Modeling the mass of Iranian export onion (*Allium cepa* L.) varieties using some physical characteristics

R. Ghabel, A. Rajabipour, M. Ghasemi-Varnamkhasti, M. Oveisi

Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

Abstract

Ghabel R., Rajabipour A., Ghasemi-Varnamkhasti M., Oveisi M., 2010. **Modeling the mass of Iranian export onion** (*Allium cepa* L.) **varieties using some physical characteristics**. Res. Agr. Eng., *56*: 33–40.

Mass modeling can be used for development of post-harvest equipment related to onion (*Allium cepa* L.) processing such as grading, packing and food production processes. There are instances in which it is desirable to determine relationships among crop physical characteristics. In this study, the mass of Iranian export onion varieties (Azarshahr and Sefide Qom) was predicted by using different physical characteristics applying linear models with three different classifications: (1) – single or multiple variable regressions of onion dimensional characteristics, (2) – single or multiple variable regressions of onion projected areas, (3) – estimating onion mass based on measured (actual) volume and volumes of assumed shapes (prolate spheroid and ellipsoid). The results showed that mass modeling of onion based on length and three projected areas are the most appropriate models in the first and second classification, respectively. In third classification, the highest determination coefficient was obtained for mass modeling based on the actual volume as $R^2 = 0.99$ whereas corresponding values were 0.96 for both assumed onion shapes (prolate spheroid and ellipsoid), respectively. In economical and agronomical point of view, suitable grading system of onion mass was obtained based on length as nonlinear relation $M = 0.035a^2 - 1.64a + 36.137$, $R^2 = 0.96$.

Keywords: onion; vegetable; mass modeling; physical characteristics; grading

Onion (*Allium cepa* L.), is considered as one of the most important crops in all countries. It is estimated that about 55 million tons of onions are produced annually all over the world. In many parts of the world it is staple food of the people. Annual onion production in Iran is 1.45 million tones, which is ranked as the 7th in the world (Anonymous 2006).

Exporting of agricultural products is one of the main goals of the current policy of the Iran Government, especially to Europe. To be able to achieve such target, it is vital to apply the proper post-harvest technologies for each crop. For onion bulbs, it has to be well sorted, graded and packed. To achieve such operations, information about physical characteristics of bulbs is required. Physical characteristics of agricultural products are the most important parameters for designing of grading, conveying, processing, and packaging systems. Among these physical characteristics, mass, volume, projected area, and center of gravity are the most important in sizing systems (Malcolm et al. 1986; Safwat 1971). Other important parameters are width, length, and thickness (Mohsenin 1986). 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, Hamannhn 1994).

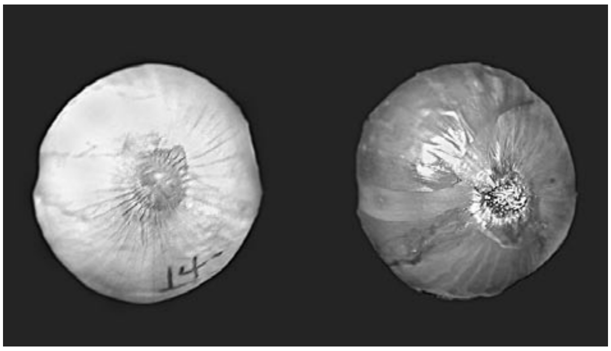

Fig 1. Right: Azarshahr variety, Left: Sefide Qom variety

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 was related to the surface area 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, Zahradnik 1968).

Consumers prefer crops of equal weight and uniform shape. Mass grading of crop can reduce packaging and transportation costs, and also may provide an optimum packaging configuration (Peleg et al. 1985). Sizing by weighing mechanism is recommended for the irregular shape product (Stroshine, Hamann 1994). Since electrical sizing mechanism is expensive and mechanical sizing mechanism reacts poorly; for onion, dimensional method (of length, area, and volume) can be used. Determining a relationships between mass and dimensions and projected areas may be useful and applicable (Stroshine, Hamann 1994; Marvin et al. 1987). In weight sizer machines, individual vegetables 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 (Khoshnam et al. 2007). Successive triggering mechanisms are set to dump the tray at lower weight. If the density of the product is constant, the weight sizer sorts by volume. The sizing error will depend upon the correlation between weight and volume (Stroshine, 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.

