Mass modeling of green bell pepper fruit with some physical characteristics

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Abstract— **Horticultural crops with the similar weight and uniform shape are in high demand in terms of marketing value that used as food. For proper design of grading systems, important relationships among the mass and other properties of fruits such as length, width, thickness, volumes and projected areas must be known. The aim of this research was to measure and present some physical properties of green bell pepper fruits. In addition, Linear, Quadratic, S-curve and Power models were used for mass predication of bell pepper fruits based on measured physical properties. The results showed that all measured physical properties were statically significant at the 1% probability level. For mass predication of bell pepper fruits, the best and the worst models were obtained based on first projected area and length of the fruits with determination coefficients (R^2) of 0.887 and 0.415, respectively. At last, from economical standpoint, mass modeling of green bell pepper based on first projected area is recommended.**

Keywords- green bell pepper, physical characteristics, mass prediction

I. INTRODUCTION

Physical characteristics of agricultural materials and their relationships are necessary for the design of some post harvest processing systems such as handling, sorting and packaging. Among these properties, mass, dimensions, volume and projected areas are the most important factors (Mohsenin, 1986). Consumers prefer fruits with equal weight and uniform shape. Mass grading of fruit can reduce packaging and transportation costs by providing accurate method of automatic classification and optimum packaging configuration (Peleg, 1985). Classification of fruits is often done based on their mass, size, volume and projected areas. Using the electrical grading system is more complex and expensive and mechanical systems work slowly. Therefore, developing a grading system which grades fruits based their mass may be more economical. Mass classification of more fruits is the most accurate automatic classification. Therefore, determining the relationships between mass and dimensions, volumes and projected areas can be useful and applicable (Al-Maiman and Ahmad 2002; Tabatabaeefar and Rajabipour, 2005; Khoshnam et al., 2007; Lorestani and Ghari, 2012).

A number of studies have been conducted on the mass modeling of fruits based upon their physical properties. No detailed studies concerning mass modeling of green bell pepper fruit have yet been performed. The aims of this study were to determine the most suitable model for predicting green bell pepper mass by its physical attributes and specify some physical properties of green bell pepper to form an important database for other researches.

II. MATERIALS & METHODS

Fresh harvested green bell peppers were obtained in August 2012 from Lorestan province Iran. In order to determine the physical properties, 150 green bell peppers were randomly selected. Selected samples were healthy and free from any injuries. Samples of fruits were weighed and dried in an oven at a temperature of 78°C for 48 hours then weight loss on drying to a final constant weight was recorded as moisture content. The mass of each bell pepper (M) was measured using a digital balance with accuracy of 0.01 g. For each bell pepper, three linear dimensions were measured by using a digital caliper with accuracy of 0.01mm, including length (L), width (W) and thickness (T). Water displacement method was used for determining the fruits measured volume (V_m). Fruits geometric mean diameter (D_g) and surface are (S) were determined as suggested by Mohsenin (1986):

$$D_g = (LWT)^{1/3} \tag{1}$$

$$S = \pi (D_g)^2 \tag{2}$$

Where: L is length (mm), W is width, T is thickness of green bell pepper (mm) S is fruit surface are (mm^2) and D_g is geometric mean diameter (mm). In addition, fruit average projected areas perpendicular to dimensions (PA_1, PA_2 and PA_3) were measured by a Δ T are-meter, MK2 model, device with accuracy of 10 mm^2 and then the criteria projected area (CPA) was calculated as suggested by Mohsenin (1986):

$$CPA = \frac{AP_1 + AP_2 + AP_3}{3} \tag{3}$$

Where: PA_1 (perpendicular to L direction of fruit), PA_2 (perpendicular to T direction of fruit) and PA_3 (perpendicular to W direction of fruit), are first, second and third projected areas (mm^2), respectively.

