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Mass Modeling of Castor Seed (*Ricinus Communis*) with Some Geometrical Attributes

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Abstract Horticultural crops with the similar weight and uniform shape are in high demand in terms of marketing value. Therefore, an awareness of grading fruits and vegetables based on weight is crucial. A part of this research was aimed to present some physical properties of Castor seed. In addition, in this study the mass of Castor seed variety was predicted with using different physical characteristics in four models includes: Linear, Quadratic, S-curve, and Power. According to the results, all properties considered in the current study were found to be statistically significant at the 1% probability level and the best and the worst models for prediction the mass of Castor seed were based on third projected area and first projected area of the Castor seed with determination coefficients of 0.82 and 0.757, respectively. At last, mass model based on third projected area from economical standpoint is recommended.

Keywords Mass, modeling, Castor seed, physical characteristics

1. Introduction

Ricinus communis seed, commonly known as "higuerilla", "ricine" or "mamona", is a member of the Euphorbiaceae family and it is native from tropical climates although it has been adapted to a wide range of sub-tropical and temperate climates. The *R. communis* plant has been cultivated since antiquity not only as a garden ornament for its striking foliage and interesting flowers but also because their seeds were used as a medicinal plant. The annual world production is around one million tons and nowadays it is used mainly for the production of non-edible oil, as these seeds are poisonous to humans and animals, because they contain ricin, a protein with cytotoxic activity that inhibits protein synthesis at ribosome levels[1]. *R. communis* plant is considered as an important source of oil because of their seeds which contain about 35–55% of oil by weight. The oil, also known as "castor oil", enjoys a tremendous annual demand worldwide, which is estimated in about 220,000 tons[1]. It contains a high concentration (over 85–90%) of ricinoleic acid (12-hydroxy-oleate), which has multiple nonfood applications in the production of different products such as paints and varnishes, nylon-type synthetic polymers, fungicides, medications, cosmetics, hydraulic fluids and high quality lubricants. As additive, the ricinoleic acid has been found useful to replace sulfur based lubricity components in petroleum diesel, helping to reduce sulfur emissions, among others Applications[1].

To design and optimization a machine for handling, cleaning, conveying and storing, the physical attributes and their relationships must be known. As an instance, grading of fruits by their size can be replaced with grading by their weight because it may be more economical. Grading fruit based on weight is important in packing and handling. In nearly all cases raw product grades are based on weight[2]. Size and shape determine how many fruit can be placed in containers of a given size. Volume and surface area could be beneficial in proper prediction drying rates and hence drying time in the dryer. On the other hand, volume and its relationship with packing coefficient are very important because having any information about Packing coefficient of fruits could result in efficient control of fruit quality during storage. Physical characteristics of agricultural products are the most important parameters to determine the proper standards of design of grading, conveying, processing and packaging systems[3].

Among these physical characteristics, mass, volume, projected area are the most important ones in determining sizing systems[4, 5]. Many researches 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[6]. Determining relationships between mass and dimensions and projected areas may be useful and applicable[7, 8]. Tabatabaeefar predicted apple mass by models that were based upon apple physical properties[3]. Al-Maiman studied the physical properties of pomegranate and found models of predicting fruit mass while employing dimensions, volume and surface areas[9].

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Keramat investigated some physical properties of date (cv. Lasht). They determined dimensions and projected areas by using image processing technique[10]. Lorestani concluded that the linear regression models of kiwi fruit have higher R^2 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[11]. Also Tabatabaeefar determined a total of 11 regression models in the three different categories for two different varieties of apple fruits[3]. Lorestani concluded that the best model for prediction the mass of Fava bean among the dimensional models was Linear as:

$M = -1.607 + 0.264\,W$; $R^2 = 0.733$ and the best model for prediction the mass of Fava bean was based on third projected area which perpendicular to L direction of Fava bean and it was Power form as $M = 0.006\,PA_3^{1.071}$, $R^2 = 0.819$, and the worst was based on first projected area of Fava bean and it was Linear form as $M = 1.686 + 0.006\,PA_1$, $R^2 = 0.152$,[12].

No detailed studies concerning mass modeling of Castor seed *(Ricinus Communis)* have yet been performed. The aims of this study were to determine the most suitable model for predicting Castor seed mass by its physical attributes and study some physical properties of Iranian Castor seed to form an important database for other investigators.

2. Materials and Methods

The common Castor seed was obtained from farms located in the west of Iran in June2011. 100 Castor seed samples collected from cultivations growing in Iranian farms were used for measurement in the Biophysical laboratory and Biological laboratory of Razi University of Kermanshah, Iran. The samples were weighted and dried in an oven at 105℃ for 24 h[13] 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. Castor seed mass (M) was determined with an electronic balance with 0.01 g sensitivity. To determine the average size of the samples, three linear dimensions namely as length, width and thickness were measured by using a digital caliper with 0.01 mm sensitivity. Volume (V) was determined by the water displacement method[14]. The geometric mean diameter (D_g) and surface areas (S) were determined by using following formulas[14], respectively:

