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Peach Mass Modeling Based on Geometrical Attributes

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Abstract: Eighteen linear regression models for modeling peach mass based on its geometrical attributes such as major diameter (a), intermediate diameter (b), minor diameter (c), geometrical mean diameter (GMD), first projected area (PA_1), second projected area (PA_2), third projected area (PA_3), criteria area (CAE), estimated volume based on an ellipsoid assumed shape (V_{Ell}) and measured volume (V_M) were suggested. Models were divided into three main classifications, i.e. first classification (outer dimensions), second classification (projected areas) and third classification (volumes). The statistical results of the study indicated that in order to predict peach mass based on outer dimensions, the mass model based on intermediate and minor diameters as $M = - 152.35 + 2.38\ b + 2.09\ c$ with $R^2 = 0.93$ may be suggested. Also, to predict peach mass based on projected areas, the mass model based on third projected area as $M = - 32.71 + 5.34\ PA_3$ with $R^2 = 0.93$ may be recommended. In addition, to predict peach mass based on volumes, the mass model based on estimated volume as $M = 3.90 + 1.03\ V_{Ell}$ with $R^2 = 0.91$ may be utilized. These models can be verified and used to design and develop sizing machines equipped with an image processing system.

Key words: Peach mass · Modeling · Geometrical attributes · Linear regression models

INTRODUCTION

Peach (*Prunus persica*) belongs to the Rosaceae family and is thought to have originated in China. Chinese literature dates cultivation of the peach in China to 1000 B.C. and it was probably carried from China to Iran [1]. Peach, at one time called "Persian apple", quickly spread from there to Europe. In the 16th century, it was established in Mexico and in the 18th century Spanish missionaries introduced the peach to California, which turned out to be the most important production area after China and Italy [2]. On the basis of the separation of the stone from the flesh, peaches can be divided into two groups: freestone and clingstone. In addition, based on the amount of softening of the flesh that occurs during ripening, peaches can be either of a melting or non-melting type [3]. Most cultivars have yellow flesh, but white-fleshed cultivars have always been known and are being increasingly planted. Peaches with low, medium or high acid concentrations are also available [4]. Peaches are also rich in ascorbic acid (vitamin C), carotenoids (provitamin A) and phenolic compounds that are good sources of antioxidants [5]. Currently, world production of peaches stands at 11 million tones, with the three major producing countries being China, Italy and the United States in the Northern hemisphere and Chile, South Africa and Australia in the Southern hemisphere. All of these different combinations of peach, i.e. clingstone or freestone, yellow or white flesh, low, medium or high acidity are available as freshly harvested fruit from April through September in the Northern Hemisphere and from November to March in the Southern Hemisphere [6].

Similar to other fruits, peach size is one of the most important quality parameters for evaluation by consumer preference. Consumers prefer fruits of equal size and shape. Sorting can increase uniformity in size and shape, reduce packaging and transportation costs and also may provide an optimum packaging configuration [7, 8]. Moreover, sorting is important in meeting quality standards, increasing market value and marketing operations [9, 10]. Sorting manually is associated with high labor costs in addition to subjectivity, tediousness and inconsistency which lower the quality of sorting [11].

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However, replacing human with a machine may still be questionable where the labor cost is comparable with the sorting equipment [12]. 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 [13, 14].

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 [15-17]. The size of produce is frequently represented by its mass because it is relatively simple to measure. However, sorting based on some geometrical attributes may provide a more efficient method than mass sorting. Moreover, the mass of produce can be easily estimated from geometrical attributes if the mass model of the produce in known [18]. For that reason, modeling of peach mass based on some geometrical attributes may be useful and applicable. Therefore, the main purpose of this research was to determine optimum mass model(s) based on some geometrical attributes of peach.

MATERIALS AND METHODS

Experimental Procedure: One hundred randomly selected peaches (cv. French) of various sizes were purchased from a local market. Peaches 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 peach was measured to 0.1 g accuracy on a digital balance. Moreover, the volume of each peach was measured using the water displacement method. Each peach was submerged into water and the volume of water displaced was measured. Water temperature during measurements was kept at 25°C.

By assuming the shape of peaches as an ellipsoid (Fig. 1), the outer dimensions of each peach, i.e. major diameter (a), intermediate diameter (b) and minor diameter (c) was measured to 0.1 mm accuracy by a digital caliper. The geometric mean diameter (GMD) of each peach was then calculated by equation 1.

