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Prediction of cucumber mass by geometrical attributes

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Knowing physical characteristics, such as, dimensions, mass, volume and projected areas and relationship among them, are important in harvest and post harvest technology. It is necessary to know relationships between mass and size of Cucumber fruit in order to design and develop of planting, harvesting, grading and handling equipments. Therefore, an awareness of grading fruit based on weight is important. In this research was aimed to present some physical properties of Cucumber fruits. The mass of Cucumber was predicted with using different physical characteristics in four models include: Linear, Quadratic, S-curve, and Power. The results shown that, all properties considered in the current study were found to be statistically significant at the 1% probability level, and the models for prediction the mass of Cucumber were based on medium projected area, small diameter, surface area, geometric mean diameter, arithmetic mean diameter, criteria area and volume of the Cucumber with determination coefficients of 0.991, 0.94, 0.997, 0.965, 0.954, 0.973 and 0.9994 respectively. At last, mass model based on medium projected area from economical standpoint is recommended.

Key words: Cucumber, mass modeling, geometrical attributes, physical characteristics

Nomenclature

m	mass(g)	P_A	small projected area(mm^2)
a	big diameters(mm)	P_B	medium projected area(mm^2)
b	medium diameter(mm)	P_C	big projected area(mm^2)
c	small diameter(mm)	D_g	geometric mean diameter(mm)
D_a	arithmetic men diameter(mm)	CPA	criteria area(mm^2)
V	volume(ml)	b_0,b_1,b_2	curve fitting parameters
		X	independent parameter

Introduction

The cucumber (*Cucumus sativus*) is a warm-season vining crop in the Cucurbit family. Cucumbers suitable for immediate consumption are referred to as “slicers,” while those for processing are picklers. All cucumbers grown commercially in the state are now for fresh market consumption. Cucumber

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plant is native to India and has found its way from there to other parts of the world. Herbaceous plant is cucumber and a year with creeping stems and covered with thin and tough thorns. It has large leaves and jagged angles, and the flowers are yellow and green fruit and depending on different races may be small or long. Cucumber with materials and substances sulfur and nitrogen and a little fat, with minerals such as manganese, calcium carbonate, is cellulose. Furthermore, is capable of vitamin C_3, B_1, B_3, also. Moreover, vitamin A plays important role in reproduction and growing functions of our bodies, in increasing body resistance against infections. In cucumber seed oil in a light yellow color with a flavor similar to the taste of olive oil, there is in saturated fatty acids such as stearic acid, palmitic acid and unsaturated acids such as oleic acid and linoleic acid. Cucumbers are very sensitive to unfavorable conditions, and the slightest stress affects their growth and productivity. Physical 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).

Among these physical characteristics, mass, volume, projected area are the most important ones in determining sizing systems (Peleg and Ramraz, 1975; Khodabandehloo, 1999). Many researchers have been conducted to find physical properties of various types of agricultural products. Mass grading of fruit can reduce packaging and transportation costs, and also may provide an optimum packaging configuration (Peleg, 1985). Tabatabaeefar *et al*. (2000) found 11 models for the prediction of Orange mass based upon dimensions, volume and surface areas. The regression analysis was used by Chuma *et al.* (1982) to develop equations for predicting volume and surface area. Determining relationships between mass and dimensions and projected areas may be useful and applicable (Stroshine, 1998; Marvin *et al*., 1987). Tabatabaeefar and Rajabipour (2005) predicted apple mass by models that were based upon apple physical properties. 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. Keramat Jahromi *et al*. (2007) investigated some physical properties of Date (cv. Lasht). They determined dimensions and projected areas by using image processing technique.