The following models were considers in the estimation of mass models for green bell peppers:

- Single variable regression of bell peppers mass based on fruits dimensional properties including length (L), width (W), thickness (T) and geometric mean diameter (D_g).
- Single or multiple variable regression of bell peppers mass based on fruits projected areas (PA_1, PA_2 and PA_3), surface area (S) and criteria projected are (CPA).
- Singe regression of bell peppers mass based on measured volume (V_m), volume of the fruits assumed as

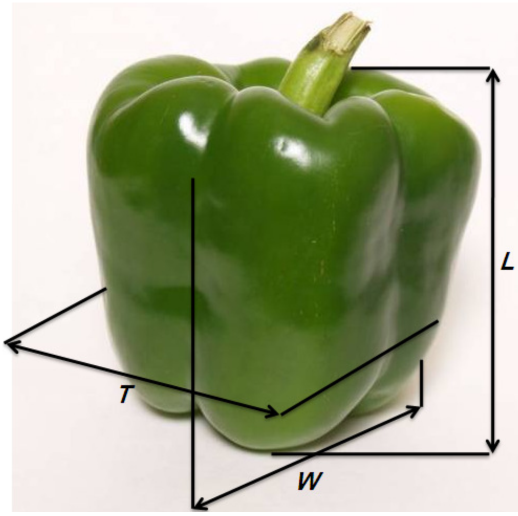

Fig.1. dimensional characteristics of green bell pepper: *l*, length; *w*, width; *t*, thickness

oblate spheroid shape (V_{osp}) and volume of the fruits assumed as ellipsoid shape (V_{ellip}).

In the case of the third classification, to achieve models, which can predict the green bell pepper mass, based on volumes, three volume values were either measured or calculated. At first, measured volume (V_m) as stated earlier was measured and then the green bell pepper shape was assumed as a regular geometric shape, i.e. oblate spheroid (V_{osp}) and ellipsoid (V_{ellip}) shapes, and their volume was thus calculated as:

$$V_{osp} = \frac{4\pi}{3}(\frac{L}{2})(\frac{W}{2})^2 \quad (4)$$

$$V_{ellip} = \frac{4\pi}{3}(\frac{L}{2})(\frac{W}{2})(\frac{T}{2}) \quad (5)$$

Four models including: Linear, Quadratic, S-curve and Power models were used for mass predication of green bell peppers based on measured physical properties, as are represented in the following expressions, respectively:

$$M = b_0 + b_1 X \quad (6)$$

$$M = b_0 + b_1 X + b_2 X^2 \quad (7)$$

$$M = b_0 + \frac{b_1}{X} \quad (8)$$

$$M = b_0 X^{b_1} \quad (9)$$

Where: M is mass (g), X is the value of a parameter (physical characteristics) that we want to find its relationship with fruit mass, and b_0, b_1 and b_2 are curve fitting constants. The value of the coefficient of determination (R^2) was used for evaluation of the goodness of fit. In general, for regression equations the R^2 value near to 1.00 shows the better fit (Stroshine, 1998). The analyzing the data and finding the green bell pepper mass models based on measured physical properties were done by SPSS15, software.

III. RESULTS & DISCUSSION

A. Physical Properties of Green Bell Peppers

The mean values of measured physical properties of studied green bell pepper fruits (length, width, thickness, geometric mean diameter, surface area, mass, first projected area, second projected area, third projected area, criteria projected area, measured volume, oblate spheroid volume and ellipsoid shapes volume) were 84.254 mm, 84.415 mm, 74.071 mm, 80.545 mm, 20497.90 mm^2, 138.541 g, 5576.82 mm^2, 6557.80 mm^2, 6490.81 mm^2, 6208.47 mm^2, 294737.01 mm^3, 319383.67 mm^3 and 278533.07 mm^3 respectively.

B. Mass Modeling

Table 1 shows the obtained the best models and their coefficient of determination (R^2) for mass predication of green bell peppers based on the measured physical properties. The results of the F-test and T-test in SPSS 15 software showed that all the coefficients of the models were significant at the 1% probability level.

