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Mass modeling of pomegranate (*Punica granatum* L.) fruit with some physical characteristics

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Abstract

Among physical characteristics, dimensions, mass, volume and projected areas are important parameters in sizing and grading systems. Fruits with the similar weight and uniform shape are desirable in terms of marketing value. Therefore, grading fruit based on weight reduces packing and handling costs and also provides suitable packing patterns. The different grading systems require different fruit sizing based on particular parameters. In this study pomegranate mass was predicted by applying different physical characteristics with linear and nonlinear models as three different classifications: (1) single or multiple variable regressions of pomegranate dimensional characteristics, (2) single or multiple variable regression of pomegranate projected areas and (3) estimating pomegranate mass based on its volume. The results showed that mass modeling of pomegranate based on minor diameter and three projected areas are the most appropriate models in the first and second classifications, respectively. In third classification, the highest determination coefficient was obtained for mass modeling based on the actual volume as $R^2 = 0.99$ whereas corresponding values were 0.93 and 0.79 for assumed pomegranate shapes (oblate spheroid and ellipsoid), respectively. In economical and agronomical point of view, suitable grading system of pomegranate mass was ascertained based on minor diameter as nonlinear relation $M = 0.06c^2 - 4.11c + 143.56$, $R^2 = 0.91$.

Keywords: Pomegranate; Mass modeling; Physical characteristics; Grading; Packing; Saveh township

1. Introduction

The pomegranate (*Punica granatum* L.) fruit, native of Iran, is extensively cultivated in Spain, Egypt, Russia, France, China, Japan and USA and in India (Patil and Karade, 1996). Pomegranate is consumed directly as fresh seeds as well as fresh juice which can also be used in flavoring and coloring agents (La Rue, 1969). The edible part of the fruit contains considerable amounts of acids, sugar, vitamins, polysaccharides, polyphenoles and important mineral. Pomegranate fruits are most widely grown in Iran. The annual production of pomegranate is equal to 700,000 tonnes and more than 150,000 tonnes is exported to other countries.

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 areas and center of gravity are the most important ones in sizing systems (Malcolm et al., 1986; Safwat, 1971). Other important parameters are width, length, and thickness (Mohsenin, 1986). There are some situations in which it is desirable to determine relationships among physical characteristics; for example, fruits are often graded by size, but it may be more economical to develop a machine which grades by weight. Therefore, the relationship between weight and the major, minor and intermediate diameters is needed (Stroshine and Hamann, 1994).

The regression analysis was used by Chuma et al. (1982) to develop equations for predicting volume and surface area. They used logarithmic transformation to develop equations for wheat kernels at 15.7%. They suggested that the volume was related to the surface area by a linear regression relationship: $V = 1.10S + 17.2$. Frequently, the surface area of fruit is determined on the basis of its diameter or weight. Knowing the diameter or weight of a fruit, its surface area may be calculated using empirical equations, or read from an appropriate plot (Sitkei, 1986; Frechette and Zahradnik, 1968).

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Nomenclature

a	major diameter (mm)
b	intermediate diameter (mm)
c	minor diameter (mm)
CPA	criteria projected area (mm^2)
d	average diameter of calyx (mm)
GMD	geometric mean diameter (mm)
K_{i}	regression coefficient
M	mass (g)
PA_1	first projected area (mm^2)
PA_2	second projected area (mm^2)
PA_3	third projected area (mm^2)
R^2	coefficient of determination
V	volume (cm^3)
V_{ellip}	volume of ellipsoid(cm^3)
V_{m}	measured volume (cm^3)
V_{osp}	volume of oblate spheroid (cm^3)
W	weight of displaced water (g)

Greek symbol

γ	weight density of water (g/cm^3)

Consumers prefer fruits with equal weight and uniform shape. Mass grading of fruit can reduce packaging and transportation costs, and also may provide an optimum packaging configuration (Peleg, 1985). Sizing by weighing mechanism is recommended for the irregular shape product (Stroshine and Hamann, 1994). Since electrical sizing mechanism is expensive and mechanical sizing mechanism reacts poorly; therefore, for pomegranate, dimensional method (of length, area and volume) can be used. Determining relationships between mass and dimensions and projected areas may be useful and applicable (Stroshine and Hamann, 1994; Marvin et al., 1987). In weight sizer 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 sizer sorts by volume. The sizing error will depend upon the correlation between weight and volume (Stroshine and Hamann, 1994).