Lorestani and Tabatabaeefar (2006) concluded that the linear regression models of Kiwi fruit have higher R2 than nonlinear models for them, and are economical models for application. Among the linear regression dimensions models, the model that is based on width and among the linear projected area models, the model that is based on third projected area, and among the other models, the model that is based on measured volume, had higher R^2, that are recommended for sizing of kiwi fruit. Also Tabatabaeefar and Rajabipourm (2005) determined a total of 11 regression models in the three different categories for two different varieties of apple fruits. Khoshnam *et al*. (2007) determined mass modeling of Pomegranate with some physical characteristics. No detailed studies concerning mass modeling of Cucumber have yet been performed. The aims of this study were to determine the most suitable model for predicting Cucumber mass by its physical attributes and study some physical properties of Cucumber to form an important database for other investigators.

Materials and methods

In this research 100 cucumbers collected from Kermanshah province in the west of Iran. The samples measured in the Biophysical laboratory and Biological laboratory of Razi University of Kermanshah, Iran. The samples were weighted and dried in an oven at 105˚C for 24 h (Suthar and Das, 1996) and then weight loss on drying to final content weight was recorded as moisture content. The remaining material was kept in the desiccators until use. Cucumber mass (M) was determined with an electronic balance with 0.01 g sensitivity. Dimensions of fruits were measured by using a micrometer to an accuracy of 0.01 mm. Volume (V) was determined by the water displacement method (Mohsenin, 1986). Geometric mean diameter (Dg), sphericity (Φ), arithmetic means diameter (Da) and surface areas (S) values were found using the following equation (Mohsenin, 1986; Guner, 2003).

$$Dg = (a.b.c)^{\frac{1}{3}} \tag{1}$$

$$\varphi = \frac{(a.b.c)^{\frac{1}{3}}}{a} \tag{2}$$

$$D_a = \frac{a + b + c}{3} \tag{3}$$

$$S = \pi(Dg)^2 \tag{4}$$

Where a, b and c are big, medium and small diameters, respectively. Then, projected areas (P_A, P_B and P_C) in three perpendicular directions of the Cucumber were measured by a ΔT area-meter, MK2 model device with 0.1 cm^2 accuracy and criteria projected area (CPA) is defined as follow (Mohsenin, 1986):

$$CPA = \frac{P_A + P_B + P_C}{3} \tag{5}$$

Where P_A, P_B and P_C are small, medium and big area, respectively.

In order to estimate mass models of Cucumber, the following models were considered:

1. Single variable regression of Cucumber mass based on Cucumber dimensional characteristics: big (a), medium (b) and small diameter(c), and geometric mean diameter (Dg).

2. Single variable regressions of Cucumber mass based on Cucumber projected areas and criteria projected area.

3. Single variable regression of Cucumber mass based on measured volume.

4. Single variable regression of Cucumber mass based on surface area.

In all cases, the results which were obtained from experiments were fitted to Linear, Quadratic, S-curve, and Power models which are presented as following equations, respectively:

$M = b_0 + b_1X (4)$
$M = b_0 + b_1X + b_2X^2 (5)$
$Ln(M) = b_0 + b_1/X \ (6)$
$M = b_0X^{b_1} (7)$

Where M is mass (g), X is the value of a parameter(independent parameter) that we 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. For regression equations in general, the nearer R^2 is to 1.00, the better the fit (Stroshine, 1998). SPSS 19, software was used to analyze data and determine regression models among the physical attributes.

Results and discussions

The physical properties such as big, medium and small diameter, mass, volume, specific gravity, geometric mean, and percent sphericity, surface area are shown in Table 1. The dimensions (big, medium and small diameters), of cucumber varied within the ranges of 102.35-215.04 mm, 22.5-46.95mm and 21.6-42.83mm, respectively. The arithmetic mean diameters and geometric mean diameters of cucumber were 50.62-100.61mm, 39.5-73.97mm, respectively (Table 1). The volumes and unit masses of cucumber were 33-260cm^3, 34.06-252.19 g.The ranges of surface area (big, medium and small area) and Criteria area were 2179.28-8616.31mm^2, 2024.31-8599.84mm^2, 466.74-2351.90 mm^2 and 1601.70 -6522.69 mm^2, respectively.