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

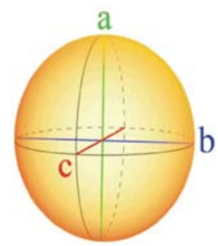

Fig. 1: The outer dimensions of a peach, i.e. major diameter (a), intermediate diameter (b) and minor diameter (c) by assuming the shape of peach as an ellipsoid

Three projected areas of each peach, i.e. first projected area (PA_1), second projected area (PA_2) and third projected area (PA_3) was also calculated by using equation 2, 3 and 4, respectively. The average projected area known as criteria area (CAE) of each peach was then determined from equation 5.

$$PA_1 = \pi\, ab/4 \quad (2)$$

$$PA_2 = \pi\, ac/4 \quad (3)$$

$$PA_3 = \pi\, bc/4 \quad (4)$$

$$CAE = (PA_1+PA_2+PA_3)/3 \quad (5)$$

In addition, the volume of ellipsoid assumed shape or estimated volume of each peach (V_{Ell}) was calculated by using equation 6.

$$V_{ell} = \pi\, abc/6 \quad (6)$$

Table 1 shows some physical and geometrical attributes of the peaches used to determine mass models.

Regression Models: A typical linear multiple regression model is shown in equation 7:

$$Y = k_0 + k_1X_1 + k_2X_2 + \ldots + k_nX_n \quad (7)$$

where:

Y	=	Dependent variable, for example mass of peach
$X_1, X_2, \ldots, X_n$	=	Independent variables, for example geometrical attributes of peach
$k_0, k_1, k_2, \ldots, k_n$	=	Regression coefficients

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

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Mass (M), g	47.12	139.7	88.17	17.65	20.01
Major diameter (a), mm	43.40	62.09	53.41	3.577	6.697
Intermediate diameter (b), mm	45.86	64.73	55.12	3.822	6.933
Minor diameter (c), mm	41.60	61.30	52.11	4.009	7.693
Geometrical mean diameter (GMD), mm	43.58	61.88	53.52	3.631	6.784
First projected area (PA_1), cm^2	15.62	30.76	23.20	3.022	13.02
Second projected area (PA_2), cm^2	14.17	28.81	21.94	3.010	13.72
Third projected area (PA_3), cm^2	14.97	31.14	22.65	3.194	14.10
Criteria area (CAE), cm^2	14.92	30.08	22.60	3.038	13.40
Estimated volume (V_{Ell}), cm^3	43.33	124.0	81.32	16.30	20.04
Measured volume (V_M), cm^3	42.58	141.9	86.68	18.12	20.90

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

Classification	Model No.	Model	Relation
Outer dimensions	1	$M = k_0 + k_1\ a$	$M = -135.37 + 4.18\ a$
	2	$M = k_0 + k_1\ b$	$M = -150.67 + 4.33\ b$
	3	$M = k_0 + k_1\ c$	$M = -126.09 + 4.11\ c$
	4	$M = k_0 + k_1\ GMD$	$M = -159.48 + 4.63\ GMD$
	5	$M = k_0 + k_1\ a + k_2\ b$	$M = -160.05 + 0.95\ a + 3.58\ b$
	6	$M = k_0 + k_1\ a + k_2\ c$	$M = -138.07 + 0.88\ a + 3.43\ c$
	7	$M = k_0 + k_1\ b + k_2\ c$	$M = -152.35 + 2.38\ b + 2.09\ c$
	8	$M = k_0 + k_1\ a + k_2\ b + k_3\ c$	$M = -153.19 + 0.09\ a + 2.35\ b + 2.05\ c$
Projected areas	9	$M = k_0 + k_1\ PA_1$	$M = -38.12 + 5.44\ PA_1$
	10	$M = k_0 + k_1\ PA_2$	$M = -31.96 + 5.47\ PA_2$
	11	$M = k_0 + k_1\ PA_3$	$M = -32.71 + 5.34\ PA_3$
	12	$M = k_0 + k_1\ CAE$	$M = -28.53 + 5.14\ CAE$
	13	$M = k_0 + k_1\ PA_1 + k_2\ PA_2$	$M = -36.99 + 2.68\ PA_1 + 2.87\ PA_2$
	14	$M = k_0 + k_1\ PA_1 + k_2\ PA_3$	$M = -33.72 + 0.38\ PA_1 + 4.99\ PA_3$
	15	$M = k_0 + k_1\ PA_2 + k_2\ PA_3$	$M = -32.91 + 0.14\ PA_2 + 5.20\ PA_3$
	16	$M = k_0 + k_1\ PA_1 + k_2\ PA_3 + k_3\ PA_3$	$M = -33.72 + 0.45\ PA_1 - 0.12\ PA_2 + 5.04\ PA_3$
Volumes	17	$M = k_0 + k_1\ V_{Ell}$	$M = 3.90 + 1.03\ V_{Ell}$
	18	$M = k_0 + k_1\ V_M$	$M = 4.60 + 0.96\ V_M$

In order to model peach mass based on geometrical attributes, eighteen 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 (volumes).

