameters (c).
2. Single or multiple variable regressions of loquat fruit projected areas: PA1, PA2 and PA3.
3. Single regression of loquat fruit volume: actual volume, volume of the fruit assumed as oblate spheroid and ellipsoid shapes.

From the above classifications, all three classifications were considered for mass modeling while the third classification was neglected in volume modeling. In other words, volume modeling based on mass was not done because the results of mass modeling based on volume, and volume modeling based on mass are the same.

In the case of the first classification, mass and volume modeling was accomplished with respect to major, intermediate and minor diameters. The models obtained with three variables for predicting loquat fruit mass and volume were:

$M = k_1a + k_2b + k_3c + k_3$, (6)

$V = k_1a + k_2b + k_3c + k_3$ (7)

In these models, the mass and volume can be estimated as a function of one, two and three dimensions.

In the second classification models, mass and volume of loquat fruit was estimated based on mutually perpendicular projected areas as follows:

$M = k_1PA_1 + k_2PA_2 + k_3PA_3 + k_4$ (8)

$V = k_1PA_1 + k_2PA_2 + k_3PA_3 + k_4$ (9)

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

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

$V_{osp} = 4/3\pi$ (a/2) (b/2)2 (10)

$V_{ellip} = 4/3\ \pi$ (a/2) (b/2) (c/2) (11)

In this classification (applied only for mass modeling), the mass can be estimated as either a function of volume of supposed shape or the measured volume as given in following equations:

$M = k_1V_{osp} + k_2$ (12)

$M = k_1V_{ellip} + k_2$ (13)

$M = k_1V_m + k_2$ (14)

RESULTS AND DISCUSSION

First classification models - Length

Among the first classification models Nos 1, 2, 3, 4, 5, 6 and 7 shown in Tables 1 and 2, model 7, in which all three dimensions were considered, had a higher R^2 value

Table 1. Coefficient of determination (R^2) and regression standard error (R.S.E) for linear regression mass models for three Iranian local varieties of loquat fruits and the total observations

No.	Variety Models	Param-eters	Anboo	Biva	Azgel	Total of observa-tions
1	$M=k_1a+k2$	R^2 R.S.E.	0.79 2.36	0.88 1.18	0.79 0.55	0.89 1.77
2	$M=k_1b+k2$	R^2 R.S.E.	0.88 1.80	0.81 1.47	0.80 .055	0.91 1.60
3	$M=k_1c+k2$	R^2 R.S.E.	0.87 1.85	0.70 1.83	0.74 0.62	0.83 2.16
4	$M=k_1a+k_2b+k_3$	R^2 R.S.E.	0.89 1.71	0.88 1.15	0.81 0.53	0.92 1.52
5	$M=k_1a+k_2c+k_3$	R^2 R.S.E.	0.89 1.74	0.93 0.92	0.85 0.47	0.91 1.60
6	$M=k_1b+k_2c+k_3$	R^2 R.S.E.	0.88 1.80	0.81 1.43	0.80 0.54	0.91 1.59
7	$M=k_1a+k_2b+k_3c+k_4$	R^2 R.S.E.	0.89 1.70	0.94 0.79	0.85 0.46	0.92 1.51
8	$M=k_1PA_1+k_2$	R^2 R.S.E.	0.98 0.73	0.93 0.86	0.35 0.98	0.95 1.19
9	$M=k_1PA_2+k_2$	R^2 R.S.E.	0.94 1.25	0.97 0.57	0.77 0.57	0.96 1.09
10	$M=k_1PA_3+k_2$	R^2 R.S.E.	0.95 1.08	0.65 1.98	0.16 1.11	0.89 1.77
11	$M=k_1PA_1+k_2PA_2+k_3$	R^2 R.S.E.	0.98 0.68	0.97 0.58	0.78 0.58	0.96 1.00
12	$M=k_1PA_1+k_2PA_3+k_3$	R^2 R.S.E.	0.98 0.61	0.93 0.86	0.35 0.98	0.95 1.17
13	$M= k_1PA_2+k_2PA_3+k3$	R^2 R.S.E.	0.96 0.98	0.97 0.57	0.77 0.57	0.96 1.05
14	$M=k_1PA_1+k_2PA_2+k_3PA_3+k_3$	R^2 R.S.E.	0.98 0.60	0.97 0.58	0.78 0.57	0.96 0.99
15	$M= k_1V_m+k_2$	R^2 R.S.E.	0.99 0.32	0.99 0.22	0.95 0.27	0.99 0.32
16	$M=k_1V_{osp}+k_2$	R^2 R.S.E.	0.89 1.70	0.90 1.04	0.82 0.51	0.95 1.21
17	$M=k_1V_{ell}+k_2$	R^2 R.S.E.	0.91 1.52	0.91 1.00	0.85 0.46	0.95 1.14