No detailed studies concerning mass modeling of onion have been performed up to now. The objective of this research was to determine an optimum onion mass model based on its dimensions. This information will be used to design and develop sizing systems.

MATERIALS AND METHODS

Two different Iranian export varieties of onion, as shown in Fig. 1, were Azarshahr ($n = 65$) and Sefide Qom ($n = 65$), from the Seed and Plant Breeding and Improvement, Karaj, Iran (Longitude: 51°21'N, Latitude: 36°12'E). The onions were transported to physical laboratory of Faculty of Biosystem Engineering, University of Tehran, Karaj, Iran. Onion moisture content was determined (ASAE Standard 1998) and obtained as 89.4% w.b. and 88.8% w.b. for Azarshahr and Sefide Qom, respectively; then required experiments were conducted in three days at laboratory temperature ranging from 25°C to 29°C.

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, WinArea-Ut-06 system developed by Mirasheh (2006) was used (Fig. 2).

WinArea-Ut-06 system comprised following components:

1. Sony photograph camera Model CCD-TRV225E
2. Device for preparing media to taking a picture
3. Card capture named Winfast model DV2000
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 error for those objects was less than 2%. This method was used and reported by several researchers (Keramat Jahromi et al. 2007; Khoshnam et al. 2007).

Figure 3a, b, and c shows dimensions of onion, namely length, width and thickness; *PA*, *PB*, and *PC* are the projected areas taken along these three mutual perpendicular axes.

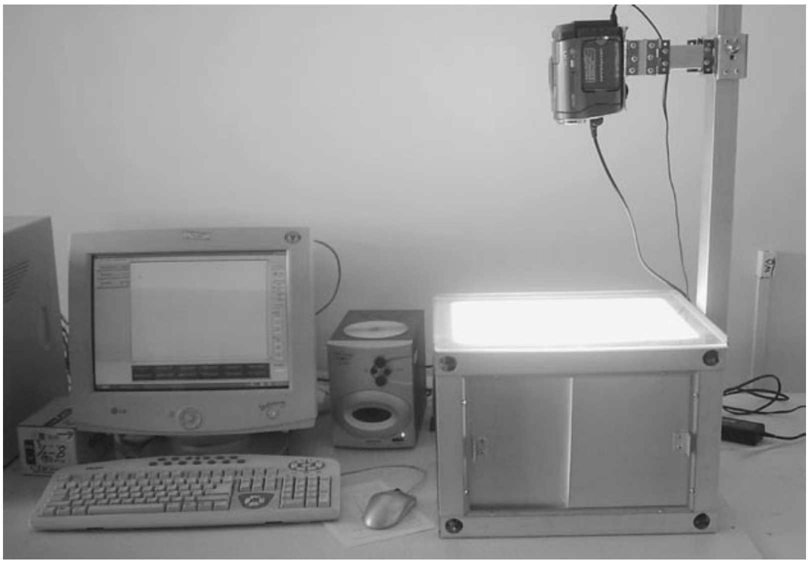

Fig. 2. Components of WinArea-Ut-06 system

Mass (g) of individual onion was determined by using an electronic balance with an accuracy of 0.01 g. Actual volume was measured by the water displacement method (Mohsenin 1986; Kabas et al. 2005; Karababa 2006). The bulk density was determined using the mass-volume relationship by filling an empty plastic container of predetermined volume and weight, the onion were 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 the Eqs. 1 and 2, respectively as reported by Mohsenin (1986) and Kabas et al. (2006).

$$\text{GMD} = (LTW)^{1/3} \quad (1)$$

$$\text{Sph} = \frac{\text{GDM}}{a} \quad (2)$$

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

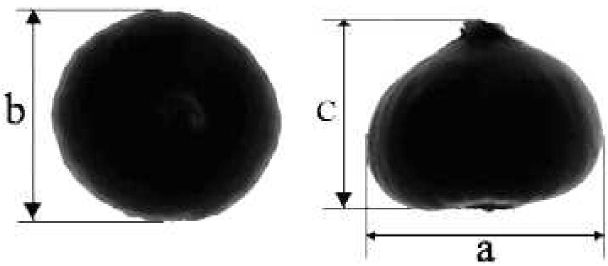

Fig. 3. Dimensional characteristics of onion

(1) Single or multiple variable regressions of onion dimension characteristics: length (a), width (b), and thickness (c).
(2) Single or multiple variable regressions of onion projected areas: PA_1, PA_2 and PA_3.
(3) Single regression of onion volume: actual volume, volume of the onion assumed as prolate spheroid and ellipsoid shape.

