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Modeling of Orange Mass Based on Dimensions

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ABSTRACT

There are instances in which it is desirable to determine relationships among fruit physical attributes. For example, fruits are often graded on the basis of size and projected area, but it may be more suitable and/or economical to develop a machine which grades by mass. Therefore, a relationship between mass and dimensions or projected areas and/or volume of fruits is needed. Various grading systems, size fruits on the basis of specific parameters. Sizing parameter depends on fruit and machine characteristics.Models for predicting mass of orange from its dimensions and projected areas were identified. Models were divided into three classifications: 1- Single and multiple variable regression of orange dimensions (1st classification). 2- Single and multiple variable regression of projected areas (2nd classification). 3- Estimation of orange shape; ellipsoid or spheroid based on volume (3rd classification). Ten Iranian varieties of oranges were selected for the study. 3rd classification models had the highest performance followed by 2nd and 1st classifications respectively, with R^2close to unity. The 2nd classification models need electronic systems with cameras for projection whereas, 1st classification models are used in the simple mechanical systems, except multiple variable ones, of and 3rd classification models need more complex mechanical systems. Among the systems that sorted oranges based on one dimension (Model 2), system that applies intermediate diameter suited better with nonlinear relationship as: $M = 0.07b^2 - 2.95\,b + 39.15$ with R^2= 0.97.

Keywords: Dimensions, Mass models, Orange, Sorting, Sizing.

INTRODUCTION

Iran produces 3.5 million tones of citrus and is ranked 22nd in the world [3]. Iranian oranges are not exported because of variability in size and shape and lack of proper packaging [6,11].

Physical characteristics of agricultural products are the most important parameters in design of grading, conveying, processing, and packaging systems. Among these physical characteristics, mass, volume, projected area, and center of gravity are the most important ones in sizing systems [10, 4]. Other important parameters are width, length, and thickness [5, 1,3].

Consumers prefer fruits of equal weight and uniform shape. Mass grading of fruit can reduce packaging and transportation costs, and also may provide an optimum packaging configuration [9].

Sizing by weighing mechanism is recommended for the irregular shape product [12]. Since electrical sizing mechanism is expensive and mechanical sizing mechanism reacts poorly; therefore, for citrus fruit (orange) dimensional method (of length, area, and volume) can be used. Determining a relationship between mass and dimensions and projected areas may be useful and applicable [5,12]. The objective of this research was to determine an optimum orange mass model based on dimensions for ten different Iranian varieties. This information can be used to design and develop sizing systems.

Sizing Parameters

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Two main dimensions for sizing mechanism system are defined as the major diameter, L, parallel to the length of fruit, and minor diameter, D, perpendicular to the major diameter. These two parameters describe the sizing mechanism systems. The following equation combines the two-diameters [8]:

$$P = \alpha L + \beta D \quad (1)$$

Where, P= Sizing function, α and β depend on the sizing mechanism system, and add up to be equal to 1.

For visual sorting of fruit's references 3 and 9 recommend $\alpha = 0.3$ and $\beta = 0.7$.

Sizing Machinery

Several types of sizing machines exist including perforated conveyer sizers, Greefa-type belt and board sizers, rotary Greefa sizers, belt and roller sizers, Wayland-type belt and roller sizers, diverging belts Jansen-type sizers, diverging roller sizers, and weight sizers.

The sizing parameters in perforated conveyor sizer are the diameter and length or a combination of these two. For example, spherical fruit sizing is based on the diameter and the spheroid fruit is based on the combination [12,8,2]. For rotary Greefa sizers, the sizing equation is $P= 0.1L + 0.9D$. In belt and roller sizers, the equation is $P= 0.17L + 0.83D$. In Wayland -type belt and roller sizer, fruit with smaller length than diameter, sizing is based on the length, $P=L$. For fruit with a large length to diameter ratio, separation is based on diameter, $P=D$ [8,12]. In diverging belts Janise-type sizers, separation is based on diameter, $P=D$ [9,8,2]. In diverging roller sizers, the equation is $P = 0.25L + 0.75D$ [9,2,12]. Sizing fruit using its weight is one of the precise methods, because fruit shape does not affect weight. Weight sizers can be used for irregular shape fruit. The electronic weight sizers with strain gauges are more expensive. Than the mechanical ones. The capacity is generally low due to weighing the fruit one at a time. By modeling the mass (weight) of oranges, one might be able to suggest a sizing system that could be as precise but not as expensive.