Table 2. Coefficient of determination (R^2) and regression standard error (R.S.E) for linear regression volume models for three Iranian local varieties of loquat fruits and the total observations

No.	Variety Models	Param-eters	Anboo	Biva	Azgel	Total of observa-tions
1	$V=k_1a+k2$	R^2 R.S.E.	0.78 2.28	0.87 1.08	0.72 0.58	0.88 1.71
2	$V=k_1b+k2$	R^2 R.S.E.	0.88 1.66	0.82 1.36	0.72 0.57	0.91 1.46
3	$V=k_1c+k2$	R^2 R.S.E.	0.87 1.71	0.72 1.70	0.71 0.58	0.85 1.94
4	$V=k_1a+k_2b+k_3$	R^2 R.S.E.	0.89 1.59	0.89 1.05	0.74 0.56	0.92 1.41
5	$V=k_1a+k_2c+k_3$	R^2 R.S.E.	0.89 1.63	0.94 0.78	0.80 0.50	0.91 1.50
6	$V=k_1b+k_2c+k_3$	R^2 R.S.E.	0.88 1.66	0.83 1.30	0.75 0.55	0.91 1.47
7	$V=k_1a+k_2b+k_3c+k_4$	R^2 R.S.E.	0.89 1.60	0.96 0.65	0.82 0.48	0.92 1.42
8	$V=k_1PA_1+k_2$	R^2 R.S.E.	0.99 0.58	0.93 0.81	0.38 0.87	0.96 0.99
9	$V=k_1PA_2+k_2$	R^2 R.S.E.	0.93 1.27	0.97 0.52	0.75 0.55	0.96 1.00
10	$V=k_1PA_3+k_2$	R^2 R.S.E.	0.95 1.07	0.65 1.90	0.15 1.02	0.89 1.63
11	$V=k_1PA_1+k_2PA_2+k_3$	R^2 R.S.E.	0.97 0.57	0.97 0.53	0.74 0.56	0.97 0.86
12	$V=k_1PA_1+k_2PA_3+k_3$	R^2 R.S.E.	0.99 0.50	0.93 0.82	0.38 0.87	0.96 0.98
13	$V=k_1PA_2+k_2PA_3+k3$	R^2 R.S.E.	0.96 1.00	0.97 0.53	0.75 0.55	0.96 0.97
14	$V=k_1PA_1+k_2PA_2+k_3$ PA_3+k_3	R^2 R.S.E.	0.99 0.51	0.97 0.52	0.75 0.56	0.98 0.85
15	$V=k_1M_m+k_2$	R^2 R.S.E.	0.99 0.30	0.99 0.21	0.95 0.24	0.99 0.29

and its regression standard error (R.S.E) was also low for all the three varieties. However, all three diameters must be measured for model 7, which makes the sizing mechanism more complex and expensive. Among models 1, 2 and 3, model 2 had a higher R^2 value and lower R.S.E. for all the varieties. Based on calculated values of R^2 and R.S.E., there ares no significant differences between models 4, 5 and 6. Therefore, in order to perform mass/volume modeling on the basis of length, model 2, among the three one-dimensional models, was selected as the best choice with intermediate diameter as an independent variable as shown in Figures 2 and 3.

For all the varieties, the best equation for the calculation of mass and volume of loquat fruit based on the intermediate diameter was given in the non-linear form of equations (15) and (16).

$M = 0.047b^2-1.284b + 12.076$ $R^2 = 0.94$ (15)

$V = 0.044b^2-1.167b + 10.891$ $R^2 = 0.94$ (16)

When comparing the above equations and their R^2, it is obvious that mass and volume sorting based on loquat fruit length are the same.