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 peach mass can be predicted using single variable linear regressions of major diameter (a), intermediate diameter (b), minor diameter (c) and geometrical mean diameter (GMD) of peach or multiple variables linear regressions of peach diameters. As indicated in Table 3, among the first classification models (models No. 1-8), model No. 7 had the highest R^2 value (0.93). Also, the p-value of independent variables (b and c) was 7.68E-14 and 2.09E-12, respectively. Based on the statistical results model No. 7 was selected as the best model of first classification. Model No. 7 is given in equation 8.

$$M = - 152.35 + 2.38\ b + 2.09\ c \qquad (8)$$

Second Classification Models (Projected Areas): In this classification peach mass can be predicted using single variable linear regressions of first projected area (PA_1), second projected area (PA_2), third projected area (PA_3) and criteria area (CAE) of peach or multiple variables

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

	p-value										
Model No.	a	b	c	GMD	PA_1	PA_2	PA_3	CAE	V_{Ell}	V_M	R^2
1	8.95E-29	---	---	---	---	---	---	---	---	---	0.72
2	---	6.81E-47	---	---	---	---	---	---	---	---	0.88
3	---	---	1.84E-45	---	---	---	---	---	---	---	0.87
4	---	---	---	4.34E-52	---	---	---	---	---	---	0.90
5	0.002665	1.41E-21	---	---	---	---	---	---	---	---	0.89
6	0.010075	---	1.27E-19	---	---	---	---	---	---	---	0.88
7	---	7.68E-14	2.09E-12	---	---	---	---	---	---	---	0.93
8	0.752085	2.76E-12	2.47E-10	---	---	---	---	---	---	---	0.93
9	---	---	---	---	6.52E-45	---	---	---	---	---	0.87
10	---	---	---	---	---	3.19E-45	---	---	---	---	0.87
11	---	---	---	---	---	---	5.84E-59	---	---	---	0.93
12	---	---	---	---	---	---	---	8.67E-43	---	---	0.85
13	---	---	---	---	0.001120	0.000525	---	---	---	---	0.88
14	---	---	---	---	0.489004	---	1.16E-15	---	---	---	0.93
15	---	---	---	---	---	0.807151	2.94E-15	---	---	---	0.93
16	---	---	---	---	0.505137	0.863996	6.83E-13	---	---	---	0.93
17	---	---	---	---	---	---	---	---	3.19E-54	---	0.91
18	---	---	---	---	---	---	---	---	---	9.35E-84	0.97

linear regressions of peach projected areas. As showed in Table 3, among the second classification models (models No. 9-16), model No. 11 had the highest R^2 value (0.93). Moreover, the p-value of independent variable (PA_3) was 5.84E-59. Again, based on the statistical results model No. 11 was chosen as the best model of second classification. Model No. 11 is given in equation 9.

$$M = - 32.71 + 5.34\ PA_3 \quad (9)$$

Third Classification Models (Volumes): In this classification peach mass can be predicted using single variable linear regressions of estimated volume calculated from an ellipsoid assumed shape (V_{Ell}) or measured volume (V_M) of peach (models No. 17 and 18). As measuring the volume of an irregularly shaped object (fruit) using water displacement method is often difficult, model No. 17 was chosen as the best model of third classification. Model No. 17 had a high R^2 value (0.91). In addition, the p-value of independent variable (V_{Ell}) was 3.19E-54 (Table 3). Model No. 17 is given in equation 10.

$$M = 3.90 + 1.03\ V_{Ell} \quad (10)$$

CONCLUSIONS

To predict peach mass based on outer dimensions, the mass model based on intermediate and minor diameters as $M = - 152.35 + 2.38\ b + 2.09\ c$ with $R^2 = 0.93$ may be suggested. Also, to predict peach mass based on projected areas, the mass model based on third projected area as $M = - 32.71 + 5.34\ PA_3$ with $R^2 = 0.93$ may be recommended. In addition, to predict peach mass based on volumes, the mass model based on estimated volume as $M = 3.90 + 1.03\ V_{Ell}$ with $R^2 = 0.91$ may be utilized. These models can be verified and used to design and develop sizing machines equipped with an image processing system.

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