MODES FOR PREDICATION THE MASS OF GREEN BELL PEPPER FRUIT WITH SOME PHYSICAL CHARACTERISTICS

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ABSTRACT
For proper design of grading systems of horticultural crops, important relationships between 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 and correlating the mass of fruits to measured physical properties using linear, quadratic, S-curve and power models. The results showed that the effects of measured physical properties, on the mass of bell pepper fruit, were found to be statistically significant at 1% probability level. According to the results obtained in this study, the S-curve model 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 (PA_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.

Keywords: Green bell pepper, physical characteristics, mass prediction.

1. INTRODUCTION

Green bell pepper (*Capsicum annum* L) is a fruit pod of small perennial shrub in the nightshade or *Solanaceae* family, of the genus, capsicum. It contains an impressive list of plant nutrients that are known to have disease preventing and health promoting properties and it is very low in calories and fat. Fresh bell peppers are rich source of vitamin-C. It also contains good level of vitamin-A.

Knowledge about physical properties of agricultural products and their relationships is necessary for the design of handling, sorting, processing and packaging systems. Among these properties, the dimensions, mass, volume and projected area are the most important ones in the design of grading system (Mohsenin, 1986). Consumers prefer fruits with equal weight and uniform shape. Mass grading of fruit can reduce packaging and transportation costs, and may provide an optimum packaging configuration. Fruits are often classified based on the size, mass, volume and projected areas. Electrical sizing mechanisms are more complex and expensive. Mechanical sizing mechanisms work slowly. Therefore, it may be more economical to develop a machine, which grades fruits by their mass. Besides, using mass as the classification parameter is the most accurate method of automatic classification for more fruits. Therefore, the relationships between mass and length, width and projected areas can be useful and applicable (Khoshnam *et al*., 2007; Lorestani *et al*., 2012).

A number of studies have been conducted on the mass modeling of fruits based upon their physical properties. Tabatabaeefar *et al*. (2000) developed 11 models based upon dimensions, volumes and surface areas for mass predication of orange fruits. Al-Maiman and Ahmad (2002) studied the physical properties of pomegranate and developed models for predicting fruit mass while employing dimensions, volume and surface areas. A Quadratic model ($M= 0.08c^2 + 4.74c + 5.14, R2=0.89$), to calculate the apple mass based on its minor diameter, was determined by Tabatabaeefar and Rajabipour, (2005). Lorestani and Tabatabaeefar (2006) determined models for predicting mass of Iranian kiwi fruit by its dimensions, volumes, and projected areas. They reported that the intermediate diameter was more appropriate to estimate the mass of kiwi fruit. Khanali *et al*. (2005) determined similar mass models for tangerine fruit. Naderi-Boldaji *et al*. (2008) also determined models for predicting the mass of apricot. They found a nonlinear equation ($M= 0.0019c^{2.693}$, $R^2 = 0.96$) between apricot mass and its minor diameter. Some researchers (Kingsly *et al*., 2006; Fadavi *et al*., 2005) reported mass models for pomegranate fruit. Lorestani and Ghari (2012) concluded that the best models for prediction the mass of fava bean were linear based on width, among the dimensional characteristics and power form based on third projected area, which perpendicular to L direction of fava bean, among the projected areas, respectively.

No detailed studies concerning mass modelling 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.

2. MATERIALS AND METHODS

Freshly harvested green bell peppers were obtained 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, fruit, three linear dimensions were measured by using a digital caliper with accuracy of 0.01mm, including Major diameter (Length, L), Intermediate diameter (Width, W) and Minor diameter (Thickness, T) (Fig 1). Water displacement method was used for determining the fruits measured volume (V_m). Fruits geometric mean diameter (D_g) and surface area (S) were determined by using the following formulas (Mohsenin, 1986; Shahbazi, 2013), respectively:

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

$$S = \pi (D_g)^2 \quad (2)$$

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 ΔT 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):

$$CPA = \frac{PA_1 + PA_2 + PA_3}{3} \quad (3)$$

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 oblate spheroid shape (V_{osp}) and volume of the fruits assumed as ellipsoid shape (V_{ellip}) (Lorestani *et al*., 2012).

