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Mass Modeling of Date Fruit (cv. Zahedi) with Some Physical Characteristics

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Abstract: Mass is often required for designing of postharvest equipment of agricultural products. Grading of fruit based on its weight is important and in nearly all cases of agricultural products grading is based on weight. In this study, mass of date (cv. Zahedi) was predicted by applying different physical characteristics with three different linear classifications as: (1) Single or multiple variable regressions of date dimensional characteristics, (2) Single or multiple variable regressions based on projected areas, (3) Estimating mass based on measured (actual) volume and volumes of assumed shapes (oblate spheroid and ellipsoid). In the first classification of mass modeling, the highest determining coefficient was obtained as R^2=0.70 based on length with a relation as M = 0.3783L-5.8761. It was found that among systems that sort dates based on one dimension, the system that applies its length is better suited. The best determining coefficients for single and multiple variable regression models based on projected areas obtained as R^2=0.73 and R^2=0.74, respectively. Based on results, it found that there is a linear relation between mass and measured volume with a very high coefficient of determination as M = 1.0859 V_m-0.3851 and R^2=0.90.

Key words: Date fruit · Zahedi · Jahrom · mass modeling · physical attributes · grading

INTRODUCTION

Most of the processing methods of agricultural products like date employed are still traditional. There is a need to develop appropriate technologies for date processing. The development of the technologies will require the properties of this product. There are instances in which it is desirable to determine relationships among fruit physical attributes. For example, fruits are often graded by size, but it may be more economical to develop a machine which grades by weight. Grading fruits based on weight is important in packing, handling and provides suitable packing patterns. The different grading systems require different fruit sizing based on particular parameters. Nearly all fruits and vegetables are graded based on quality when delivered for processing or for the fresh markets. In nearly all cases of raw products, grading is based on percent by weight [1]. Shape and physical dimensions are important in sorting and sizing of fruits and vegetables. Size and shape determine how many fruits can be placed in shipping containers or plastic bags of a given size [2].

The regression analysis was used by Chuma *et al.* [3] to develop equations for predicting volume and surface area. They used the logarithmic transformation to develop equations for wheat kernels at 15.7% (dry basis). Frequently, the surface area of fruit is determined based on its diameter or weight. Knowing the diameter or weight of a fruit, its surface area may be calculated using empirical equations, or from an appropriate plot [4, 5]. Mass grading of fruits can reduce packaging and transportation costs and also may provide an optimum packaging configuration [6]. Sizing by weighing mechanism is recommended for irregular shape products [2]. Determining relationships among mass, dimensions and projected areas may be useful and applicable [2, 7]. In weight seizer machines, individual fruits 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. Successive triggering mechanisms are set to dump the tray at lower weight. If the density of the fruit is constant, the weight seizer sorts by volume. The sizing error will depend upon the correlation between weight and volume [2].

Many researches have been conducted to find physical properties of various types of agricultural products. Topuz *et al.* [8] investigated several properties

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of four orange varieties and compared. Keramat Jahromi *et al.* [9] investigated some physical properties of date (cv. Lasht). They determined dimensions and projected areas by using image processing technique. Owolarafe and shotonde [10] investigated some physical properties of fresh okro fruit useful in designing of an okro slicer, chopper and grater. In the case of mass modeling, Tabatabaeefar *et al.* [11] determined models for predicting mass of Iranian grown oranges. In other study, Tabatabaeefar [12] determined physical properties of common varieties of Iranian grown potatoes and relationships among their physical attributes. Lorestani and Tabatabaeefar [13] determined models for predicting mass of kiwi fruit based on dimensions, projected areas perpendicular to the major diameters and volumes (measured volume and volumes of supposed shapes). Also many studies have been reported on the physical properties such as gumbo fruit [14], pear [15], onion [16] and apple [17].

The objective of this research was to determine an optimum date mass model based on its physical properties. This information is used to design and develop of grading systems.

MATERIALS AND METHODS

The selected date variety was Zahedi prepared from a local market in Jahrom (one of the most important horticultural centers in the south of Iran). From the samples, 50 fruits were randomly selected from each category of small, medium and large samples (Fig. 1).

The fruits were transported to physical laboratory of Biosystems Faculty in University of Tehran. Dry-basis moisture contents of date fruits found to be 12.60% (13.31% for pitted dates and 8.24% for their pits). The experiments were carried out in three days at laboratory temperature ranged 25 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 [18] was used (Fig. 2).

