Int. Agrophysics, 2007, 21, 391-397

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Some physical properties of orange (var. Tompson)

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Received May 8, 2007; accepted October 8, 2007

A b s t r a c t. Orange is among the popular fruits and of a high economical value. Sizing and grading of orange is needed for the fruit to be presented to local and foreign markets. A study of orange physical properties is therefore indispensable. Some physical properties of grade one (large), two (medium) and three (small) oranges were investigated. These properties included: dimensions, mass, volume, surface area, porosity and coefficient of static friction. The major, intermediate and minor diameters of the grade two orange were 84.1, 77.4 and 75.5 mm, respectively. Volume and mass of the grade two orange were 217.8 cm^3 and 215.4 g, respectively. As for grade two orange piles, the bulk density and fruit density were respectively calculated as 0.44 and 1.03 g cm^{-3}. Porosity of grade one, two and three oranges was 44.64, 49.39 and 51.2%, with their sphericity being 0.948, 0.931 and 0.923, respectively. The static angle of friction of grade two orange on galvanized, glass and plywood surfaces were found to be 20.2, 23.4 and 23.5°, respectively. The three classes of oranges were significantly different from each other regarding their physical properties. Orange mass was determined through a polynomial function of third degree involving the average diameter of the orange. The function was evaluated with a determination coefficient of 0.991.

K e y w o r d s: physical properties, orange, static friction angle, packaging coefficient

INTRODUCTION

Citrus is of high importance in agriculture nowadays and a substantial source of income for the producing countries. Among citrus fruits, orange is the more important one economically and industrially. It is consumed in different forms such as fresh fruit, concentrated juice or thin dried slices. Citrus oil, as well as essence with medicinal uses, is extracted from its rind and seeds.

Orange was introduced into Iran around 600 years ago. It was first grown in the southern coasts and later transferred to other parts of the country. Iran presently ranks 7th among the orange producing countries of the world (ASB, 2005). Iran's orange export in 2004 amounted to 31710 tons, mostly exported to northern coastal countries of the Caspian Sea, Turkey, and United Arab Emirates (FTSY, 2003). Even though Iran has been among the oldest citrus producing countries of the world, unfortunately, there has not been much progress achieved either in its industrial processing or in its export qualities, causing it not to be of a favourable standing in the international markets. Fruit packaging installations have been founded in five northern cities of Ramsar, Shahsavar, Noshahr, Chaloos and Amol to process and pack citrus in advanced modern ways, but packaging is not yet done in the most suitable and proper way.

Grading and sizing of fruit is a prerequisite to proper packaging, but not much importance has been attached to its study (ICRI, 2005). There does not exist any suitable set of standards for grading and sorting of the fruit. There only exists a rough grading manual of not much scientific value, as reported through some publications of Iran Standard and Industrial Research Institute, ISIRI (WSFV, 1999 and SWFV, 2002).

Physical specifications of agricultural products constitute the most important parameters needed in the design of grading, transfer, processing, and packaging systems. Physical specifications, mechanical, electrical, thermal, light, acoustic and chemical properties are among properties of useful engineering applications.

From among the physical specifications of agricultural product: mass, volume and centre of gravity are of high importance in sizing systems (Safwat and Moustafa, 1971). Parameters measurable through sizing systems are: dimensions (length, width, and height), surface area and weight (Khojastehpour, 1996).

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Mass, volume, surface area, dimensions, apparent volumetric mass, real volumetric mass, porosity, and angle of static friction have been determined by many researchers. Tabatabaeefar (2000), in a study of physical properties of Iranian potatoes, measured the parameters of: physical dimensions, mass, volume, specific mass, mean geometrical diameter, sphericity, and surface area for the four varieties of Vital, Draga, Agria, and Ajax. Test samples of the four varieties (350 samples) were collected from different areas throughout the country. Such parameters as physical dimensions, mass, volume, specific mass, geometrical diameter mean, sphericity, and surface areas for each, as well as for a mixture of varieties, were determined. Also, Pitts *et al.* (1987), through a study of potato physical properties, found models for prediction of tuber mass based upon dimensions.