Second classification models – Area

For both mass and volume modeling, among the second classification models 8, 9, 10, 11, 12, 13 and 14, shown in Tables 1 and 2, model 14 for all the varieties had a higher R^2 value and lower R.S.E.; model 14 needs to have all three projected areas taken for each loquat fruit.

In the case of mass modeling, among models 8, 9, 10, 11, 12 and 13, model 12 for the ‘Anboo’, model 9 for ‘Biva’, and model 11 for ‘Azgel’ had a higher R^2 value and a lower regression standard error, R.S.E. Therefore, model 12 among models 8, 9, 10, 11, 12 and 13 is chosen for the variety ‘Anboo’, model 9 is chosen for ‘Biva’ and model 11 for ‘Azgel’.

Similarly, with regard to Tables 1 and 2, it can be concluded that among models 8, 9, 10, 11, 12 and 13, model 11 is the best model regarding mass and volume modeling for all the varieties.

The overall mass and volume models based on three projected areas (model 14) for all the varieties were given in equations (17) and (18), respectively.

$M = 1.04\ PA_1 + 1.66\ PA_2 + 0.15\ PA_3 – 5.10$ $R^2 = 0.96$ (17)

$V = 1.28\ PA_1 + 1.30\ PA_2 + 0.09\ PA_3 – 1.61$ $R^2 = 0.98$ (18)

The mass and volume model of overall loquat fruits based on the 2[nd] projection area as shown in Figs. 4 and 5, was given as a non-linear form of equation s (19) and (20).

$M= 0.84\ (PA_2)1.45$ $R^2 = 0.96$ (19)

$V = 1.15\ (PA_2)1.44$ $R^2 = 0.98$ (20)

Considering the equations (17) to (20), volume modeling is more suitable than mass modeling because of higher R^2.

Each one of the three projection areas can be used to estimate the mass. There is a need to have three cameras, in order to take all the projection areas and have one R^2 value close to unity; therefore, a model using only one projection area, possibly model 9, can be used.

Third classification models - Volume

This classification was only used for mass modeling because the obtained results were the same. Among the models in the third classification (models 15, 16, 17), the R^2 for model 15 was higher and R.S.E. was lower.

Therefore, model 15 was suggested for predicting loquat fruit mass. The mass model of overall loquat fruit based on the measured