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

$$M = k_1a + k_2b + k_3c + k_4 \quad (3)$$

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

In the second classification models, mass and surface area modeling of onion was estimated based on mutually perpendicular projected areas as following:

$$M = k_1PA_1 + k_2PA_2 + k_3PA_3 + k_4 \quad (4)$$

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

In the case of the third classification, to achieve the models which can predict onion 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 onion shape was assumed as a regularly geometrical shape, i.e.

Table1. Some physical characteristics of two Iranian export varieties of onion (Azarshahr and Sefide Qom)

Property	Azarshahr				Sefide Qom				Total observations			
	mean	max	min	SD	mean	max	min	SD	mean	max	min	SD
Length (mm)	73.60	95.80	50.80	9.81	79.17	109.60	54.30	14.43	76.39	109.60	50.80	12.60
Width (mm)	72.19	92.70	51.30	9.34	76.97	104.70	53.80	13.35	74.58	104.70	51.30	11.72
Thickness (mm)	62.67	90.40	49.50	8.01	64.38	88.00	44.20	10.27	63.53	90.40	44.20	9.22
Geometric mean diameter (mm)	69.23	89.77	51.23	8.33	73.14	99.24	52.73	12.18	71.18	99.24	51.23	10.58
Sphericity (%)	94.00	99.50	85.30	3.20	92.60	98.70	87.40	3.00	93.30	99.50	85.30	3.20
Volume (cm^3)	114.47	202.20	42.50	37.23	142.23	293.20	56.80	64.60	128.35	293.20	42.50	54.33
Bulk density ($grcm^{-3}$)	0.95	1.15	0.62	0.05	0.95	1.09	0.60	0.05	0.95	1.15	0.60	0.06
First projected area (cm^2)	40.28	63.93	20.24	9.96	45.79	80.05	21.59	15.51	43.03	80.05	20.24	13.27
Second projected area (cm^2)	31.74	50.45	15.93	7.30	34.36	60.94	18.66	11.42	33.05	60.94	15.93	9.64
Third projected area (cm^2)	30.33	47.53	15.74	6.96	36.48	64.94	18.52	12.03	33.40	64.94	15.74	10.27

prolate spheroid (V_{psp}) and ellipsoid (V_{ell}) shapes and thus their volumes (cm^3) were calculated as:

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

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

In this classification, the mass can be estimated as either a function of volume of supposed shape or the measured volume as represented in the following expressions:

$$M = k_1V_m + k_2 \quad (7)$$

$$M = k_1V_{psp} + k_2 \quad (8)$$

$$M = k_1V_{ell} + k_2 \quad (9)$$

Packages of statistical programs, available on both main frame and personal computers, can perform such regression analysis. Many spreadsheet programs can also perform multiple regressions. When evaluating the usefulness of such regression analyses, it is necessary to know how well the data fit the model. One trait 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 1998). If values of k_i exactly predict the mass, then R^2 would be equal to 1.00. WinArea-Ut-06 software was used to analyze data and determine regression models between the physical attributes.

RESULTS AND DISCUSSION

A summary of some selected physical characteristics of the studied onion varieties is presented in Table 1. Also, a total of 11 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 on two Iranian export varieties of onion are shown in Table 2.

First classification models, dimension

Among the first category models (numbers of 1, 2, 3, and 4), model number 4 had the highest R^2 and the