Mass models and coefficient of determination (R^2) that obtained from the data for Cucumber are shown in Table 1. All of the models coefficients were analyzed with SPSS 19 Software, where, all of them were significant at 1%.

Among the linear regression dimensions models, the model that is based on the smallest diameter, and among the linear projected area models, the model that is based on projected area normal to the smallest diameter, and among the other linear regression models, the model that is based on measured volume, had higher R^2 that are recommended for sizing of Oak.

For mass modeling based on dimensional characteristic including small, medium and big dimension, the best model was Quadratic with $R^2 = 0.94$:

$$M = 58.726 - 6.494\, c + 0.253 c^2 \qquad R^2 = 0.94$$

Whereas this model can predict the relationships between the mass with dimensions.

Tabatabaeefar *et al.* (2000) reported that among systems that sort oranges based on one dimension, the system that applies intermediate diameter is suited with nonlinear relationship.

For prediction of the mass of Cucumber based on volume the best model was Linear with R^2 =0.9994, (shown in fig.1):

$$M = 1.422 + 0.97\, V \qquad R^2 = 0.9994$$

According to the results, for prediction of the mass of the Cucumber based on geometric mean diameter, Quadratic models were the best models with $R^2 = 0.985$:

$$M = 81.31 - 4.965\, Dg + 0.098 Dg^2 \qquad R^2 = 0.985$$

This model is not economical because for calculating the geometric mean diameter(Dg) we must measure three dimensions of Cucumber and it is time consuming and costly.

For mass modeling of Cucumber based on projected areas including P_A, P_B , P_C and CPA, the best model was Quadratic $R^2 = 0.991$:

$$M = -3.76 + 0.12 P_B + (21 * 10^{-6}) {P_B}^2 \qquad R^2 = 0.991$$

For prediction of the mass of the Cucumber based on surface area the best model was Power with $R^2 = 0.977$:

$M = 0.0008\,S^{1.528}$ $R^2 = 0.997$

For mass modeling of Cucumber based on D_a best model was Quadratic $R^2 = 0.991$:

$M = 173.01 - 6.27D_a + 0.07{D_a}^2$ $R^2 = 0.991$

According to the results the Quadratic model could predict the relationships among the mass and some physical properties of Cucumber with proper value for determination coefficient. So we suggest the Quadratic model based on projected area for prediction the mass of Cucumber because we need one camera and it is applicable and economical method.

Conclusion

Some physical properties and their relationships of mass of Cucumber are presented in this study. From this study it can be concluded that all properties considered in the current study were found to be statistically significant at the 1% probability level. The best model for prediction the mass of Cucumber among the dimensional models was Quadratic as: $M = 58.726\text{-}6.494\,c + 0.253c^2$ $R^2 = 0.94$.

The best model for prediction the mass of Cucumber was based on medium projected area of Cucumber, and it was Quadratic form as: $M = -3.76 + 0.12P_B + (21 * 10^{-6}){P_B}^2$ $R^2 = 0.991$

For prediction of the mass of Cucumber based on volume the best model was Linear as form:

$M = 1.422 + 0.97\,V$ $R^2 = 0.9994$

For prediction of the mass of the Cucumber based on geometric mean diameter, Quadratic models were the best models as form: $M = 81.31\text{-}4.965\,Dg + 0.098Dg^2$ $R^2 = 0.985$

For prediction of the mass of the Cucumber based on surface area the best model was Power as form; $M = 0.0008\,S^{1.528}$ $R^2 = 0.997$

At last for prediction of the mass of the Cucumber based on arithmetic mean diameter, Quadratic models were the best models as form: $M = 173.01\text{-}6.27D_a + 0.07{D_a}^2$ $R^2 = 0.991$

The results showed a good relationship was found for mass and measured (actual) volume of Cucumber. This information can be used in the design and development of sizing mechanisms and other post harvest processing machines. At the end, it is recommended that other properties of Cucumber such as thermal, mechanical, and nutritional characteristics are to be studied and changes of these properties are to be examined as a function of moisture content and ripening phases.