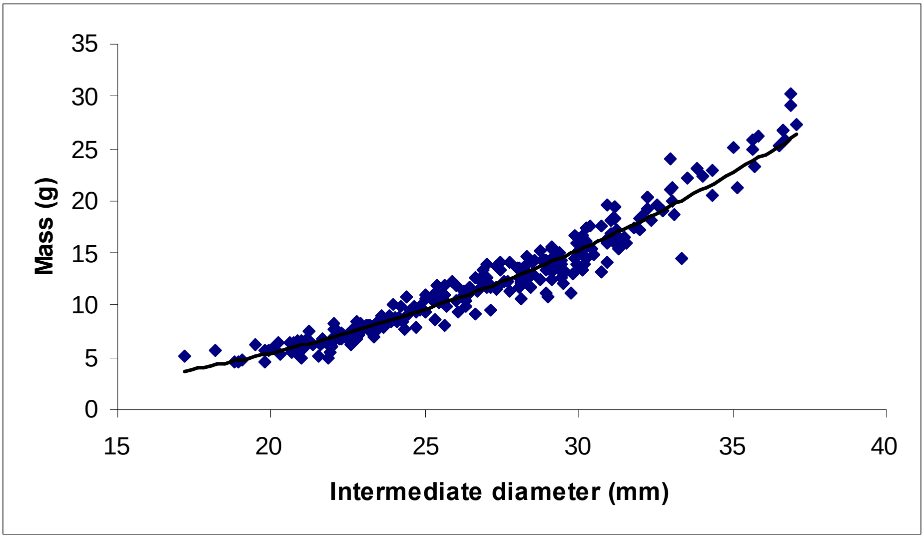

Figure 2. Mass model of loquat fruit based on intermediate diameter

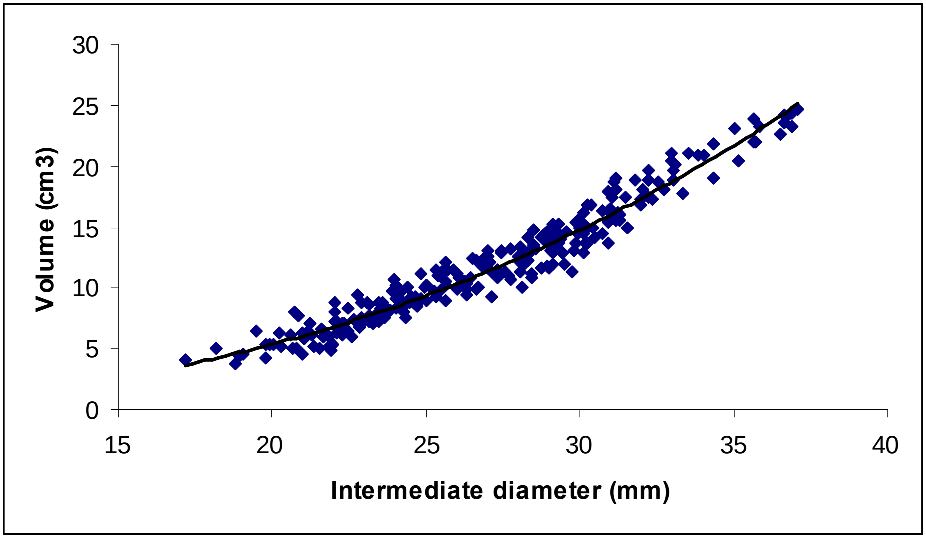

Figure 3. Volume model of loquat fruit based on intermediate diameter

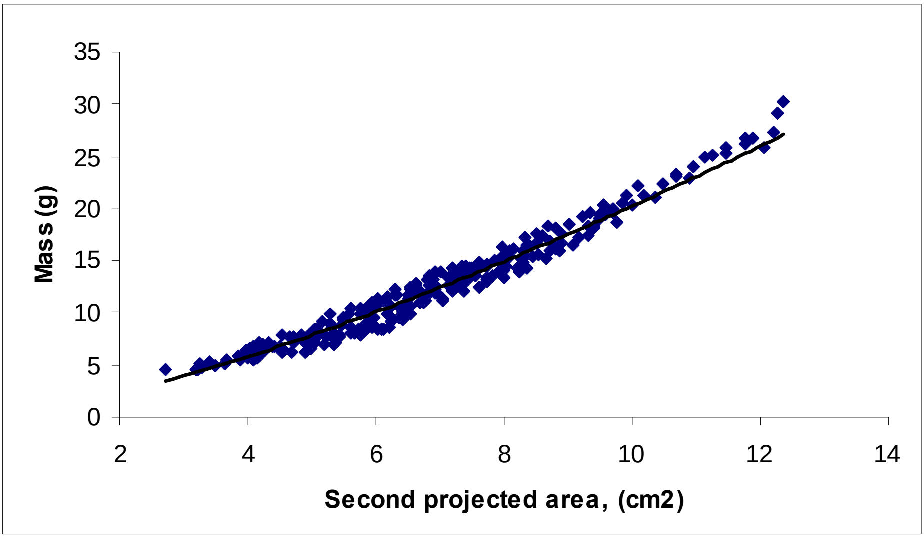

Figure 4. Overall mass model of all loquat fruits versus the second projected area