Table 2. Onion mass models based on selected independent variables

No.	Model	Parameter	Azashahr	Sefide Qom	Total of observations
1	$M = k_1a + k_2$	R^2	0.91	0.95	0.94
		R.S.E.	10.72	13.34	12.91
2	$M = k_1b + k_2$	R^2	0.60	0.79	0.70
		R.S.E.	22.11	27.73	27.88
3	$M = k_1c + k_2$	R^2	0.91	0.94	0.92
		R.S.E.	10.65	15.46	14.32
4	$M = k_1a + k_2b + k_3c + k_4$	R^2	0.94	0.97	0.95
		R.S.E.	8.55	11.61	11.22
5	$M = k_1PA_1 + k_2$	R^2	0.94	0.98	0.97
		R.S.E.	8.36	9.05	9.53
6	$M = k_1PA_2 + k_2$	R^2	0.95	0.98	0.96
		R.S.E.	7.93	8.51	10.81
7	$M = k_1PA_3 + k_2$	R^2	0.95	0.98	0.97
		R.S.E.	7.80	8.00	8.23
8	$M = k_1PA_1 + k_2PA_2 + k_3PA_3 + k_4$	R^2	0.97	0.99	0.99
		R.S.E.	6.47	5.98	6.41
9	$M = k_1V + k_2$	R^2	0.98	0.98	0.98
		R.S.E.	5.22	8.54	7.77
10	$M = k_1V_{ell} + k_2$	R^2	0.97	0.97	0.96
		R.S.E.	6.32	10.54	10.25
11	$M = k_1V_{psp} + k_2$	R^2	0.97	0.97	0.96
		R.S.E.	6.19	10.41	10.08

lowest R.S.E.; however, measurement of three diameters is needed for this model, which makes the sizing mechanism more tedious and expensive. Among the models numbers of 1, 2, and 3 model number 3 for Azarshahr variety and model number 1 for Sefide Qom variety as well as for total of observations, had higher R^2 and lower R.S.E. than the other models.

Eleven 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

$M = 0.08c^2 - 4.74c + 5.14$, $R^2 = 0.89$.

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

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

The mass model of onion (for two varieties) based on the model 4 (all the three diameters) is given in Eq. 10.

$$M = 4.39a + 1.15b - 1.25c - 193.83,\quad R^2 = 0.95,\ \text{R.S.E} = 11.22 \qquad (10)$$

For two varieties, the best equation to calculate mass of onion based on the length was given in nonlinear form of Eq. 11 (Fig. 4).

$$M = 0.35a^2 - 1.64a + 36.137,\ R^2 = 0.96 \qquad (11)$$

Therefore, sizing onion based on length is recommended.

Second classification models, projected areas

Among the linear regression projected area models (numbers of 5, 6, 7, and 8) for two Iranian export varieties of onion, model number 8, shown in Table 2, had higher R^2 and lower R.S.E. than the other models. This equation is given as:

$$M = 1.4PA_1 + 0.56PA_2 + 2.62PA_3 - 44.35,\quad R^2 = 0.98,\ \text{R.S.E.} = 6.41 \qquad (12)$$

The overall mass model of onion based on one projected area as shown in Fig. 5, was given as nonlinear form in following equation:

$$M = 1.02(PA_3)^{1.36},\ R^2 = 0.97 \qquad (13)$$

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

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

Each of the three projected areas can be used to estimate the mass. There is a need to have three cam-

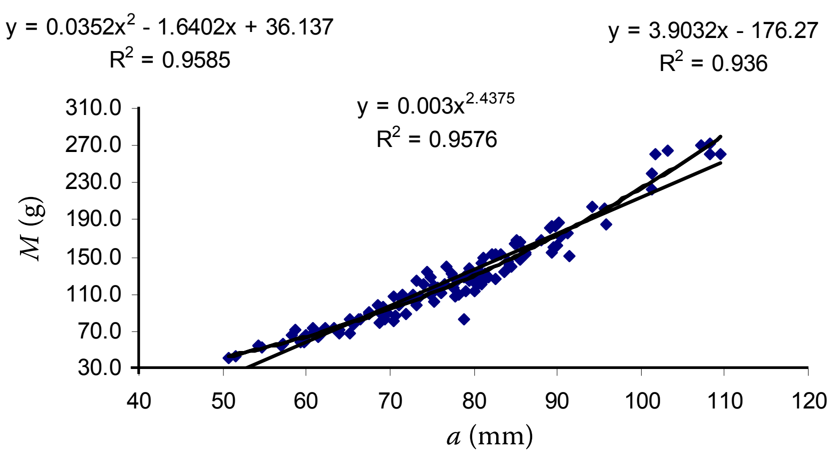

Fig. 4. Onion mass model based on length

eras, 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 7 can be used.

Third classification models, volume

Among the models in the third classification (models 9, 10, and 11), the R^2 for model 9 had maximum value and minimum R.S.E. As to the models 10 and 11, the model 11 for both the onion varieties had the highest R^2 value and the lowest R.S.E. Therefore, model 9 was recommended for predicting onion mass. The mass model of overall onions based on measured volume as shown in Fig. 6, was given as linear form of Eq. 13.

$$M = 0.92V + 3.16,\ R^2 = 0.98 \qquad (14)$$

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

$M = 0.93V – 0.6$, $R^2 = 0.994$.