Tabatabaeefar *et al*. (2000) in a study found 11 models for the prediction of orange mass based upon dimensions, volume and surface areas. Lorestani and Tabatabaeefar (2006) also, while studying the physical properties of two varieties of kiwi (About and Hayward), came up with 11 models for estimating fruit mass based on dimensions, mass, and surface areas. Tabatabaeefar and Rajabipour (2005) predicted apple mass through models that were based upon apple physical properties. Khojastehpour (1996) presented his report on the design and development of a potato grading machine suited for Iranian conditions.

Safwat and Moustafa (1971) studied theoretically and predicted the volume, surface area and centre of gravity of different agricultural products. Safa and Khazaei (2003) and Al-Maiman and Ahmad (2002) studied the physical properties of pomegranate and found models of predicting fruit mass while employing dimensions, volume and surface areas.

Topuz *et al.* (2005) studied the physical and nutritional properties of four varieties of orange. They presented their report on dimensions, volume, mean geometrical diameter, surface area, fruit density, pile density, porosity, packaging coefficient, and friction coefficient. Owolarafe *et al*. (2006) investigated the physical properties of two varieties of palm fruit useful in production of palm oil and palm kernel.

Also, studies on physical properties of special fruits, such as gumbo, can be found in the literature (Akar and Aydin, 2005). Shape, size, surface area, density, porosity, and angle of static friction are among the physical specifications that are of paramount importance in either design of machines or in analysis of matter behaviour during handling and transport. In the present study, the above mentioned properties have been found and the results are presented for orange, Tompson variety.

MATERIALS AND METHODS

As per standards of the American Society of Agricultural Engineering and to attain results at an acceptable level (USDA, 1997), 80 kg of orange, Tompson variety, in three size grades: one (large), two (medium) and three (small), 50 of each, were taken as study samples.

Physical characteristics such as dimensions, mass, volume, surface area, porosity, and angle of static friction were found for the oranges. Mean standard deviation, coefficient of variation, maxima and minima for the data were calculated according to the standards mentioned.

Other parameters, such as coefficient of sphericity, mean geometrical diameter, apparent specific mass, an orange pile specific mass, rind ratio, and packing coefficient (Mohsenin, 1986) were obtained.

Dimension a (the longest), b (the longest dimension perpendicular to a), c (the longest dimension perpendicular to a and b) (Fig. 1), surface area P_a (area perpendicular to diameter a), P_b (area perpendicular to diameter b), and P_c (area perpendicular to diameter c) of each orange were recorded with an accuracy of 0.05 mm using a set of Win Area-UT-06 (Mirasheh, 2006). A set of Win Area-UT-06 (Fig. 2) 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.

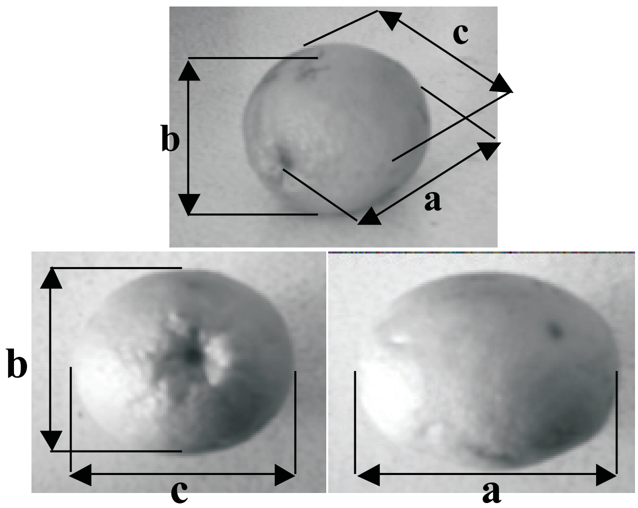


Fig. 1. Three major dimensions and projected area of fruit.

The basic operating principle of this equipment set is ‘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.

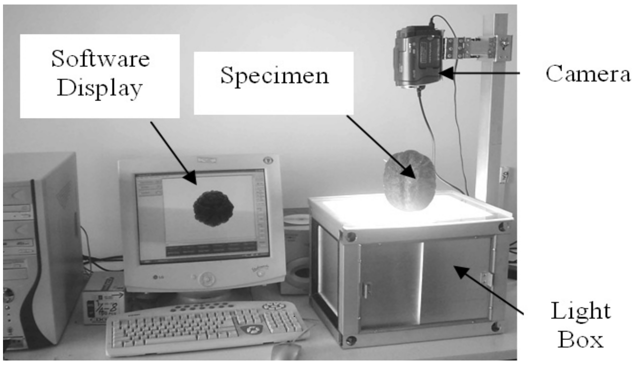


Fig. 2. WinAreaUt_06 system (Mirasheh, 2006).