C. Modeling Based on Dimensions

The results of mass modeling of green bell pepper based on the dimensional characteristics, including: length (L), width (W), thickness (T) and geometric mean diameter (D_g), showed that S-curve model to calculate mass of bell pepper fruit based on its geometric mean diameter, had the highest R^2 among the others as:

$$M = 7.203 - \frac{183.714}{D_g} \quad R^2=0.708 \quad (10)$$

However, measurement of three diameters of fruit is needed for calculating the geometric mean diameter (D_g) to use this model, which makes the sizing mechanism more tedious and expensive. Among three dimensions including length (L), width (W) and thickness (T), S-curve model, which expresses the width (W) as independent variable, had the highest R^2 among the others (Table 1). Therefore, the mass model of bell pepper fruit based on width is given as S-curve form:

$$M = 7.167 - \frac{189.899}{W} \quad R^2=0.519 \quad (11)$$

In addition, S-curve model can predict the relationships between the mass with length (L) and thickness (T) with R^2 values of 0.412 and 0.470, respectively. Therefore, mass modeling of green bell pepper based on width is recommended.

D. Modeling Based on Areas

Among the investigated models based on projected areas (PA_1, PA_2, PA_3 and CPA), S-curve model of PA_1 was preferred because of the highest value of R^2 as:

$$M = 5.973 - \frac{572.252}{AP_1} \qquad R^2=0.887 \qquad (12)$$

For mass prediction of the green bell pepper based on surface area, the best model was S-curve with R^2=0.711 as:

$$M = 6.036 - \frac{22545.106}{S} \qquad R^2=0.711 \qquad (13)$$

However, measurement of three dimensions of green bell pepper is needed for geometric mean diameter (D_g) and surface area (S) to use this model, which makes the grading mechanisms more tedious and expensive.

E. Modeling Based on Volumes

According to the results, for mass prediction of the green bell pepper based on volumes (V_m, V_{osp} and V_{ellip}), shown in Table 2, the S-curve model based on measured volume (V_m) with R^2=0.884, was the best model as:

$$M = 6.012 - \frac{187521.76}{V_m} \qquad R^2=0.884 \qquad (14)$$

IV. CONCLUSION

According to the results obtained in this study, the S-curve models could predict the relationships between the mass and some physical properties of green bell pepper fruits with proper values of coefficient of determination. Finally, the S-curve model based of the first projected area (AP_1) for mass predication of green bell pepper is suggested because it needs one camera, as the main part of the grading systems and it is applicable and is an economic method.

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Table 1. The best models for mass prediction of green bell pepper with some physical characteristics

Dependent variable	Independent variable	The best fitted model	Constant parameters			R^2
			b_0	b_1	b_2	
M (g)	L (mm)	Quadratic	109.979	-0.713	0.012	0.415
M (g)	W (mm)	S-curve	7.167	-189.899	-	0.519
M (g)	T (mm)	Quadratic	-901.568	25.52	-0.154	0.470
M (g)	D_g (mm)	S-curve	7.203	-183.714	-	0.708
M (g)	AP_1 (mm^2)	S-curve	5.973	-572.252	-	0.887
M (g)	AP_2 (mm^2)	Quadratic	4.418	0.016	6.841×10^{-7}	0.741
M (g)	AP_3 (mm^2)	Quadratic	-496.021	0.0173	-1.104×10^{-5}	0.782
M (g)	CPA (mm^2)	S-curve	6.088	-7126.03	-	0.816
M (g)	S (mm^2)	S-curve	6.036	-22545.10	-	0.711
M (g)	V_m (mm^3)	S-curve	6.012	-314783.73	-	0.884
M (g)	V_{osp} (mm^3)	S-curve	5.535	-187521.76	-	0.572
M (g)	V_{ellip} (mm^3)	S-curve	5.646	-194344.46	-	0.712