Statistical Modeling of Pomegranate (Punica granatum L.) Fruit with Some Physical Attributes

Yaser Siah Mansouri1*, Javad Khazaei1, Seyyed Reza Hassan Beygi1 and Seyed Saeid Mohtasebi2

1Department of Agrotechnology, College of Abuoreihan, University of Tehran, Tehran, Iran
2Department of Agricultural Machinery, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

Abstract

In this study mass and surface area of pomegranate fruit were predicted with using different physical characteristics in linear models classified as follows: (1) Single or multiple variable regressions of pomegranate dimensional characteristics, (2) Single or multiple variable regressions of pomegranate projected areas, (3) Single regression of pomegranate mass based on measured (actual) volume and volumes of shapes assumed (oblate spheroid and ellipsoid). The results showed that in the first classification of single variable mass modeling of pomegranate based on dimension, the highest determining coefficient was obtained as $R^2=0.95$ based on geometric mean diameter $M = 0.528 + 10.7 D_g$ while that as $R^2=0.96$ for multiple variable models. Also, there was a very good relationship between mass and measured volume of pomegranates for the two varieties with $R^2$ as 0.97 (highest $R^2$ value among all the models).

At least, the models which predict mass of pomegranates based on estimated volume, the shape of pomegranates considered as spheroid and elliptical were found to be the most appropriate models.

Keywords: Mass modeling; Pomegranate fruit; Physical attributes; Peeling; Grading

Introduction

New industrial machinery development has traditionally required extensive research and development before a final design is selected. Agricultural crops and food products have several unique characteristics which set them different from engineering materials. These properties determine the quality of the fruit and identification of correlation among in these properties makes quality control easier [1]. Physical characteristics of agricultural products are the most important parameters in design of grading, conveying, processing and packaging systems [2]. As an instance, slat conveyor system for displacing of fruits can be designed by fruit size and weight. These features in grading fruit based on weight or size is important in packing and handling machine. Therefore, the relationship between weight and geometric attributes is needed [3]. Pomegranate fruit has been cultivated extensively in Iran, India and some parts in the U.S.A (California), China, Japan and Russia [4-6] but No published articles were found in the literature that described of pomegranate processing machine associated with physical attributes and other engineering properties of fruit. However, a number of patents have been issued. For horticultural commodities, dimensions (length, diameter, thickness) are widely used properties to describe them. Frequently, all cases raw product grades are based on weight [7]. Size and shape determine the number of fruits that can be placed in containers with given size in conveyor system or packing machines. Volume and surface area could be beneficial in proper prediction drying rates and hence drying time in the dryer. The conventional utilization of wild pomegranate fruit lies in the drying seeds along with pulp (arils), which constitute the product “Anardana” [8]. The dehydrated arils are acidic (7.8–15.4%) and help in improving mouth-feel and digestion. Many studies have reported on the physical properties of fruits, such as wild plum [9], cornelian cherry [10,11], rose fruit [12], fresh okra fruit [13], cherry laurel [14,15], orange [16], berries [17], Juniperus drupacea fruit [18]. 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. Knowing the diameter or weight of a fruit, its surface area may be calculated using empirical equations, or read from an appropriate plot [3,19,20] with mass modeling several cultivars of the pomegranate fruit determined models for predicting other properties for grading that can not be enough for studies and design of a suitable machine for pomegranate processing.

The objective of this study was to determine the most suitable model for predicting pomegranate fruit mass by its geometrical attributes and evaluation with similar studies. This information can be used in the design and development of slat conveyor mechanisms for suitable transport with minimal damage to fruits.

Material and Method

The Iranian pomegranate cultivars consisted of malas saveh and Hondos jal alahd were obtained from orchard located in Saveh, Iran (from markazi Province) in October 2009. The 77 fruits of each variety were tested in the Biophysical laboratory and Biological laboratory of University of Tehran, Karaj, Iran. The physical properties of pomegranate such as mass, volume, dimensions and projected area were measured. The samples of the fruits were weighted and dried in an oven at a temperature of 75 °C for 72 h and then weight loss on drying to final content weight was recorded as moisture content [21]. The remaining material was kept in cold storage at 5 °C until use. Fruit mass (M) was determined with an electronic balance with ±0.01 g sensitivity. To determine the average size of the fruits, three linear dimensions namely as length, width and thickness were measured by using a digital caliper with ±0.01 mm sensitivity. Volume (V) was determined by the water displacement method [22]. The geometric mean diameter (Dg) and surface areas (S) and sphericity were determined by using following formula [22], respectively:

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\[ D_g = 3 \sqrt[3]{LWT} \]  

\[ S = \pi (D_g)^2 \]  

\[ \text{sphericity} = \frac{D_g}{\text{Max length in linear dimension}} \]  

\[ \alpha = L + \beta W + \lambda T + \xi D_g + \psi \]  

\[ \alpha = PA_1 + PA_2 + PA_3 \]  

\[ \text{Volume} = \frac{\pi}{6} LWT \]  

\[ \text{Sphericity} \]  

\[ \text{Mass} \]  

\[ M = \alpha PA_1 + \beta PA_2 + \lambda PA_3 + \xi \]  

\[ \text{Table 1: Selected physical properties of the two pomegranate varieties (Malas-e-Saveh, Hondos-e-Yal abad).} \]  

\[ \text{Table 2: Pomegranate mass models based on selected independent variables for of the two pomegranate varieties (Malas-e-Saveh, Hondos-e-Yal abad).} \]  

\[ \text{Figure 1: Dimensions of pomegranate, three linear dimensions (left) and crown dimension (right).} \]
Result and Discussion

A summary of some selected physical characteristics of the pomegranate fruit and crown are represented in Table 1. They were found for Malas-e-Saveh and Hondos-e-Yalabad pomegranate varieties, at specific fruit moisture contents of 75 and 77% (w.b), respectively. The models were derived through stepwise method and on the basis of the selected attributes together R², R.S.E, are presented in Table 2 for Malas saveh and Hondos yal abad varieties, respectively.

First classification models, dimensions

Among the models Nos. 1-6, shown in Table 2 based on liner dimension, models 4, 5 and 6 for any two varieties had higher R² and lower R.S.E than models 1-12 while for these models, measurement of three diameters is needed, which make the sizing mechanism more tedious and expensive. Therefore, model 4, among the one-dimensional models was selected as the best pomegranate mass model with Geometric mean diameter as shown in Figure 2 and Figure 3 for Malas and Hondos varieties, respectively. Tabatabaeefar and Rajabipour (2005) reported an equation calculating apple mass (mixed variety) on the basis of intermediate diameter (b) as M = 0.08b² - 4.74b + 5.14, which is quadratic like the recommended models in the form of Figure 2. They recommended an equation calculating apple mass on the basis of minor diameter as M = 0.08c² – 4.74c + 5.14, R² = 0.89. Also Khoshnam and et al., (2007) reported that equations to calculate pomegranate mass based on minor diameter had highest R² value among all the models. Results showed that all of the mass models of pomegranate fruit based on diameters were appropriate in the first classification as shown in Table 2.

Second classification models, projected areas

The results shown in Table 2 showed that all mass models of pomegranate fruit based on single projected areas has the lowest determining coefficient as 0.5 and highest R.S.E about 39 among models of Table 2. The overall mass model of pomegranate fruit (Malas-e-Saveh variety) based on the one projected area as shown in Figure 4, was given as nonlinear form in following equations:

\[ M = 1.7072(V_{ellip})^{0.95} \]
\[ R^2 = 0.9414 \]

Where PC is third projected area. Khoshnam and et al., (2007) reported that each one of the three projected areas can be used to estimate the mass. Also, there is a need to have three cameras, in order to take all the projected areas and have one R² value close to unit or even lower than R² for just one projected area but results in this study showed that for the two varieties of pomegranate, R² is too weak.

Third classification models, volume

Among the models in third classification the R² for model 12 and 13 had maximum value and minimum R.S.E. According to stepwise method, among mass models on basis volume with single variable, the models based on M=αV ellip+β and M=αV+β were the best models for

\[ M = 290.31Ln(V_{ellip}) - 1274.1 \]
\[ R^2 = 0.9287 \]

\[ M = 1.7072(V_{ellip})^{0.95} \]
\[ R^2 = 0.9496 \]

\[ M = 0.0007(V_{ellip})^2 + 0.9239(V_{ellip}) + 50.325 \]
\[ R^2 = 0.9503 \]
malas saveh and Hondos yalabad varieties, which are given in equations 14 and 15, respectively:

\[
M = 13.1 + 1.26 V \text{ (ellipse)} \tag{14}
\]

\[
M = 26.9 + 1.17 V \text{ (ellipse)} \tag{15}
\]

Therefore, models 12 and 13 were recommended for predicting pomegranate mass. The mass models of overall pomegranate based on assumed volume as shown in Figure 5.

**Conclusion**

In the first classification of single variable mass modeling of pomegranate based on dimension, the highest determining coefficient was obtained as \( R^2 = 0.95 \) based on geometric mean diameter \( M = -528 + 10.7 \) (Dg) while that was as \( R^2 = 0.96 \) for multiple variable models (equations No. 6 in Table 2).

There was a very good relationship between mass and measured volume of pomegranates for the two varieties with \( R^2 \) as 0.97 (highest \( R^2 \) value among all the models).

The model which predicts mass of pomegranates based on estimated volume, the shape of pomegranates considered as spheroid and elliptical were found to be the most appropriate (model 12 and 13 is recommended).

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**References**