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Volume Modelling of Three Apple Varieties Based on Physical Parameters

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Abstract

Knowledge of physical properties of agricultural products is important for food engineers and researchers due to different aims. In this research, volume of three apple varieties including Red delicious, Golden delicious and Granny smith was modeled based on dimensions, surface area, mass and sphericity by nonlinear regression analysis. Results indicated that the best models for volume predicting based on above mentioned physical parameters were third-order, exponential and second-order equations for dimensions, mass and sphericity, respectively. Among them the best model for prediction the volume for all three varieties were based on the mass of fruits. For Red delicious, Golden delicious and Granny smith varieties the determination coefficient was obtained 0.984, 0.955 and 0.961, respectively. Also, modeling of apple volume based on the sphericity had the least determination coefficient for all three varieties. The volume had the best fit with the estimated volume by V_{ellip} than estimation by V_{osp}.

Keywords: Apple; modeling; volume; mass.

1. Introduction

There are more than 7,500 known cultivars of apples (Kheiralipour *et al*., 2008). Annual apple production in Iran was about 1.65 mt, which was ranked as 8th in the world (FAO, 2011). This amount of production is much more than domestic consumption, while only 8.5 percent of apple production was exported in 2011. The reason may back to the variance in size, shape and lake of proper packaging.

Agricultural crops and food products have several unique characteristics which set them different from engineering materials. These physical properties determine the quality of the fruit and identification of correlation among these properties makes quality control easier (Jannatizadeh *et al.*, 2008). The physical attributes and their relationships must be known. For instance, characteristics of agricultural products are the most important parameters to determine the proper standards of design of grading, conveying, processing and packaging systems (Tabatabaeefar and Rajabipour, 2005)**.** Volume and surface area could be beneficial in proper prediction drying rates and hence drying time in the dryer. Among these physical characteristics, mass and volume are the most important attributes in determining sizing systems (Peleg and Ramraz, 1975; Khodabandehloo, 1999). Width, length, and thickness are other important parameters (Mohsenin, 1986). Many researches have been conducted to find physical properties of various types of agricultural products.

The main aim of this study was to determine the best models for volume based on dimensions, surface area, sphericity and mass for three different apples varieties including *Red* delicious, *Golden* delicious and *Granny* smith. This information can be used to design and modification of grading, conveying, processing and packaging systems.

2. Materials and Methods

This research was conducted on Granny smith (import variety), Red delicious of Semirom and Golden delicious of Damavand obtained from Sari commercial fruit distributers. The physical properties of apples such as mass, volume, and dimensions were measured. Fruit mass (*M*) was determined with an electronic balance with 0.01 *g* sensitivity. Its volume (V) was measured by the water displacement method (Akar and Aydin, 2005; Aydin and Ozcan, 2007). To determine the average size of the fruits, three linear dimensions, namely length (*a*); equivalent distance of the stem (top) to the calyx (bottom), width (*b*); the longest dimension perpendicular to a, and thickness (*c*); the longest dimension perpendicular to *a* and *b*, were measured by using a digital caliper with accuracy of 0.01 *mm*. Geometric mean diameter (*GMD*) and Sphericity were calculated by using the following equations as reported by Mohsenin (1986).

$$\textit{Geometric mean diameter (GMD)} = \sqrt[3]{abc} \quad (1)$$

$$\textit{Sphericity} = \frac{GMD}{a} \quad (2)$$

Surface area (*S*) was calculated by using the following equations as reported by (Topuz *et al.*, 2005).

$$\textit{Surface area (s)} = \pi(GMD)^2 \quad (3)$$

To achieve models which can predict the apple volume on the basis of volume, two volume values were calculated. The apple shape was assumed as a regular geometric shape *ie* oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes, and their volume was thus calculated as:

$$V_{osp} = \frac{4}{3}\pi\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)^2 \quad (4)$$

$$V_{ellip} = \frac{4}{3}\pi\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)\left(\frac{c}{2}\right) \quad (5)$$

Spreadsheet software, Microsoft EXCEL, was used to analyze the data and to determine regression models between the parameters.

3. Results and Discussion

3.1 Model based on dimensions

In volume modeling based on dimensional parameters (a, b, c, GMD) Logarithmic, Exponential and Polynomial equations for each of the three varieties were investigated. The third degree polynomial equation for each variety was the most appropriate. Equations 6 to 8 show the best volume model based on a dimensional parameter (GMD) for Red Delicious, Golden Delicious and Granny Smith, respectively.

$$V = 0.183\ (GMD)^3 - 36.69\ (GMD)^2 + 2450.2\ (GMD) - 5440 R^2=0.95 \quad (6)$$

$$V = -0.1985\ (GMD)^3 + 39.341\ (GMD)^2 - 2589.8\ (GMD) + 5679 R^2=0.93 \quad (7)$$

$$V = 1.5323\ (GMD)^3 - 322.91\ (GMD)^2 + 22687\ (GMD) - 53119 R^2=0.79 \quad (8)$$

Where V is the volume, GMD is the Geometric mean diameter and R^2 is the correlation coefficient.

3.2 Model based on surface area

In volume modeling based on surface area (s) Logarithmic, Exponential and Polynomial equations for each of the three varieties were investigated (Figure 1). The equation of the third degree polynomial equation for each variety was the most appropriate. The formula for the surface area and its reliance on the geometric mean diameters, R^2 for each variety were predictable. Equations 9 to 11 show best volume model based on a surface area (s) for Red Delicious, Golden Delicious and Granny Smith, respectively.

$$V = 0.0023\ s^3 - 0.9498\ s^2 + 134.11\ s - 6176.6 \quad R^2 = 0.95 \quad (9)$$

$$V = -0.0028\ s^3 + 1.158\ s^2 - 156.36\ s + 7102.2 \quad R^2=0.93 \quad (10)$$

$$V = 0.0183\ s^3 - 8.5068\ s^2 + 1320.5\ s - 68163 \quad R^2=0.79 \quad (11)$$

Where V is the volume, s is the surface area and R^2 is the correlation coefficient.