MATERIALS AND METHODS

Ten different common commercial varieties of Iranian oranges were considered for this study. About 770 samples of oranges were obtained from Agricultural Research, Education, and Extension Organization, from Citrus Research Institutes placed in North and South Iran. The oranges were picked up at random from their storage piles. Ten different popular varieties sampled were included from south; Parson brown (n=60), Hamelien south (n=55), Mars early (n=61), Local south (n=60), Saloustina (n=60), Pineapple (n=60), and from north; Local north (n=103), Thomson (n=108), Mars north (n=100), Hamelien north (n=110).

The mass of each orange was measured to 0.01g accuracy on a digital balance. Its volume was obtained by water displacement method. An orange was submerged into water and the volume of water displaced was measured. Water temperature was kept at 25º C. The bulk density of each orange was calculated from the mass divided by the measured volume.

Three mutually perpendicular axes; a major, (longest intercept), b intermediate, (longest intercept normal to a), and c minor, (longest intercept normal to a, b), of orange were measured to 0.01 mm accuracy by a micrometer (caliper); when it was laid on a flat surface and reached natural rest position [7].

Projected Area

Average projected area, as a criterion for sizing machine was proposed [8]. Three mutually perpendicular areas, PA_1, PA_2, PA_3, were measured by a ΔT Area-meter, MK2 model from United Kingdom. Average projected area (known as criteria area, CAE) was determined from equation 2.

Projected area,

$$CAE,(cm^2)= (PA_1 + PA_2 + PA_3)/3 \qquad (2)$$

Regression Models

Spreadsheet software, Microsoft EXCEL 98, was used to analyze the data and determine regression models among the parameters. A typical linear multiple regression model is shown in equation 3.

$$Y = a_1 X_1 + a_2 X_2 +,...,+ a_n X_n + a_0 \qquad (3)$$

Where, Y= Dependent variable, for example mass, or volume,…, $X_1, X_2, X_3,..., X_n$ = Independent variables, for example axes, or $CAE,....,a_0, a_1,a_2,...,a_n$ = Regression coefficients

In order to estimate the orange mass from dimensions (length, area, and volume), the following three classifications of models were suggested.

1. Regression of each and multiple variables of length *(a)*, width *(b)*, and thickness *(c)*.
2. Regression of each and multiple variables of projected areas, (PA_1, PA_2, PA_3).
3. Regression of orange shape, ellipsoid (ellip), spheroid (sp) and volume (v).

First classification of models measured length. The independent variable(s) of this model was (were) one, two or three mutually perpendicular diameter(s).

$$M = k_1 a + k_2 b + k_3 c + k_0 \qquad (4)$$

Where M = mass of orange, gr., k_i = regression coefficient, *a, b, c* = major, intermediate, minor diameter, mm.

In this classification, the mass can be estimated as a function of one, two or three dimensions.

Second classification models, areas (cm^2); the independent variables of this model were mutually perpendicular areas.

$$M = k_1 PA_1 + k_2 PA_2 + k_3 PA_3 + k_0 \qquad (5)$$

Where, PA_i =Projected areas, cm^2. In this classification, the mass can be estimated as a function of one, two, or three projected areas.

Mass is related to volume calculated from an assumed shape. Third classification models, volume; in this classification, the mass can be estimated as a function of volume of resembled shapes and the measured volume.

$$M = K_1 V_{sp} + K_2 \qquad (6)$$

$$M = K_1 V_{ellip} + K_2 \qquad (7)$$

$$M = K_1 V_m + K_2 \qquad (8)$$

Where, $V_{SP} = 4/3\ \pi\ (a/2)\ (b/2)^2$, $V_{ellip}=4/3\ \pi\ (a/2)\ (b/2)\ (c/2)$, V_m =Measured volume of overall oranges, cc

RESULTS AND DISCUSSION

A total of 11 linear regression models in three different categories have been classified. The coefficient of determination $R^2$and coefficient of variation C.V. of all the linear models are shown in Table 1.