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:

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

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

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 (Shahbazi and Rahmati, 2013 a, b):

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

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

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

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

Where M is mass (g), X is the value of an independent (physical characteristics) parameter which want to find its relationship with mass, and b_0, b_1, and b_2 are curve fitting parameters which are different in each equation. One evaluation of the goodness of fit is the value of the coefficient of determination (R^2). For regression equations in general, the nearer R^2 is to 1.00, the better the fit (Stroshine, 1998). SPSS 15, software was used to analyze the data and determine regression models between the physical characteristics.

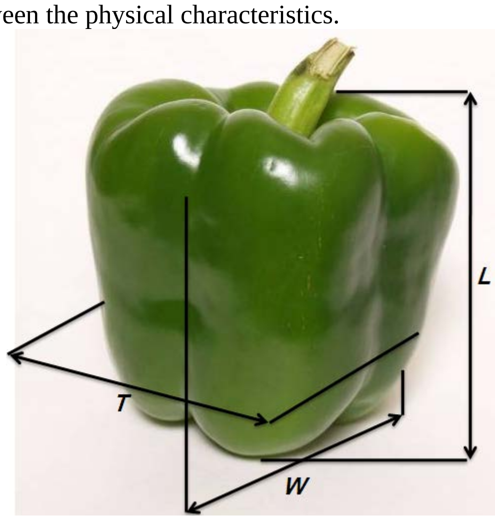

Figure1: Dimensional characteristics of green bell pepper: L, length; W, width; T, thickness.

3. RESULTS AND DISCUSSION

3.1. Physical Properties of Green Bell Peppers

Table 1 shows the measured physical properties of studied green bell peppers. The properties are measures at the moisture content of about 83.13% wet basis. As seen in Table 1, the effects of all properties, on the mass of bell pepper fruit, were found to be statistically significant at 1% probability level. The mean values of measured physical properties of studied green bell pepper fruits include: length (L), width (W), thickness (T), geometric mean diameter (D_g), surface area (S), mass (M), first projected area (AP_1), second projected area (AP_2), third projected area (AP_3), criteria projected area (CPA), measured volume (V_m), oblate spheroid volume (V_{osp}) and ellipsoid shapes volume (V_{ellip}) 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.

Table 1. Some physical properties of green bell pepper (at 83.13% w.b. moisture content).

Properties	Value			Significant level
	Average	Maximum	Minimum	
L, mm	84.254	110.02	67.45	P <0.01
W, mm	84.41	91.56	73.38	P <0.01
T, mm	74.07	87.61	61.13	P <0.01
D_g, mm	80.54	90.96	69.71	P <0.01
S, mm^2	20497.90	25981.99	15260.12	P <0.01
M, g	138.54	193.75	93.47	P <0.01
PA_1, mm^2	5576.82	7069.12	4040.31	P <0.01
PA_2, mm^2	6557.80	8484.52	4801.23	P <0.01
PA_3, mm^2	6490.80	9352.32	4888.65	P <0.01
CPA, mm^2	6208.47	8156.33	4694.64	P <0.01
V_m, mm^3	294737.0	392050.3	207420.	P <0.01
V_{osp}, mm^3	319383.6	482682.5	190070.9	P <0.01
V_{ellip}, mm^3	278533.07	393906.08	177304.95	P <0.01

CPA =criteria projected area; D_g=geometric mean diameter; L=length; M=mass; PA_1, PA_2, PA_3=first, second, third projected area; S= surface areas; T = thickness; V_m= measured volume; V_{osp}= oblate spheroid volume; V_{ellip} = ellipsoid shapes volume; W = width.

3.2. Mass Modeling

Table 2 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.