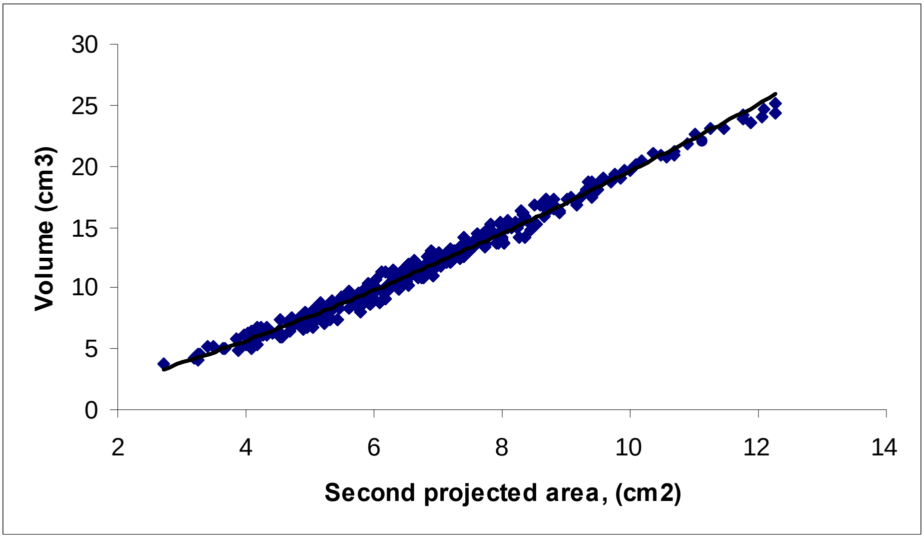

Figure 5. Overall volume model of all loquat fruits versus the second projected area

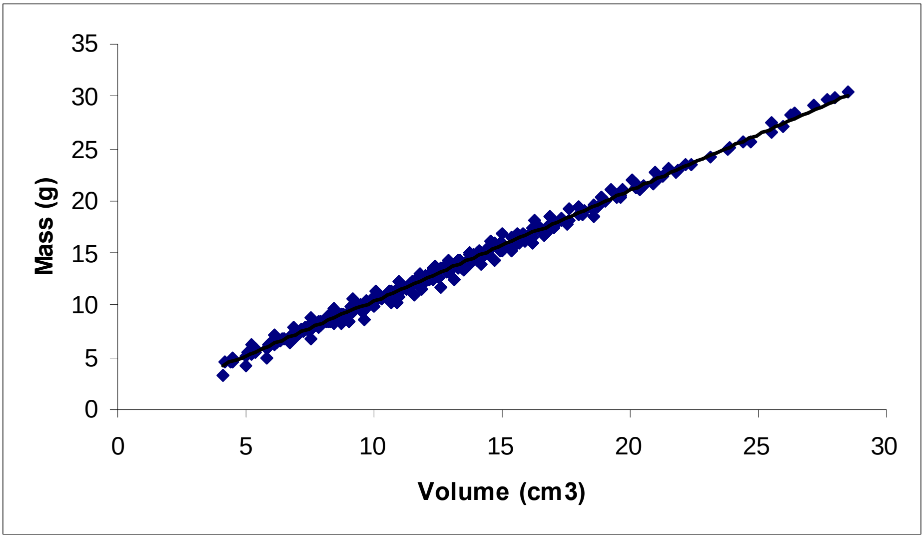

Figure 6. Mass model of loquat fruit based on measured volume

volume as shown in Fig. 6, was given as a linear form of equation (21):

$M = 1.06\, V_m - 0.07 \quad R^2 = 0.99$ (21).

Considering equations 15-21 it can be concluded that the best model for mass modeling of loquat fruit is the model based on the measured volume i.e. model 15 (equation 21), while equation 20 (model 9) is the best model for volume modeling. Measurement of one projected area is far easier than that of the actual volume of loquat fruit, so volume modeling of loquat fruit seems to be more convenient and economical.

The relationship among mass/-volume and dimensional parameters of three Iranian local varieties of loquat fruit and the total observations are shown in Tables 3 and 4.

CONCLUSIONS

1. The recommended equation for the calculation of loquat fruit mass and volume based on intermediate diameter was of a non-linear form:
   $M = 0.047b^2 - 1.284b + 12.076 \quad R^2 = 0.94$,
   $V = 0.044b^2 - 1.167b + 10.891 \quad R^2 = 0.94$.
2. The recommended mass/volume model for sizing the loquat fruit based on any one projected area was of a non-linear form:
   $M = 0.84\, (PA_2)1.45 \quad R^2 = 0.96$,
   $V = 1.15\, (PA_2)1.44 \quad R^2 = 0.98$.
3. There was a very good relationship between mass and measured volume of loquat fruits for all varieties with R^2 in the order of 0.99.
4. Mass and volume modeling, respectively on the basis of the actual volume and one projected area, were identified as the best models.
5. From the economical point of view, volume modeling was discerned as the most convenient modeling.