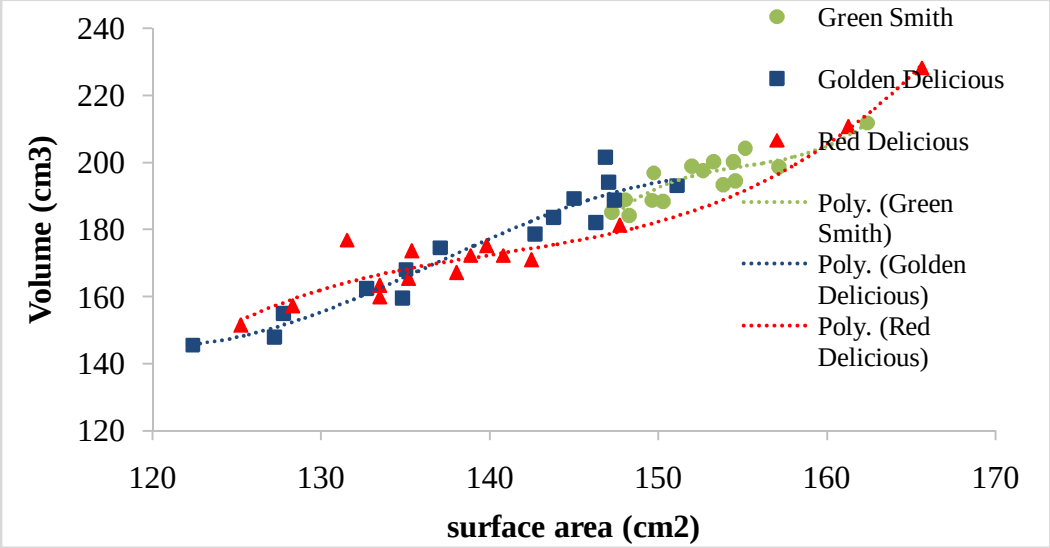

Figure 1: Relationship between volume and surface area of three apple varieties

3.3 Model based on calculated volume

A linear equation is the best equation to predict the volume. Variety of Golden Delicious in each one of the parameters V_{ellip} and V_{osp}‘, achieved R^2 of 0.92 and 0.91, respectively. The Granny Smith variety R^2 was 0.76, and 0.59, respectively. The values of R^2 for the Red Delicious variety were 0.90 and 0.82, respectively. Omid et al (2010) predict the volume of citrus fruits by image processing. They obtained a linear relationship (R^2 = 0.985) between calculation volume and displaced water volume for volume modeling of oranges. V_{ellip} provides a better model than V_{osp}. The model for the Golden Delicious variety is a better model than the other varieties (Eqs. 12-14). Equations 12 to 14 show best volume model based on a volume ellipsoid (V_{ellip}) for Golden Delicious, Red Delicious, and Granny Smith, respectively.

$$V = 1.1642\ V_{ellip} - 5.0976\ R^2 = 0.92 \quad (12)$$

$$V = 0.9974\ V_{ellip} + 19.609\ R^2 = 0.90 \quad (13)$$

$$V = 0.9408\ V_{ellip} + 28.554\ R^2 = 0.76 \quad (14)$$

Where V is the volume, V_{ellip} is the ellipsoid volume and R^2 is the correlation coefficient.

3.4 Model based on mass

The equation of the Exponential equation for each variety was the most appropriate model based on mass. Khoshnam et al (2007) in mass modeling of pomegranate obtained equation $M = 0.96\,V + 4.25$ with R^2 = 0.99. Equations 15 to 17 show best volume model based on mass (m) for Red Delicious, Granny Smith and Golden Delicious, respectively. According to these equations, it can be agreed that Granny

Smith variety before export was graded based on the mass. Also, Red Delicious compare with Granny Smith variety will be graded better based on mass.

$$V = 64.399e^{0.0068m} R^2 = 0.98 \quad (15)$$
$$V = 76.066e^{0.0059m} R^2 = 0.96 \quad (16)$$
$$V = 52.804e^{0.0085m} R^2 = 0.95 \quad (17)$$

Where V is the volume, m is the mass and R^2 is the correlation coefficient.

3.5 Model based on sphericity

Modeling based on sphericity by the Logarithmic, Exponential and Polynomial equations for each of the three varieties show that the fitting equations are not suitable and the prediction of apple volume based on the sphericity is not recommended.

4. Conclusion

In this study, volume of three apple varieties was modeled based on physical attributes such as, dimensions, surface area, mass and sphericity by nonlinear regression analysis. Following results can be concluded:

1. The geometric mean diameter (GMD) provides a better model than the other dimensional parameters. The model for the Red Delicious variety was better model than the other varieties.
2. Among models, the third-order polynomial for dimensional attribute, exponential for mass and second- order for sphericity were the best equations for prediction the volume of apples.
3. The best model for prediction the volume of three apple varieties was based on mass of fruit.
4. For Red delicious, Golden delicious and Granny smith varieties the determination coefficient was obtained 0.984, 0.955 and 0.961, respectively.
5. Volume of apple varieties was estimated better by V_{ellip} than estimation by V_{osp}.

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