• The function of the card is to change the analogue image into a digital one.

• The digitised 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%.

Fruit mass was determined through a sensitive digital balance.

In order to figure out fruit volume, a container filled with water was placed on the balance and the displaced water caused by the floated fruit was calculated:

$$volume\ (cm^3) = \frac{displaced\ water\ (g)}{water\ density\ (g\ cm^{-3})}.$$

Bulk density was obtained as:

$$BD = \frac{M_c}{V_c},$$

where: BD – apparent density (g cm^{-3}), M_c – fruits carton mass (g), V_c – fruits carton volume (cm^3) (Mohsenin, 1986).
Density of a pile of fruit was obtained as:

$$SD = \frac{M}{V},$$

where: SD – solid density (g cm^{-3}), M – fruit mass (g), V – fruit volume (cm^3) (Mohsenin, 1986).
Porosity was obtained as:

$$P = \left(\frac{V_c - V_o}{V_c}\right)100,$$

where: P – porosity, V_o – volume of oranges present in the carton.

Static angle of friction was obtained through the use of an inclinometer and 3 (galvanized, glass and wooden) planes (Al-Maiman and Ahmad, 2002).
Mean geometrical diameter was obtained as:

$$GM = (ac^2)^{1/3},$$

where: GM – mean geometrical diameter (mm), a – the main (longest) diameter (mm), c – the longest diameter perpendicular to a and b (mm) (Topuz *et al*., 2005).
Sphericity was obtained as:

$$S_{ph} = \frac{GM}{a},$$

where: S_{ph} – sphericity, GM – mean geometrical diameter (mm), a – the longest diameter of the fruit (mm).
Surface area was obtained as:

$$S = \pi\, GM^2,$$

where: S – surface area (mm^2), GM – mean geometrical diameter (mm) (Topuz *et al*., 2005).
Coefficient of packaging was obtained as:

$$\lambda = \frac{V}{V_o},$$

where: V – volume of fruit present in the carton (cm^3), V_o – volume of the carton (cm^3) (Topuz *et al*., 2005).
Rind ratio was obtained as:

$$R_s = \left(\frac{M_s}{M_f}\right)100,$$

where: R_s – rind ratio, M_s – rind mass, M_f – fruit mass (g) (Topuz *et al*., 2005).

Fruit mass can be estimated on the basis of independent variables of the three dimensions, surface areas normal to the three dimensions and volume of the fruit.

To achieve this, SPSS-13 software and stepwise method were employed. The overall model is based on the following equation:

$$M = k_1 a + k_2 b + k_3 c + k_4 P_a + k_5 P_b + k_6 P_c + k_7 V + k_8$$

where: M is fruit mass (g); a, b, c – major, intermediate, and minor diameters (mm); P_a, P_b, P_c – surface areas perpendicular to the above diameters (mm^2); V – volume (cm^3); and k_1 through k_8 are coefficients of regression.

In a stepwise method, the independent variables enter the equation successively based upon their degree of dependency. The fruit model introduced bears the least independent variables. Other succeeding variables gradually get into the model by the order of their prominence.

RESULTS AND DISCUSSION

Determined physical features of orange samples are presented in Table 1. The mean lengths of the grade one (large), two (medium) and three (small) oranges were 90.4, 84.06 and 77.93 mm, and for the mean width were 85.03, 77.93 and 70.62 mm, respectively. As observed from Table 1, the mean thickness values of grade one, two and three oranges were 84.39, 75.54 and 69.15 mm, respectively. Also as seen in the same table, the mean volumes of grade one, two and three oranges were 277.53, 215.38 and 159.76 cm^3, respectively.

Bulk density of grade one, two and three (0.367, 0.442 0.435 g cm^{-3}) oranges were found to be lower than that of varieties Alanya (0.527), Shamouti (0.526), and Finike (0.515 g cm^{-3}) oranges (Topuz *et al*., 2005).