Table 1. Physical properties

Physical properties	**Mean**	**Max**	**Min**	**SD**	**CV %**	**Significant level**
Big dimension (mm)	139.65	215.04	102.35	15.95	17.96	$p < 0.01$
Medium dimension (mm)	26.56	46.95	22.5	2.72	10.22	$p < 0.01$
Small dimension (mm)	25.91	42.83	21.60	2.57	9.9	$p < 0.01$
Biggest projected area P_A (mm^2)	3357.06	8616.31	2179.28	602.81	17.96	$p < 0.01$
Medium projected area P_B (mm^2)	3285.24	8599.84	2024.31	593.77	18.07	$p < 0.01$
Smallest projected area P_C (mm^2)	689.07	2351.90	466.74	143.87	20.88	$p < 0.01$
Mass (gr)	66.92	252.19	34.06	17.89	26.74	$p < 0.01$
Volume (cm^3)	67.47	260	33	18.27	27.08	$p < 0.01$
Density (gr/cm^3)	0.99	1.03	0.97	0.01	1.29	$p < 0.01$
Criteria areas (mm^2)	2539.77	6522.69	1601.70	556.92	21.93	$p < 0.01$
Arithmetic means diameter (mm)	64.48	100.61	50.62	6.98	10.82	$p < 0.01$
Sphericity %	32.95	38.81	29.60	1.85	5.61	$p < 0.01$
Geometric mean diameter (mm)	46.11	73.97	39.50	4.85	10.52	$p < 0.01$
Moisture %	96.14	96.67	95.72	0.3	0.31	

Table 2. The best models for prediction the mass of Cucumber with some physical Characteristics

Dependent Parameter	Independent Parameters	The best model	Constant Values of model			R^2
			b_0	b_1	b_2	
M (g)	a (mm)	Quadratic	219.84	-3.46	0.017	0.878
M (g)	b (mm)	Quadratic	66.74	-6.78	0.246	0.93
M (g)	c (mm)	Quadratic	58.79	-6.42	0.253	0.94
M (g)	V (ml)	Linear	1.42	0.30397	-	0.9994
M (g)	D_g (mm)	Quadratic	81.31	-4.96	0.098	0.985
M (g)	S (mm^2)	Power	0.0008	1.528	-	0.997
M (g)	P_A (mm^2)	Quadratic	0.986	0.009	$2.3*10^{-6}$	0.982
M (g)	P_B (mm^2)	Quadratic	-3.760	0.012	$2.1*10^{-5}$	0.991
M (g)	P_C (mm^2)	Quadratic	75.15	-0.064	$6.5*10^{-5}$	0.623
M (g)	CPA (mm^2)	Power	0.001	1.48	-	0.973
M (g)	D_a (mm)	Quadratic	173.01	-6.27	0.07	0.991

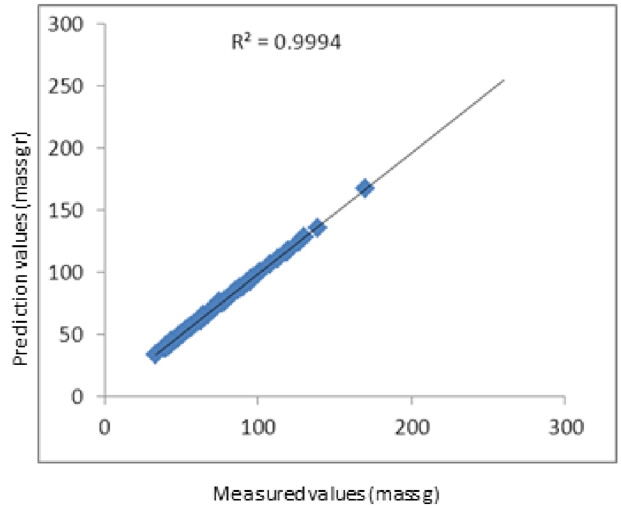

Fig. 1. Comparison between measured and predicted mass of Cucumber based on the volume for the total number of observations.

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