First Classification Models, Lengths

Among the first classification models no. 1,2,3, and 4, shown in table, model 4 where all three dimensions were considered had a higher R^2 value and coefficient of variation was also low for all the ten varieties. However, all the three diameters must be measured for the model 4, which make the sizing mechanism more complex and expensive.

Among the models 1, 2, and 3, models 1, 2 had high and similar R^2 values; whereas, model 3 had a lower R^2 value and more variation for all the varieties except for the Hamlien south variety. The Thomson variety had a relatively lower R^2 value for model 1 but the rest had a good agreement. Therefore, Model 2, among the three one-dimensional models was selected as the best choice with intermediate diameter as independent variable as shown in Fig. 1. The mean difference of mean R^2 value for model 4 relative to model 2 for all the ten varieties

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Table 1. Linear regression models, Coefficient of determination, R^2 and coefficient of variation C.V.

No.	Variety Models		Parson brown	Hamlien south	Mars early	Local south	Salous-tina	Pineap-ple	Local north	Thom-son	Mars north	Hamelien north
1	$M= k_1a+k_0$	R^2	0.95	0.95	0.95	0.95	0.95	0.94	0.96	0.88	0.97	0.96
		CV	5.1	4.6	6.1	6.4	6.7	6	6.5	7.1	6.1	5.5
2	$M=k_2b+k_0$	R^2	0.96	0.95	0.97	0.97	0.95	0.96	0.96	0.95	0.95	0.97
		CV	4.6	4.8	4.2	6.0	7.1	4.6	6.4	4.8	7.4	5.1
3	$M=k_3c+k_0$	R^2	0.88	0.96	0.91	0.9	0.74	0.87	0.91	0.95	0.89	0.73
		CV	8	4.1	7.9	10.7	15.3	8.7	9.2	6.8	11.5	14.5
4	$M=k_1a+k_2b+k_3c+k_0$	R^2	0.97	0.98	0.98	0.97	0.96	0.98	0.98	0.97	0.98	0.97
		CV	3.7	3.4	3.7	5.6	6.2	3.3	4.4	3.8	5.0	4.9
5	$M=k_1PA_1+K_0$	R^2	0.97	0.96	0.98	0.99	0.97	0.93	0.93	0.96	0.99	0.96
		CV	3.8	4.3	3.8	4.2	5.1	6.6	7.9	4.1	4.1	5.6
6	$M=k_2PA_2+k_0$	R^2	0.97	0.98	0.97	0.99	0.94	0.98	0.96	0.95	0.98	0.98
		CV	3.8	3	4.6	4.1	7.3	2.7	6.3	4.6	4.5	3.6
7	$M=k_3PA_3+k_0$	R^2	0.97	0.97	0.90	0.98	0.94	0.96	0.96	0.95	0.97	0.98
		CV	3.8	3.6	8.5	4.4	7.6	4.9	5.8	4.6	5.8	3.6
8	$M=k_1PA_1+K_2PA_2+k_3PA_3+k_0$	R^2	0.99	0.98	0.98	0.99	0.97	0.99	0.97	0.98	0.99	0.99
		CV	2.4	2.9	3.2	3.6	5	2.6	5.7	2.8	2.9	2.8
9	$M=k_1 V_{sp} + k_0$	R^2	0.97	0.97	0.98	0.99	0.95	0.96	0.96	0.95	0.98	0.97
		CV	3.8	4.0	3.5	3.6	6.4	4.7	5.8	4.5	5.1	4.4
10	$M=k_1 V_{ellip} +k_0$	R^2	0.98	0.98	0.98	0.99	0.95	0.98	0.98	0.96	0.99	0.95
		CV	3.6	3.0	3.8	3.6	7.0	3.1	4.2	4.2	4.1	6.5
11	$M= k_1V_m +k_0$	R^2	0.99	0.98	0.99	0.99	0.98	0.99	0.99	0.98	0.99	1.0
		CV	2.1	3.1	3.4	2.6	4.7	1.6	2.2	3.1	2.5	1.7

is 1.66 %.

