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Modeling of Tangerine Mass Based on Geometrical Properties

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Abstract: Nine linear regression models for predicting tangerine mass based on some geometrical properties of tangerine such as length (L), diameter (D), geometrical mean diameter (GMD), first projected area (PA_1), second projected area (PA_2), criteria area (CAE) and estimated volume based on an oblate spheroid assumed shape (V_{Sp}) were suggested. The statistical results of the study indicated that in order to predict tangerine mass based on outer dimensions, the mass model based on GMD as M = - 150.5 +43.94 GMD with R^2 = 0.89 can be recommended. In addition, to predict tangerine mass based on projected areas, the mass model based on CAE as M = - 26.08 + 4.842 CAE with R^2 = 0.90 can be suggested. Moreover, to predict tangerine mass based on estimated volume, the mass model based on V_{Sp} as M = 16.00 + 0.828 V_{Sp} with R^2 = 0.88 can be used.

Key words: Tangerine · Mass · Modeling · Sorting · Grading · Geometrical properties

INTRODUCTION

The tangerine (*Citrus tangerina*) is an orange-colored citrus fruit (Fig. 1) which is closely related to the Mandarin orange (*Citrus reticulata*). They are smaller than most oranges and are usually much easier to peel and to split into segments. Tangerines have been found in many shapes and sizes, from as small as a small walnut, to larger than an average orange. The number of seeds in each segment varies greatly. The taste is often less sour, or tart, than that of an orange. While less tart, tangerines are also sweeter than oranges. Peak tangerine season lasts from October to April in the Northern Hemisphere. Tangerines are most commonly peeled and eaten out of hand. The fresh fruit is also used in salads, desserts and main dishes. The peel is dried and used in some foods. Fresh tangerine juice and frozen juice concentrate are commonly available. Moreover, tangerines are a good source of vitamin C, folate and beta-carotene. They also contain potassium, magnesium and vitamins B_1, B_2 and B_3 [1].

Iran products 3.5 million tones of citrus and is ranked 22nd in the world. But, Iranian tangerines are not exported because of variability in size and shape and lack of suitable packaging [2]. Similar to other fruits, tangerine size is one of the most important quality parameters for evaluation by consumer preference. Consumers prefer fruits of equal size and shape [3, 4]. Sorting can increase uniformity in size and shape, reduce packaging and transportation costs and also may provide an optimum packaging configuration [5]. Moreover, sorting is important in meeting quality standards, increasing market value and marketing operations [6]. Sorting manually is associated with high labor costs in addition to subjectivity, tediousness and inconsistency which lower the quality of sorting [7]. However, replacing human with a machine may still be questionable where the labor cost is comparable with the sorting equipment [8]. Studies on sorting in recent years have focused on automated sorting strategies and eliminating human efforts to provide more efficient and accurate sorting systems which improve the classification success or speed up the classification process [9, 10].

Physical and geometrical characteristics of products are the most important parameters in design of sorting systems. Among these characteristics, mass, outer dimensions, projected areas and volume are the most important ones in sizing systems [11]. The size of produce is frequently represented by its mass because it is relatively simple to measure. However, sorting based on

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some geometrical properties may provide a more efficient method than mass sorting. Moreover, the mass of produce can be easily estimated from geometrical properties if the mass model of the produce in known [12-16]. For that reason, modeling of tangerine mass based on some geometrical properties may be useful and applicable. Therefore, the main objectives of this research were to determine suitable mass model(s) based on some geometrical properties of tangerine and to verify selected mass model(s) by comparing its (their) results with those of the measuring method.

MATERIALS AND METHODS

Experimental Procedure: One of the most common commercial cultivars of tangerine in Iran, i.e. Clementine was considered for this study. One hundred randomly selected tangerines of various sizes were purchased from a local market. Tangerines were selected for freedom from defects by careful visual inspection, transferred to the laboratory and held at 5±1°C and 90±5% relative humidity until experimental procedure. In order to obtain required parameters for determining mass models, the mass of each tangerine was measured to 1.0 g accuracy on a digital balance. By assuming the shape of tangerine as an oblate spheroid, the outer dimensions of each tangerine, i.e. length (L) and diameter (D) was measured to 0.1 cm accuracy by a digital caliper. The geometric mean diameter (GMD) of each tangerine was then calculated by equation 1.

$$GMD = (LD^2)^{1/3} \quad (1)$$

Two projected areas of each tangerine, i.e. first projected area (PA_1) and second projected area (PA_2) was also calculated by using equation 2 and 3, respectively. The average projected area known as criteria area (CAE) of each tangerine was then determined from equation 4.

$$PA_1 = \eta D^2/4 \quad (2)$$

$$PA_2 = \eta LD/4 \quad (3)$$

$$CAE = (PA_1+2PA_2)/3 \quad (4)$$

In addition, the estimated volume of each tangerine by assuming the shape of tangerine as an oblate spheroid (V_{Sp}) was calculated by using equation 5.

$$V_{Sp} = \eta LD^2/6 \quad (5)$$

Table 1: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of physical and geometrical properties of the 100 randomly selected tangerines used to determine mass models

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Mass (M), g	42.00	193.0	101.2	33.00	32.61
Length (L), cm	3.300	8.600	5.059	0.762	15.06
Diameter (D), cm	4.600	7.900	6.104	0.757	12.40
Geometrical mean diameter (GMD), cm	4.118	7.326	5.728	0.706	12.33
First projected area (PA_1), cm^2	16.62	49.02	29.71	7.327	24.67
Second projected area (PA_2), cm^2	11.92	41.20	24.58	6.183	25.15
Criteria area (CAE), cm^2	13.49	42.40	26.29	6.424	24.43
Estimated volume (V_{Sp}), cm^3	36.56	205.9	102.8	37.42	36.39