In the case of mass modeling, Tabatabaeefar et al. (2000) determined models for predicting mass of Iranian grown orange from its volumes, dimensions, and projected areas. They reported that among the systems that sorted oranges based on one dimension, the system that applies intermediate diameter is suitable with nonlinear relationship.

The physical properties of different fruits and vegetables have been determined by other researcher; caper fruit (Sessiz et al., 2007), potato (Singh et al., 2006; Sadowska et al., 2004a,b), gumbo fruit (Akar and Aydin, 2005), pear (Wang, 2004), onion (Abhayawick et al., 2002), apple (Woensel et al., 1987). Also, some physical properties of pomegranate have been investigated and reported by several researchers (Kingsly et al., 2006; Fadavi et al., 2005; Kaya and Sozer, 2005; Al-Maiman and Ahmad, 2002; Safa and Khazaei, 2003) and others.

No detailed studies concerning mass modeling of pomegranate have been performed up to now. The objective of this research was to determine an optimum pomegranate mass model based on its physical characteristics. This information is used to design and develop of sizing systems.

2. Materials and methods

This research was conducted on Malase-Torsh Saveh variety (export variety) obtained from three different regions as Agh-Dareh, Solghan and Soghanligh located in Saveh township (latitude: 35°, 01′E and longitude: 50, 20′N). The number of fruits obtained from the aforementioned regions was 81, 57 and 54, respectively.

The mass of each pomegranate (M) was measured using a digital balance with accuracy 0.01. Three mutually perpendicular axes (a) major diameter (total height of fruit), (b) intermediate diameter and (c) minor diameter were measured by applying WinArea-Ut-06 system (Fig. 1) developed by Mirasheh (2006). Average diameter of pomegranate calyx (d) was measured. Then projected areas (PA) in three perpendicular directions of pomegranate using WinArea-Ut-06 were determined. Dimensional characteristics obtained from WinArea-Ut-06 are based on image processing. Captured images from a camera are transmitted to a computer card which works as an analog to digital converter. Digital images are then processed in the software and the desired user needs are determined. Through three normal images of the fruit, this device was capable of determining the required diameters as well as projected areas perpendicular to these dimensions. Total error, for those objects that was taken at the camera field, was less than 2%. This method have been used and reported by several researchers (Rafiee et al., 2006; Keramat Jahromi et al., 2007). The average projected areas (known as criteria projected areas),

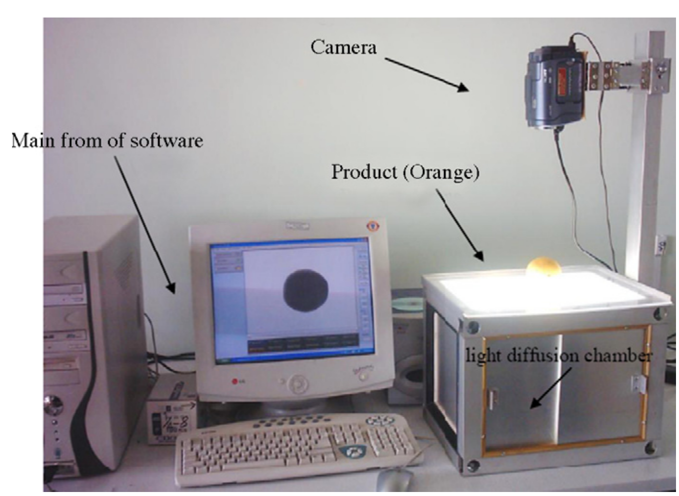

Fig. 1. Components of WinArea-Ut-06 system (Keramat Jahromi et al., 2007).