T a b l e 3 . Relationship among mass and dimensional parameters of three Iranian local varieties of loquat fruit and the total observations

Total observations				Azgel				Biva				Anboo				Variety	No
k4	k3	k2	k1	k4	k3	k2	k1	k4	k3	k2	k1	k4	K3	k2	k1	Models	
-	-	-20.37	1.18	-	-	-8.05	0.64	-	-	-24.63	1.33	-	-	-31.74	1.54	$M=k_1a+k2$	1
-	-	-20.25	1.22	-	-	-9.99	0.76	-	-	-24.76	1.35	-	-	-25.30	1.40	$M=k_1b+k2$	2
-	-	-17.6	1.14	-	-	-9.42	0.77	-	-	-21.16	1.20	-	-	-25.96	1.48	$M=k_1c+k2$	3
-	-20.92	0.78	0.45	-	-9.44	0.39	0.33	-	-25.64	0.322	1.05	-	-29.73	1.05	0.46	$M=k_1a+k_2b+k_3$	4
-	-20.8	0.41	0.8	-	-10.17	0.36	0.41	-	-28.25	0.47	0.99	-	-29.70	1.09	0.48	$M=k_1a+k_2c+k_3$	5
-	-20.32	-0.23	1.45	-	-10.36	0.23	0.55	-	-25.65	0.33	1.05	-	-25.70	0.47	0.96	$M=k_1b+k_2c+k_3$	6
-20.92	-0.06	0.85	0.43	-9.84	0.55	-0.41	0.61	-28.19	0.80	-0.84	1.48	-29.24	0.25	0.833	0.44	$M=k_1a+k_2b+k_3c+k_4$	7
-	-	-4.26	2.78	-	-	0.88	1.46	-	-	-5.20	2.77	-	-	-4.14	2.87	$M=k_1PA_1+k_2$	8
-	-	-5.34	2.87	-	-	-0.67	1.73	-	-	-5.58	2.79	-	-	-5.29	2.94	$M=k_1PA_2+k_2$	9
-	-	-3.70	2.45	-	-	3.03	0.83	-	-	-1.13	1.95	-	-	-6.70	2.92	$M=k_1PA_3+k_2$	10
-	-5.08	1.70	1.15	-	-0.28	1.9	-0.27	-	-5.58	2.84	-0.05	-	-4.63	0.64	2.28	$M=k_1PA_1+k_2PA_2+k_3$	11
-	-4.36	0.36	2.40	-	0.47	0.24	1.31	-	-5.17	-0.06	2.83	-	-5.27	0.95	1.98	$M=k_1PA_1+k_2PA_3+k_3$	12
-	-5.32	0.42	2.42	-	-0.40	-0.12	1.79	-	-5.63	0.07	2.73	-	-6.50	1.86	1.11	$M=k_1PA_2+k_2PA_3+k3$	13
-5.10	0.15	1.66	1.04	-0.16	-0.80	1.91	-0.24	-5.63	0.09	2.89	-0.19	-5.29	0.85	0.177	1.91	$M=k_1PA_1+k_2PA_2+k_3PA_3+k_3$	14
-	-	-0.07	1.06	-	-	-0.09	1.07	-	-	0.03	1.04	-	-	0.146	1.06	$M=k_1V_m+k_2$	15
-	-	0.30	1.05	-	-	0.93	0.95	-	-	-0.77	1.17	-	-	-0.39	1.08	$M=k_1V_{osp}+k_2$	16
-	-	0.28	1.11	-	-	0.40	1.13	-	-	-1.40	1.22	-	-	0.47	1.12	$M=k_1V_{ell}+k_2$	17

T a b l e 4 . Relationship among volume and dimensional parameters of three Iranian local varieties of loquat fruit and the total observations