Porosity of grade one, two and three oranges was 44.64, 49.39 and 51.2%, respectively. Static angle of friction for grade one, two and three oranges of Tompson variety on different surfaces was found to be as follows:

Galvanized iron, 26.4, 20.2 and 16.8°; glass surface, 27.6, 23.4 and 21.4°; wooden surface 23.6, 23.5 and 23.26°.

Packing coefficients, as indicated in Table 1 were 0.31, 0.42, and 0.53 for the three sizes of grade one, two and three oranges. The figures are lower as compared with those in the case of Alanya, Shamouti and Finike varieties with packing coefficients of 0.62, 0.61, and 0.57 (Topuz *et al*., 2005).

Ratio of rind to total fruit weight for the grades of one, two and three fruits was found to be 0.254, 0.256, and 0.251, respectively.

Means of major, intermediate and minor diameters, specific volume of fruit and of a pile of fruit, fruit volume and mass of the three grades of orange were compared and are shown in Table 2. There are significant differences among them as revealed by multi range Duncan test at 5% level of probability.

Major, intermediate and minor diameter figures for grade one orange are higher than those of the grade two as well as those of the grade three oranges. These figures are higher for the medium size oranges as compared with the small ones (Table 3).

Density of a pile of oranges is significantly higher for grade one oranges in comparison with those of grade two and three ones, but no difference was observed between the figures for grade two and three oranges (Table 3).

No difference was observed between either grade one and two or grade two and three oranges as far as density is concerned, but the fruit density of grade one oranges was found to be less than that of the grade three ones (Table 3).

T a b l e 1. Assessed physical characteristics of oranges

Physical property		Number of observations	Grade of oranges		
			large	medium	small
Average:					
a (length) (mm)		150	90.4	84.06	77.93
b (width) (mm)			85.03	77.39	70.62
c (thickness) (mm)			84.39	75.54	69.15
P_a (mm^2)		150	56.9×10^2	47.1×10^2	39.4×10^2
P_b (mm^2)			59.4×10^2	50.2×10^2	42.8×10^2
P_c (mm^2)			60.1×10^2	51.2×10^2	43.4×10^2
fruit mass (g)		150	268.28	217.82	168.19
fruit volume cm^3			277.53	215.38	159.76
Geometric mean diameter (mm)		150	85.66	78.27	71.96
Sphericity (%)			0.948	0.931	0.923
Surface area (mm^2)			23.1×10^3	19.2×10^3	16.2×10^3
Fruit density (g cm^{-3})		15	0.999	1.013	1.046
Bulk density (g cm^{-3})			0.367	0.442	0.435
Porosity (%)			44.64	49.39	51.20
Packaging coefficient (-)		30	0.31	0.42	0.53
Rind ratio (-)			0.254	0.256	0.251
Coefficient of static friction	Glass (°)	30	27.6	23.4	21.4
	Galvanized steel (°)		26.4	20.2	16.8
	Plywood (°)		23.6	23.5	23.26

T a b l e 2. Analysis of variance as related to graded orange physical properties

Dependent variety	Source	Sum of squares	Mean of squares	F*
Major diameter (mm)		3892.85	1946.43	120.60
	Error	2372.49	16.14	
	Total	6265.34		
Intermediate diameter (mm)		5191.75	2595.87	596.90
	Error	639.29	4.35	
	Total	5830.04		
Minor diameter (mm)		5090.05	2545.03	489.57
	Error	764.18	5.20	
	Total	5854.23		
Fruit density (g cm^{-3})		0.008	0.004	35.20
	Error	0.001	0.000	
	Total	0.009		
Bulk density (g cm^{-3})		0.003	0.002	9.32
	Error	0.001	0.000	
	Total	0.005		
Fruit volume (cm^3)		80.5×10^4	40.2×10^4	33.58
	Error	71.9×10^3	11.9×10^3	
	Total	87.7×10^4		
Fruit mass (g)		51.1×10^4	25.5×10^4	37.15
	Error	41.3×10^3	68.8×10^3	
	Total	55.3×10^4		

*Significant at 1% level.