3.2.1. Modeling Based on Dimensions

The results of mass (M) 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:

$$M = 7.203 - \frac{183.714}{D_g} \qquad R^2=0.908 \qquad (10)$$

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 2). Therefore, the mass model of bell pepper fruit based on width is given as S-curve form:

$$M = 7.167 - \frac{189.899}{W} \qquad R^2=0.819 \qquad (11)$$

In addition, S-curve model can predict the relationships between the mass with length (L) and thickness (T) with R^2 values of 0.512 and 0.570, respectively. Therefore, mass modeling of green bell pepper based on width is recommended. Similar model (nonlinear) suggested by Tabatabaeefar *et al*. (2000) for mass predication of orange fruit mass based on fruit width too. Their recommended model was: $M= 0.069b^2 - 2.95b - 39.15$, $R^2=0.97$. In addition, eleven models for predicting mass of apples based on geometrical attributes were recommended by Tabatabaeefar and Rajabipour (2005). They recommended an equation for calculating apple mass based on minor diameter as $M= 0.08c^2 - 4.74c + 5.14$, $R^2 = 0.89$. Ghabel *et al*. (2010) recommended a nonlinear model for onion mass determination based on length as $M = 0.035a^2 - 1.64a + 36.137$, $R^2 = 0.96$.

3.2.2. 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:

$$M = 5.973 - \frac{572.252}{PA_1} \qquad R^2=0.987 \qquad (12)$$

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

$$M = 6.036 - \frac{22545.106}{S} \qquad R^2=0.811 \qquad (13)$$

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. Therefore, mass modeling of bell pepper based on first projected area (PA_1) is recommended. Similar model (nonlinear) suggested by Shahbazi and Rahmati (2013a) for mass predication of sweet cherry fruit mass based on fruit first projected area (PA_1) too.

3.2.3. 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 =0.984, was the best model as:

$$M = 6.012 - \frac{187521.76}{V_m} \qquad R^2=0.984 \qquad (14)$$

4. CONCLUSIONS

The results of this study can be concluded that:

In this study, some physical properties of green bell pepper fruits and their relationships with fruit mass were presented. All considered properties were statically significant at 1% probability level.

The best model for green bell pepper s mass predication among the dimensional properties was S-curve form based on width (W) of fruit as: $M = 7.167 - \frac{189.899}{W}$, R^2=0.819.

The best model for mass prediction of green bell pepper based on three projected areas was S-curve form based on first projected area (perpendicular to L direction of fruit) as: $M = 5.973 - \frac{572.252}{AP_1}$, R^2=0.987.

S-curve model based on measured volume (V_m) with R^2 =0.984, was the best model for mass prediction of the green bell pepper based on volumes as: $M = 6.012 - \frac{187521.76}{V_m}$, R^2 =0.984.

At last, from economical standpoint of view, mass model of green bell pepper based on the first projected area is recommended to design and development of grading systems.

Table 2. The 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	0.515
M (g)	*W* (mm)	S-curve	7.167	-189.899	-	0.819
M (g)	*T* (mm)	Quadratic	-901.568	25.52	-0.154	0.570
M (g)	D_g (mm)	S-curve	7.203	-183.714	-	0.908
M (g)	PA_1 (mm^2)	S-curve	5.973	-572.252	-	0.987
M (g)	PA_2 (mm^2)	Quadratic	4.418	0.016	6.841×10^{-7}	0.741
M (g)	PA_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	-	0.811
M (g)	V_m (mm^3)	S-curve	6.012	-314783.73	-	0.984
M (g)	V_{osp} (mm^3)	S-curve	5.535	-187521.76	-	0.672
M (g)	V_{ellip} (mm^3)	S-curve	5.646	-194344.46	-	0.712

CPA=criteria projected area; D_g=geometric mean diameter; L= length; M= mass; PA_1, PA_2, PA_3 = first, second, third projected area; R^2 =coefficient of determination; S=surface areas; T=thickness; V_m =measured volume; V_{osp} = oblate spheroid volume; V_{ellip}=ellipsoid shapes volume; W=width.

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