Total observations				Azgel				Biva				Anboo				Variety	No
k4	k3	k2	k1	k4	k3	k2	k1	k4	k3	k2	k1	k4	k3	k2	k1	Models	
-	-	-18.94	1.10	-	-	-6.50	0.56	-	-	-23.75	1.27	-	-	-29.75	1.45	$V=k_1a+k2$	1
-	-	-19.02	1.15	-	-	-8.19	0.66	-	-	-23.99	1.31	-	-	-24.06	1.33	$V=k_1b+k2$	2
-	-	-16.70	1.08	-	-	-8.10	0.69	-	-	-20.61	1.67	-	-	-24.70	1.40	$V=k_1c+k2$	3
-	-19.52	0.82	0.33	-	-7.71	0.34	0.28	-	-24.81	0.34	0.99	-	-27.20	1.04	0.37	$V=k_1a+k_2b+k_3$	4
-	-19.42	0.46	0.69	-	-8.68	0.37	0.31	-	-27.36	0.47	0.94	-	-27.75	1.09	0.39	$V=k_1a+k_2c+k_3$	5
-	-19.05	-0.10	1.25	-	-8.71	0.34	0.36	-	-24.90	0.33	1.00	-	-24.46	0.47	0.89	$V=k_1b+k_2c+k_3$	6
-19.52	0.03	0.78	0.34	-8.20	0.67	-0.62	0.62	-27.31	0.79	-0.80	1.41	-27.30	0.29	0.78	0.36	$V=k_1a+k_2b+k_3c+k_4$	7
-	-	-4.00	2.62	-	-	0.80	1.39	-	-	-4.94	2.70	-	-	-4.07	2.72	$V=k_1PA_1+k_2$	8
-	-	-4.94	2.69	-	-	-0.27	1.55	-	-	-5.31	2.70	-	-	-5.00	2.76	$V=k_1PA_2+k_2$	9
-	-	-3.42	2.30	-	-	3.01	0.75	-	-	-1.02	1.87	-	-	-6.38	2.75	$V=k_1PA_3+k_2$	10
-	-4.63	1.33	1.35	-	-0.18	1.59	-0.06	-	-5.30	2.77	-0.09	-	-4.29	0.29	2.45	$V=k_1PA_1+k_2PA_2+k_3$	11
-	-4.92	0.26	2.35	-	0.50	0.17	1.29	-	-4.9	-0.07	2.73	-	-4.87	0.68	2.08	$V=k_1PA_1+k_2PA_3+k_3$	12
-	-4.92	0.43	2.24	-	-0.05	-0.10	1.60	-	-5.35	0.05	2.63	-	-6.20	1.87	0.92	$V=k_1PA_2+k_2PA_3+k3$	13
-1.61	0.09	1.30	1.28	-0.03	-0.09	1.61	-0.02	-5.35	0.08	2.81	-0.21	-4.86	0.75	-0.12	2.13	$V=k_1PA_1+k_2PA_2+k_3PA_3+k_3$	14
-	-	0.10	0.94	-	-	0.38	0.89	-	-	0.09	0.96	-	-	-0.08	0.94	$V=k_1M_m+k_2$	15

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MODELOWANIE MASY I OBJĘTOŚCI OWOCÓW NIEŚPLIKA JAPOŃSKIEGO (*Eriobotrya japonica* LINDL.) OPARTE NA CECHACH FIZYCZNYCH

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S T R E S Z C Z E N I E

Istnieją przypadki, w których wskazane jest określenie współzależności między różnymi cechami fizycznymi owoców. Na przykład są one często sortowane na podstawie wielkości oraz powierzchni rzutu, ale może bardziej ekonomiczne byłoby opracowanie urządzenia, które klasyfikowałoby owoce na podstawie masy lub objętości. Do tego celu potrzebne jest ustalenie zależności między masą/objętością a innymi cechami fizycznymi owoców. W niniejszych badaniach wybrano trzy lokalne irańskie odmiany owoców nieśplika japońskiego i stworzono różne modele do szacowania masy/objętości tych owoców na podstawie ich rozmiarów, powierzchni rzutu oraz objętości/masy. Modele podzielono na 3 grupy: 1. regresja jedno- i wieloczynnikowa rozmiarów owoców nieśplika japońskiego; 2. regresja jedno- i wieloczynnikowa powierzchni rzutu owoców; 3. szacowanie masy/objętości owocu nieśplika japońskiego bazując na jego objętości/masie. Badania pokazały, że najlepszym modelem dla szacowania masy i objętości owoców są modele bazujące na rzeczywistej objętości i powierzchni jednego rzutu. Najwyższy współczynnik determinacji (R^2 = 0,99) we wszystkich modelach uzyskano dla szacowania masy owocu w oparciu o pomiary jego objętości. W ostatecznym rozrachunku najbardziej odpowiednie z ekonomicznego punktu widzenia jest modelowanie objętości.

Słowa kluczowe: owoc nieśplika japońskiego, cechy fizyczne, masa/objętość, modelowanie, klasyfikacja