T a b l e 3. Means comparison by Duncan's multiple range tests (at 5% level)

Dependent variety	Subset	Grade of orange		
		large	medium	small
Major diameter (mm)	1	90.40		
	2		84.06	
	3			77.93
Intermediate diameter (mm)	1	85.03		
	2		77.39	
	3			70.62
Minor diameter (mm)	1	84.39		
	2		75.54	
	3			69.15
Bulk density (g cm^{-3})	1	0.36	0.43	
	2		0.43	0.44
Fruit density (g cm^{-3})	1	0.99	1.01	
	2		1.01	1.04
Fruit volume (cm^3)	1	268.28		
	2		217.82	
	3			168.19
Fruit mass (g)	1	277.53		
	2		215.38	
	3			159.76

There were no differences observed between volume and mass of grade one orange with those of grade two one, but volume and mass figures were found to be higher for grade one oranges than those of grade three ones (Table 3).

Evaluation of the regression models

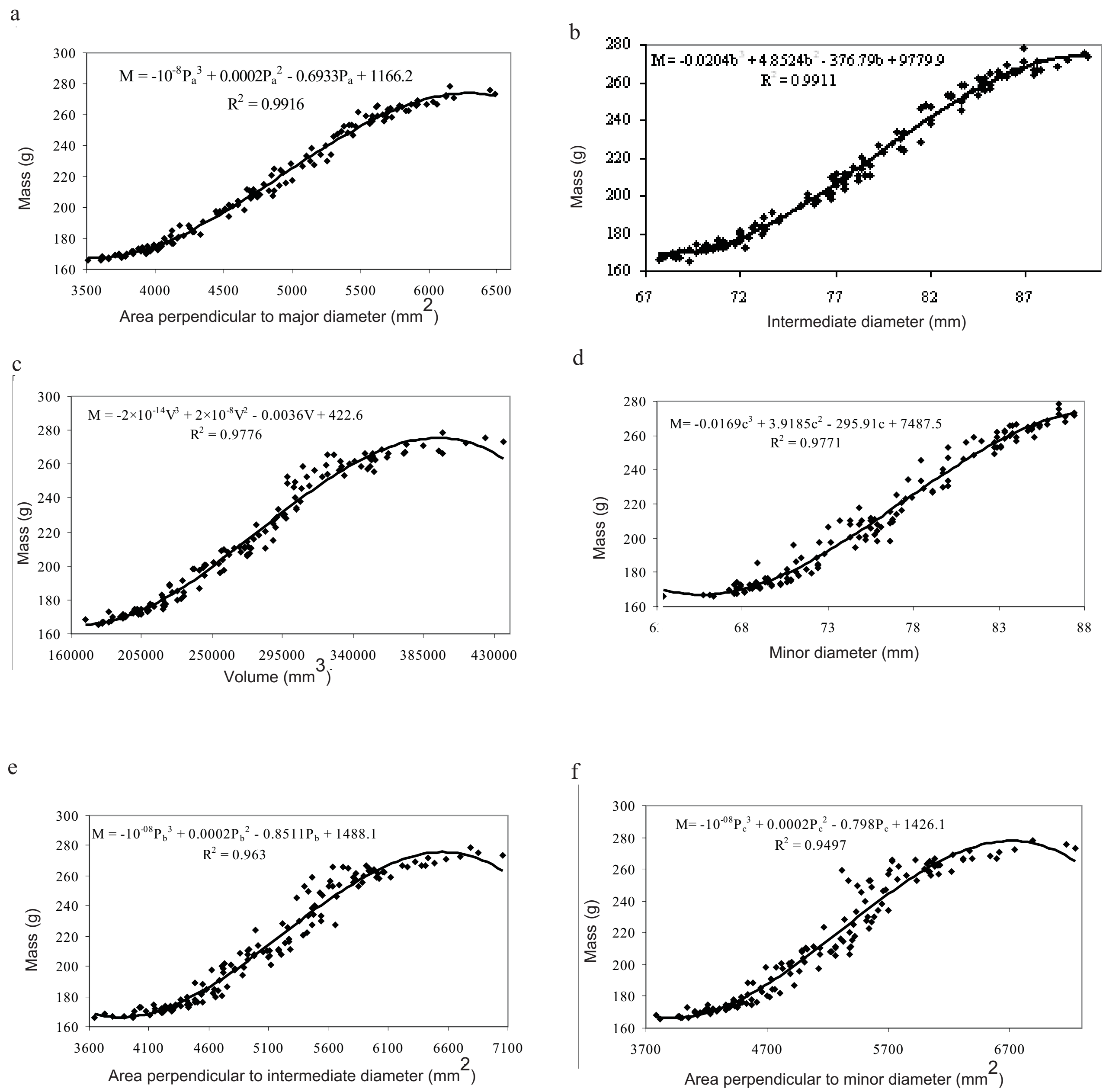
The equations were derived through stepwise method and on the basis of the intermediate diameter as the first and only independent variable the fruit mass was estimated (coefficient of determination = 0.989).