In a study conducted by Khoshnam et al. (2007), the overall mass model of pomegranate based on measured volume was reported as

$M = 0.96V + 4.25$, $R^2 = 0.99$.

Measuring of actual volume is a time-consuming task, therefore mass modeling based on it is not reasonable; consequently it seems suitable to accomplish mass modeling of onion based on the volume of assumed prolate spheroid shape (model number 11).

CONCLUSIONS

(1) The recommended equation to calculate onion mass based on length (model 1 was the best) was as nonlinear form

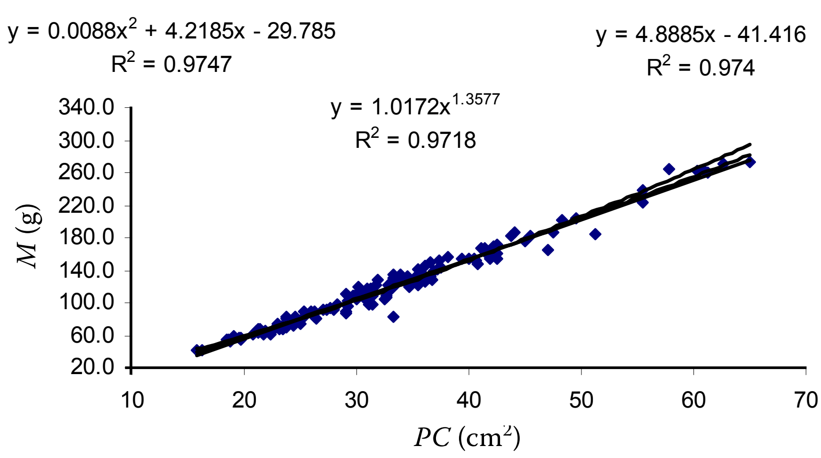

Fig. 5. Onion mass model based on one projected area

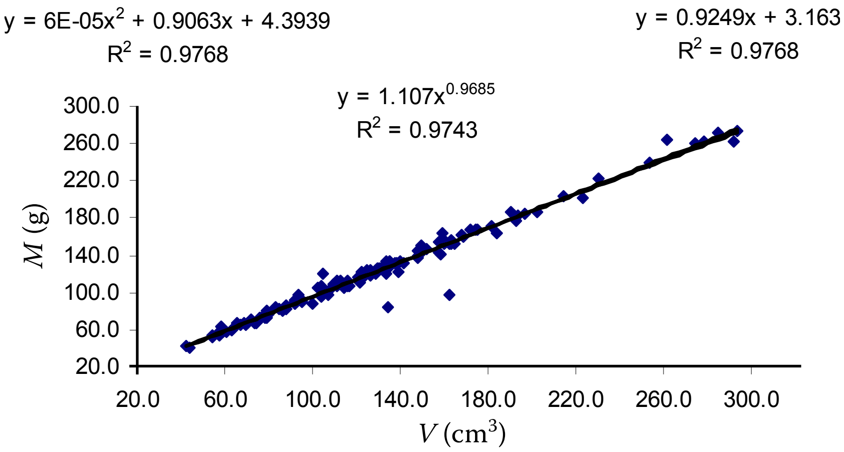

Fig. 6. Onion mass model based on measured volume

$M = 0.035a^2 - 1.64a + 36.137$, $R^2 = 0.96$

(2) The mass model recommended for sizing onion based on any one projected area (model 7 is suitable) was as nonlinear form
$M = 1.02(PA_3)^{1.36}$, $R^2 = 0.97$

(3) There was a very good relationship between mass and measured volume of onions for the entire regions with R^2 as 0.99 (highest R^2 value among all the models).

(4) The model which predicts mass of onion based on estimated volume, the shape of onions considered as prolate spheroid was found to be the most appropriate (model 11 is recommended).

(5) At last, mass model number 1 is recommended from economical standpoint.

Acknowledgments

The authors express their appreciation to the University of Tehran for full support of the project.