WinArea-UT-06 system comprises of following components:

- Sony photograph camera Model CCD-TRV225E
- device for preparing media to taking a picture
- Card capture named Winfast model DV2000
- Computer software programmed with visual basic 6.0

Fig. 1: From left to right, small, medium and large samples of date fruit (cv. Zahedi)

Fig. 2: WinAreaUt_06 system

Fig. 3: Three major dimensions and projected areas of fruit

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 outputs are determined. Total error for those objects was less than 2%. This method has been used and reported by several researchers [9, 19]. From Fig. 3, L, W and T are perpendicular dimensions of date fruit namely length, width and thickness and P_L, P_W and P_T named first, second and third projected areas, are the projected areas taken along these three mutual perpendicular axes, respectively.

Mass (g) of individual fruit was determined by using an electronic balance with an accuracy of 0.0l g. Actual volume was measured by the water displacement method [20].

Geometric mean diameter (GM) and surface area (S) were calculated using equations 1 and 2 respectively as reported by Mohsenin [20] and Kabas *et al.* [21].

$$GM = (LWT)^{1/3} \quad (1)$$

$$S = \pi.\ (GM)^2 \quad (2)$$

In order to estimate mass models, three classifications of following models were considered as:

- Single or multiple variable regressions of date dimensional characteristics: Length (L), Width (W) and Thickness (T).
- Single or multiple variable regressions of date projected areas: P_L, P_W and P_T.
- Single regressions of date volumes: Measured volume, volumes of the fruit assumed shapes as oblate spheroid and ellipsoid.

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

$$M = k_1a + k_2b + k_3c + k_3 \quad (3)$$

In some instances only one or two dimension(s) may adequately predict the mass. The appropriateness of using one, two or three dimension(s) can be compared by examining the R^2.

In Second classification models, mass 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 third classification, to achieve the models which can predict date 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 date shape was assumed as a regularly geometrical shape, i.e. oblate spheroid (V_{osp}) and ellipsoid (V_{ell}) shapes and thus their volume (cm^3) were calculated as:

$$V_{osp} = \frac{p}{6} LW^2/1000 \quad (5)$$

$$V_{ell} = \frac{p}{6} LWT/1000 \quad (6)$$

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

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

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

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

Packages of statistical programs, available on both main frame and personal computers, can perform such regression analyses. Many spreadsheet programs also can perform multiple regressions. When evaluating the usefulness of such regression analyses, it is necessary to know how well the data fit the model. One measure 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 to 1.00 is better fit to data [2]. If values of k_i exactly predict the mass or surface area, 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 selected physical characteristics of date fruit are shown in Table 1. Linear regressions of mass models based on the selected properties are presented in Table 2.

First classification models, dimensions: The results of mass modeling in the single variable classification revealed that the lowest and the highest determining coefficients obtained as $R^2 = 0.61$ and $R^2 = 0.70$ relevant to thickness and length, respectively. In the case of mass modeling based on multiple dimensions, Nos. 4 and 7, respectively with two and three variables had the highest R^2 as 0.72. Then the best equations for single and multiple variable mass modeling were determined as $M = +0.3783\ L - 5.8761$, $R^2 = 0.70$ and $M = +0.2736\ L + 0.2749\ W - 7.9059$, $R^2 = 0.72$.

Second classification models, projected areas: In order to predict date mass based on one projected area, the best determining coefficient of one variable and multiple variables equations were equal to 0.73 and 0.74,

Table 1: Some physical characteristics of date (cv. Zahedi)

Property	Obser -vations	Min	Max	Mean	SD
Fruit mass, g	150	2.38	9.84	6.02	1.69
Measured volume(cm^3)	150	2.71	9.76	5.90	1.48
Volume of oblate spheroid(cm^3)	150	3.02	12.74	7.14	2.09
Volume of ellipsoid (cm^3)	150	2.93	11.42	6.71	1.88
Length (L), mm	150	22.00	39.90	31.45	3.73
Width (W), mm	150	16.00	25.20	20.54	1.95
Thickness (T), mm	150	15.60	23.30	19.36	1.71
Projected area along L, mm	150	184.00	428.00	309.88	51.27
Projected area along W, mm	150	264.00	731.00	486.33	102.52
Projected area along T, mm	150	271.00	779.00	510.55	108.67
Geometric mean diameter, mm	150	17.75	27.94	23.20	2.23
Surface area, mm^2	150	989.66	2451.33	1705.70	322.98