Table 2: Nine linear regression mass models and their relations in three classifications

Classification	Model No.	Model	Relation
Outer dimensions	1	$M = k_0 + k_1 L$	$M = -68.23 + 33.49 L$
	2	$M = k_0 + k_1 D$	$M = -147.9 + 40.81 D$
	3	$M = k_0 + k_1 GMD$	$M = -150.5 + 43.94 GMD$
	4	$M = k_0 + k_1 L + k_2 D$	$M = -152.8 + 8.384 L + 34.66 D$
Projected areas	5	$M = k_0 + k_1 PA_1$	$M = -24.06 + 4.216 PA_1$
	6	$M = k_0 + k_1 PA_2$	$M = -18.71 + 4.878 PA_2$
	7	$M = k_0 + k_1 CAE$	$M = -26.08 + 4.842 CAE$
	8	$M = k_0 + k_1 PA_1 + k_2 PA_2$	$M = -27.52 + 2.733 PA_1 + 1.933 PA_2$
Estimated volume	9	$M = k_0 + k_1 V_{Sp}$	$M = 16.00 + 0.828 V_{Sp}$

Fig. 1: Tangerine (*Citrus tangerina*)

Table 1 shows physical and geometrical properties of the tangerines used to determine mass models.

Regression Models: A typical multiple variable linear regression model is shown in equation 6:

$$Y = k_0 + k_1X_1 + k_2X_2 + \ldots + k_nX_n \quad (6)$$

where:

Y = Dependent variable, for example mass of tangerine

$X_1, X_2, \ldots, X_n$ = Independent variables, for example geometrical properties of tangerine

$k_0, k_1, k_2, \ldots, k_n$ = Regression coefficients

In order to estimate tangerine mass from geometrical properties, nine linear regression mass models were suggested and all the data were subjected to linear regression analysis using the Microsoft Excel 2007. Models were divided into three main classifications (Table 2), i.e. first classification (outer dimensions), second classification (projected areas) and third classification (estimated volume).

RESULTS AND DISCUSSION

The p-value of the independent variable(s) and coefficient of determination (R^2) of all the linear regression mass models are shown in Table 3.

First Classification Models (Outer Dimensions): In this classification tangerine mass can be predicted using single variable linear regressions of length (L), diameter (D) and geometrical mean diameter (GMD) of tangerine, or multiple variable linear regression of tangerine outer dimensions (length and diameter). As indicated in Table 3, among the first classification models (models No. 1-4), model No. 3 had the highest R^2 values (0.89). Also, the p-value of independent variable (GMD) was the lowest (1.06E-47). Based on the statistical results model No. 3 was selected as the best model of first classification. Model No. 3 is given in equation 7.

$$M = -150.5 + 43.94\,GMD \quad (7)$$

Second Classification Models (Projected Areas): In this classification tangerine mass can be predicted using single variable linear regressions of first projected area (PA_1), second projected area (PA_2) and criteria area (CAE) of tangerine, or multiple variable linear regression of tangerine projected areas. As showed in Table 3, among the second classification models (models No. 5-8), model No. 7 had the highest R^2 values (0.90). Moreover, the p-value of independent variable (CAE) was the lowest (2.13E-48). Again, based on the statistical results model No. 7 was chosen as the best model of second classification. Model No. 7 is given in equation 8.

$$M = -26.08 + 4.842\,CAE \quad (8)$$

Table 3: Mass models, p-value of model variable(s) and coefficient of determination (R^2)

	p-value							
Model No.	L	D	GMD	PA_1	PA_2	CAE	V_{sp}	R^2
1	4.34E-21	---	---	---	---	---	---	0.60
2	---	3.80E-46	---	---	---	---	---	0.88
3	---	---	1.06E-47	---	---	---	---	0.89
4	0.000129	1.12E-29	---	---	---	---	---	0.88
5	---	---	---	2.86E-46	---	---	---	0.88
6	---	---	---	---	3.74E-40	---	---	0.83
7	---	---	---	---	---	2.13E-48	---	0.90
8	---	---	---	6.08E-12	9.54E-06	---	---	0.89
9	---	---	---	---	---	---	2.53E-47	0.88

Third Classification Model (Estimated Volume): In this classification tangerine mass can be predicted using single variable linear regression of estimated volume of tangerine (V_{Sp}). As indicated in Table 3, model No. 9 had high R^2 value (0.88). In addition, the p-value of independent variable (V_{Sp}) was (2.53E-47). Once more, based on the statistical results model No. 9 was chosen as a suitable model. Model No. 9 is given in equation 9.

$$M = 16.00 + 0.828\ V_{Sp} \quad (9)$$

CONCLUSION

To predict tangerine mass based on outer dimensions, the mass model based on GMD as $M = -150.5 + 43.94\ GMD$ with $R^2 = 0.89$ can be suggested. In addition, to predict tangerine mass based on projected areas, the mass model based on CAE as $M = -26.08 + 4.842\ CAE$ with $R^2 = 0.90$ can be recommended. Moreover, to predict tangerine mass based on estimated volume, the mass model based on V_{Sp} as $M = 16.00 + 0.828\ V_{Sp}$ with $R^2 = 0.88$ can be utilized.

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