List of selected symbols

a – length (mm)
k_i – regression coefficient
b – width (mm)
V_{pop} – volume of prolate spheroid (cm^3)
c – thickness (mm)
V_{ell} – volume of ellipsoid spheroid (cm^3)
GMD – geometric mean diameter (mm)
V_m – measured volume (cm^3)
M – mass (g)
PA – first projected area (cm^2)
V – volume (cm^3)
PB – second projected area (cm^2)
R^2 – coefficient of determination
PC – third projected area (cm^2)
L – length (mm)
T – thickness (mm)
W – width (mm)

References

Anonymous, 2006. Onion marketing strategy. Available at: www.phdeb.org.pk/MktStrategies/Onion.pdf

ASAE Standard, 1998. Compression Test of Food Materials of Convex Shape. ASAE S368.3 MAR95.

Chuma Y., Uchida S., Shemsanga H.H., 1982. Simultaneous measurement of size, surface area, and volume of grains and soybean. Transactions of the ASAE, *25*: 1752–1756.

Fraser B.M., Verma S.S., Muir W.E., 1978. Some physical properties of fababeans. Journal of Agricultural Engineering Research, *22*: 53–57.

Frechette R., Zahradnik J., 1968. Thermal properties of the Mc Intosh apple. Transactions of the ASAE., *11*: 21–24.

Kabas O., Ozmerzi A., Akinci I., 2005. Physical properties of cactus pear (*Opuntia ficus India* L.) grown wild in Turkey. Journal of Food Engineering, *73*: 198–202.

Karababa E., 2006. Physical properties of popcorn kernels. Journal of Food Engineering *72*: 100–107.

Keramat Jahromi M., Rafiee S., Jafari A., Tabatabaeefar A., 2007. Determination of dimension and area properties of date (Berhi) by image analysis. In: Proceedings International Conference of Agricultural, Food and Biological Engineering and Post Harvest/ Production Technology, January 21–24, Khon Kaen, Thailand.

Khoshnam F., Tabatabaeefar A., Ghasemi Varnamkhasti M., Borghei A., 2007. Mass modeling of pomegranate (*Punica granatum* L.) fruit with some physical characteristics. Scientia Horticulturae, *114*: 21–26.

Lorestani A.N., Tabatabaeefar A., 2006. Modeling the mass of Kiwi fruit by geometrical attributes. International Agrophysics, *20*: 135–139.

Malcolm E.W., Tappan J.H., Sister F.E., 1986. The size and shape of typical sweet potatoes. Transactions of the ASAE, 29: 678–682.

Mohsenin N.N., 1986. Physical Properties of Plant and Animal Materials. New York, Gordon and Breach science publishers: 20–89.

Marvin J.P., Hyde G.M., Cavalieri R.P., 1987. Modeling potato tuber mass with tuber dimensions. Transactions of the ASAE, 30: 1154–1159.

Mirasheh R., 2006. Designing and making procedure for a machine determining olive image dimensions. [M.Sc. Thesis.], Karaj, University of Tehran.

Peleg K., 1985. Produce Handling, Packaging and Distribution. Westport, AVI Publishing Company: 20–90.

Safwat M.A., 1971. Theoretical prediction of volume, surface area, and center of gravity for agricultural products. Transactions of the ASAE, *14*: 549–553.

Sitkei G., 1986. Mechanics of Agricultural Materials. New York, Elsevier publisher: 25.

Stroshine R. 1998. Physical Properties of Agricultural Materials and Food Products. Course manual. West Lafayette, Purdue University.

Stroshine R., Hamann D.D., 1994. Physical Properties of Agricultural Materials and Food Products. Course manual. West Lafayette, Purdue University.

Tabatabaeefar A., 2002. Size and shape of potato tubers. International Agrophysics, *16*: 301–305.

Tabatabaeefar A., Rajabipour A., 2005. Modeling the mass of apples by geometrical attributes. Scientia Horticulturae, *105*: 373–382.

Tabatabaeefar A., Vefagh-Nematolahee A., Rajabipour A., 2000. Modeling of orange mass based on dimensions. International Agricultural Science and Technology, *2*: 299–305.

Received for publication June 11, 2009
Accepted after corrections September 21, 2009

Corresponding author:

M. Ghasemi-Varnamkhasti, University of Tehran, Faculty of Agricultural Engineering and Technology, Department of Agricultural Machinery Engineering, Karaj, Iran
phone: + 98 261 280 1011, Fax: + 98 261 280 8138, e-mail: ghasemymahdi@gmail.com