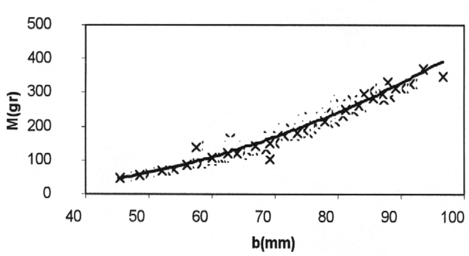

Figure.1. Mass model of orange based on intermediate diameter.

In order to size oranges based on one diameter, the intermediate diameter (*D*) is recommended, not the length (*L*) of orange. Applying model 2 to the sizing mechanism systems, the sizing mechanism, diverging belts Jansen-type, with sizing parameter *P=D* or Greefa rotary sizer with parameter *P= 0.1L + 0.9 D* can be suggested. Wayland type belt - and - roller sizers for oranges where length is shorter than diameter (all the oranges except Thomson) sizing based on length can be used. For oranges where length is longer than diameter, the mechanism based on diameter can be used if a brush is available to rotate the oranges, then model 2 can be applied [8,9].

The mass model of orange (all the varities together) based on the model 4 (all the three diameters) is given in equation 9.

$$M = 1.91\,a + 2.48\,b + 1.97\,c - 266.7 \qquad (9)$$
$$R^2 = 0.97$$

Where *M* is in gram and a, b, and c are in mm.

For all the varieties, the best equation to calculate mass of orange based on the intermediate diameter was given in nonlinear form of equation 10.

$$M = 0.07\,b^2 - 2.95b + 39.15 \quad R^2=0.97 \qquad (10)$$

Second Classification Models, Areas

Among the second classification models 5, 6, 7,and 8, shown in table 1, the model 8 for all the varieties had a higher R^2 value and lower coefficient of variation, C.V. Model 8 needs to have all three-projection areas taken for each one orange.

Models 5, 6, and 7 had similar R^2 value and C.V. except for the variety of Mars early. Model 7 for Mars early had a lower R^2 and higher C.V. Therefore, Model 6 among the models 5, 6, 7 are chosen because of the higher R^2 and a lower C.V.

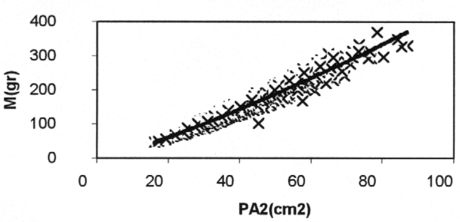

Figure 2. Overall mass of all oranges versus the projection areas.

The overall mass model based on three projection areas (model 8) for all the varieties, was given in equation 11.

$$M = 2.26\,PA_1 + 0.62\,PA_2 + 1.79\,PA_3 + 43.35 \quad R^2 = 0.96 \qquad (11)$$

Where M is in gram and PA is in cm^2.

The mass model of overall oranges based on the 2nd projection area as shown in Fig. 2, was given as nonlinear form of equation 12.

$$M = 1.47\,(PA_2)^{1.24} \quad R^2 = 0.96 \qquad (12)$$

Each one of the three projection areas can be used to estimate the mass. There is a need to have three cameras, in order to take all the projection areas and have on R^2 value close to uting or even lower than R^2 for just one projection area; therefore, model using only one projection area, possibly model 6 can be used.

Third Classification Models, Volume

Among the models in third classification (models 9, 10, 11), the R^2 for model 11 was higher and C.V. was lower. Fig. 3 shows the relationship between the mass and volume of all the oranges with $R^2 = 0.99$.