$$M = -232.8 + 5.7b\ ,\ R^2 = 0.989, RMSE = 5.47\,.$$

A coefficient of determination of 0.991 was achieved when the minor diameter was also added to the model.

$$M = -232.1 + 3.7b + 2c\ \ R^2 = 0.991, RMSE = 4.85\,.$$

Taking into account all the independent variables, the outcome of the stepwise procedure for the mass of orange with a determination coefficient of 0.993 was found to be:



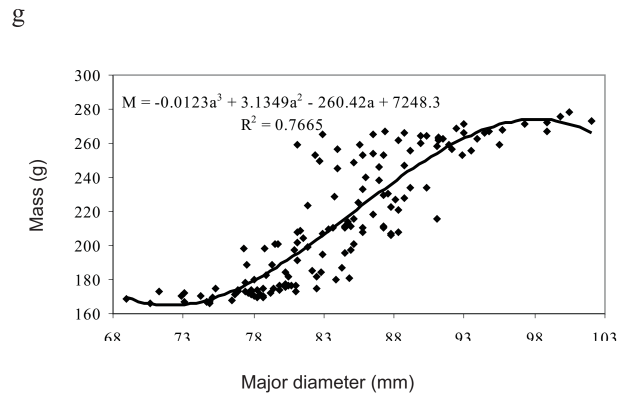


Fig. 3. Relationship between mass of oranges and: a – area perpendicular to major diameter; b – intermediate diameter; c – volume; d – minor diameter; e – area prependicular to intermediate diameter; f – area prependicular to minor diameter and g – major diameter.

$$M = -102.8 + 1.8b + 1.1c + 0.0231P_a -$$
$$0.0149P_c + 0.00017V$$
$$R^2 = 0.993, RMSE = 4.47 .$$

An equation of the third degree was found to be more responsive to estimate the mass of orange based upon any of the independent variables of dimension or projected areas with respect to any of the minor, intermediate and major diameters. These are demonstrated in Fig. 3 in order of their coefficients of determination.

As indicated in Fig. 3, orange mass can be estimated on the basis of projected area perpendicular to the major diameter, and on the basis of intermediate diameter with the respective coefficients of determination of 0.992 and 0.991. Predictions of orange mass on the basis of any of the variables of volume, minor diameter, and projected areas perpendicular to the intermediate and major diameter are presented in Fig. 3 with coefficients of determination 0.978, 0.977, 0.963, 0.950 and 0.766, respectively. Any of the above variables is in significant correlation with orange mass and can be employed in development of the third degree regression for estimation of the orange mass. Since measurement of the intermediate diameter is the easiest, this parameter can be employed in an equation to predict the orange mass as follows (Fig. 3):

$$M = -0.0204b^3 + 4.852b^2 - 376.79b + 9779.9 .$$

CONCLUSIONS

1. Since the rind and flesh of the fruit grow almost simultaneously, for all orange grades under this study the rind ratio was found to be the same.

2. Since the price of all orange grades in Iran is the same in the domestic market, it is reasonable to export grades one and two and keep grade three for Iranian market. Besides, due to higher packaging coefficients, more oranges in grades two and three can be packed in a box than grade one. For domestic use, this is an important issue since the labour and transportation costs are very high. For export, the higher income compensates for the higher expenses involved.

3. A linear model of the orange mass was developed on the basis of the independent variables of major, intermediate and minor diameters, as well as on the basis of projected area at right angle with the major, intermediate and minor diameters. The R^2 and $RMSE$ were 0.993 and 4.477, respectively.

4. The most recommended regression model to fit orange mass was the one based upon the intermediate diameter of orange and of the third degree.

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