Table 2: Mass models based on selected independent variables

No.	Models	Relation	R^2
1	$M=k_1a+k_2$	$M=+0.3783\ L-5.8761$	0.70
2	$M=k_1b+k_2$	$M=+0.6888\ W-8.1294$	0.63
3	$M=k_1c+k_2$	$M=+0.7691\ T-8.8715$	0.61
4	$M=k_1a+k_2c+ k_3$	$M=+0.2736\ L+0.2749\ W-7.9059$	0.72
5	$M=k_1a+k_2b+ k_3$	$M=+0.2748\ L+0.2253\ W-7.2514$	0.71
6	$M=k_1b+k_2c+ k_3$	$M=+0.4121\ W+0.3592\ T-9.4008$	0.66
7	$M=k_1a+k_2b+k_3c+k_4$	$M=+0.2480L+0.0994\ W+0.2222\ T-8.1238$	0.72
8	$M=k_1P_L+k_2$	$M=+0.0277\ P_L-2.5480$	0.70
9	$M=k_1P_W+k_2$	$M=+.0141\ P_W-0.83840$	0.73
10	$M=k_1P_T+k_2$	$M=+0.0132\ P_T-0.7172$	0.72
11	$M=k_1P_L+k_2P_T+k_3$	$M=+0.0111\ P_L+0.0082\ P_T-(1.6166)$	0.73
12	$M=k_1P_L+k_2P_W+k_3$	$M=+0.0089\ P_L+0.0099\ P_W-(1.5433)$	0.74
13	$M=k_1P_W+k_2P_T+k_3$	$M=+0.0089\ P_W+0.0051\ P_T-(0.9006)$	0.74
	$M=k_1P_L+k_2P_W+k_3P_T+k_4$	$M=+0.0064\ P_L+0.0073\ P_W+0.0036\ P_T-0.3922$	0.74
15	$M=k_1V_m+k_2$	$M=+1.0859\ V_m-0.3851$	0.90
16	$M=k_1V_{osp}+k_2$	$M=+0.6640\ V_{osp}+1.2772$	0.67
17	$M=k_1V_{ell}+k_2$	$M=+.7526\ V_{ell}+0.9669$	0.70

respectively. Models having multiple variables make the sizing mechanism more complex and expensive because there is a need to have three cameras, in order to take all the dimensions. Therefore, mass models using only one projected area was suggested as M = +.0141 PW -0.83840.

Third classification models, volumes: The results showed that mass model based on actual volume is favorable and volume of assumed shape of ellipsoid is acceptable while the model based on oblate spheroid wasn't acceptable. Considering Table 2 it can be concluded that among the models 15, 16 and 17, model 15 is the best model concerned with measured volume as $M = +1.0859\ V_m -0.3851$, $R^2 = 090$.

Determining coefficients were obtained as 0.67 and 0.70 for oblate spheroid and ellipsoid assumed shapes. Then this fact can be concluded that the best model for mass modeling based on the assumed shaped volumes is ellipsoid shape.

Comparing mass equations and their R^2, it is indicated that mass modeling based on measured volume is more accurate while measurement of dimention(s) and projected area (s) are far easier and reasonable than that of measured volume of date.

Tabatabaeefar *et al.* [11] reported that among systems that sort oranges based on one dimension, the system that applies intermediate diameter is suited with nonlinear relationship. In other study, Tabatabaeefar [12] plotted Mass versus volume of mixed variety of potato and found that there is a linear relation between mass and volume with a very high coefficient of determination as $M = 0.93V - 0.6$; R^2=0.99. Relation between the mean projected areas and the volume of potatoes was determined from the plot and the coefficient of determination was very high and close to unity. A nonlinear regression equation for the mixed variety of potatoes was determined as $P_T = 1.1V^{0.71}$; $R^2 = 0.99$. The linear regression had a very high correlation, too. Lorestani and Tabatabaeefar [13] concluded that the linear regression models of kiwi fruits have higher R^2 than nonlinear models for them and are economical models for application. Among the linear regression dimensions models, the model that is based on width, and among the linear projected areas models, the model that is based on third projected area, and among the other models, the model that is based on measured volume, had higher R^2, that are recommended for sizing of kiwi fruit. Also Tabatabaeefar and Rajabipour [12] determined a total of 11 regression models in the three different categories for two different varieties of apple fruit.

CONCLUSIONS

- In the first classification of single variable mass modeling of date, the highest determining coefficient was obtained as R^2=0.70 based on length while that was as R^2=0.72 for of multiple variables model.
- The best determining coefficients of mass models based on one projected area (along width) was obtained as 0.73 and the best determining coefficient of multiple variables equation was equal to 0.74.

- The highest determining coefficient of mass models among volumes was obtained based on actual volume as R^2=0.90.

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