Models 9,10 were almost similar as far as R^2 and C.V. were concerned; therefore, Model 9, which need to measure only two diameters, rather than three, was suggested.

In order to grade oranges based on one, two or three dimensions models 2, 4, 5, 9 and 11 could be recommended. Two of the diameters are needed for Model 5, therefore a sizing mechanism of diverging roller sizers with sizing parameter $P = 0.25L + 0.75D$ or belt and roller grader with sizing parameter $P = 0.17L + 0.83D$ may respond better.

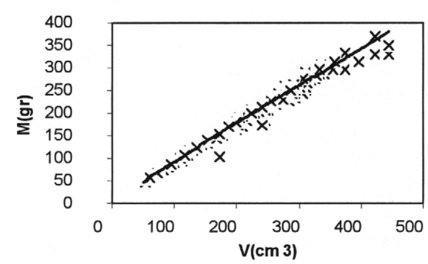

Figure 3. Mass model of orange based on volume.

At the end it may be concluded that:

1-The recommended equation to calculate orange mass based on intermediate diameter (Model 2 was the best) was as nonlinear form;

$$M = 0.07b^2 - 2.95\,b + 39.15 \qquad R^2 = 0.97$$

2-The mass model recommended for sizing oranges based on any one projected area (Model 6 is suitable) was as nonlinear form:

$$M = 1.47\,(PA_2)^{1.24} \qquad R^2 = 0.96$$

3-There was a very good relationship between mass and measured volume of oranges for all varieties with R^2 in the order of 0.99.

4-The model to predict mass of oranges based on estimated volume, the shape of oranges considered as spheroid was found to be the most appropriate (Model 9 is suggested).

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مدلینگ جرم پرتقال بر پایه ابعاد

چکیده

در بسیاری از موارد بایستی روابط بین خواص مختلف فیزیکی میوه ها تعیین گردند. برای مثال میوه ها بر پایه اندازه و سطح تصویر درجه بندی می شوند، اما شاید طراحی یک ماشین که درجه بندی را براساس جرم انجام دهد اقتصادی تر و مناسبتر باشد. بنابراین، رابطه ای بین جرم و ابعاد یا سطح تصویر و یا حجم میوه ها مورد نیاز است. سیستمهای درجه بندی گوناگون، اندازه بندی میوه ها را

براساس پارامترهای خاص تعیین میکنند. پارامترهای مورد نظر اندازه بندی بستگی به میوه و مشخصه های ماشین دارد. مدلهایی که برای پیش بینی جرم پرتقال با توجه به ابعاد و سطح تصویر مشخص شدند در سه دسته، طبقه بندی شدند: ۱- رگرسیون یک و یا چند متغیره ابعاد پرتقال (دسته ۱) ۲- رگرسیون یک و یا چند متغیره سطح تصویر (دسته ۲) ۳- تخمین شکل پرتقال، بیضوی یا کروی براساس حجم (دسته ۳) ده رقم گوناگون پرتقال برای این تحقیق انتخاب شدند. مدلهای دسته سوم بالاترین همبستگی با ضریب تعیین نزدیک به یک را داشت و بعد از آن مدل دسته دوم و سپس مدلهای دسته اول از ضریب همبستگی بالاتری برخوردار بودند. مدلهای دسته دوم نیازمند سیستمهای الکترونیکی با دوربینهای دیجیتالی برای تصویربرداری می باشند، در حالی که مدلهای دسته اول غیر از مدل رگرسیون های چند متغیره، بصورت سیستمهای مکانیکی ساده، می توانند درجه بندی را انجام دهند. مدلهای دسته سوم نیز نیازمند سیستمهای پیچیده مکانیکی می باشند. در بین سیستمهایی که درجه بندی پرتقالها را براساس ابعاد (مدل ۲) انجام می دهند. سیستمی که از قطر میانی استفاده می کند و دارای رابطه غیرخطی $M = 0.07b^2 - 2.95\ b + 39.15$ با ضریب تعیین $R^2=0.97$ می باشد مناسب ترین سیستم است.

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