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

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

Where: L is length of Castor seed (mm), W is width of Castor seed (mm); T is thickness of Castor seed (mm), S is surface area (mm^2) and Dg is geometric mean diameter (mm). Then, projected areas (PA_1, PA_2 and PA_3) in three perpendicular directions of the Castor seed 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[14]:

$$CPA = (PA_1 + PA_2 + PA_3)/3 \quad (3)$$

Where: PA_1, PA_2 and PA_3 are first, second and third projected area (mm^2), respectively. In order to estimate mass models of Castor seeds, the following models were considered:

1. Single variable regression of Castor seed mass based on Castor seed dimensional characteristics: length (L), width (W), thickness (T), and geometric mean diameter (D_g).
2. Single variable regressions of Castor seed mass based on Castor seed projected areas and criteria projected area.
3. Single variable regression of Castor seed mass based on measured volume.
4. Single variable regression of Castor seed 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:

$$M = b_0 + b_1 X \quad (4)$$

$$M = b_0 + b_1 X + b_2 X^2 \quad (5)$$

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

$$M = b_0 X^{b_1} \quad (7)$$

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[7]. SPSS 15, software was used to analyse data and determine regression models among the physical attributes.

3. Results and Discussion

A summary of the physical properties of Castor seed is shown in Table 1. These properties were found at specific moisture contents about 85.82% wet basis.

Table 1. Some physical properties of Castor seed

Physical Properties	Castor seed*		
	Max	Min	Average
L (mm)	15.01	10.06	13.52
W (mm)	14.26	11.39	13.39
T (mm)	14.89	10.36	13.38
M (g)	1.54	0.89	1.29
V (ml)	0.25	0.12	0.17
D_g (mm)	14.31	11.34	13.42
S (mm^2)	643.94	404.07	566.62
PA_1 (mm^2)	159.2	123.7	143.80
PA_2 (mm^2)	163.5	102.6	117.50
PA_3 (mm^2)	155.80	127.00	143.10
CPA (mm^2)	145.90	117.80	134.8

* Significant level: P <0.01

Table 2. The best models for prediction the mass of Castor seed 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)	L(mm)	Quadratic	5.648	-0.805	0.036	0.771
M(g)	W(mm)	Quadratic	15.844	-2.290	0.090	0.547
M(g)	T (mm)	S-curve	1.481	-16.457	-	0.701
M(g)	V(ml)	Linear	1.367	-0.466	-	0.409
M(g)	D_g(mm)	Quadratic	3.171	-0.470	0.025	0.741
M(g)	S(mm^2)	Quadratic	1.000	-0.001	$3.1*10^{-6}$	0.742
M(g)	PA_1(mm^2)	Linear	-0.262	0.011	-	0.757
M(g)	PA_2(mm^2)	Quadratic	-5.165	0.096	0.000	0.820
M(g)	PA_3(mm^2)	Quadratic	-7.899	0.116	0.000	0.780
M(g)	CPA (mm^2)	Quadratic	-11.685	0.179	-0.001	0.870

As seen in Table 1, all properties which were considered in the current study were found to be statistically significant at 1% probability level. According to the results, the mean values of properties which were studied in this research (length, width, thickness, geometric mean diameter, Volume, surface area, mass and projected areas) are 13.52 mm, 13.39 mm, 13.38 mm, 13.42 mm, 0.17 cm^3, 566.62 mm^2, 1.29 g, 143.8 mm^2, 117.5 mm^2 and 143.1 mm^2, respectively.

Mass models and coefficient of determination (R^2) that obtained from the data for Castor seed are shown in table 2. All of the models coefficients were analysed with F-test and t-test in SPSS 15 Software, where, all of them were significant at α=1%.

Nonlinear models were used only for comparison with linear regression models. Lorestani reported that the linear regression models have higher R^2 than the other models, and are economical models for application. Among the linear regression dimensions models, the model that is based on the smallest diameter (T), and among the linear projected area models, the model that is based on projected area normal to the smallest diameter; (PA_3), and among the other linear regression models, the model that is based on measured volume (V), had higher R^2 that are recommended for sizing of Oak[15].

For mass modeling based on dimensional characteristic including length, width and thickness, the best model was Quadratic with R^2 = 0.771:

$$M = 5.648 - 0.805L + 0.771\ L^2,\ R^2 = 0.771$$

Whereas this model can predict the relationships between the mass with thickness and width with R^2 of 0.701 and 0.547, respectively.

Tabatabaeefar reported that among systems that sort oranges based on one dimension, the system that applies intermediate diameter is suited with nonlinear relationship[16].

For prediction of the mass of Castor seed based on volume the best model was Linear with R^2 = 0.409.

$$M = 1.307 - 0.466\ V \qquad R^2 = 0.409$$

According to the results, for prediction of the mass of the Castor seed based on geometric mean diameter, Quadratic model was the best models with R^2 = 0.741.

$$M = 3.171 - 0.470\ D_g + 0.025\ D_g^2\ ,\ R^2 = 0.741$$

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

For mass modeling of Castor seed based on projected areas including PA_1, PA_2 , PA_3 and CPA, the best model was Quadratic with R^2 = 0.870.

$$M = -11.685 + 0.179\ CPA - 0.001\ CPA^2,\ R^2 = 0.870$$

For prediction of the mass of the Castor seed based on surface area the best model was Quadratic with R^2 = 0.742.

$$M = 1 - 0.001\ S + 3.1 * 10^{-6} S^2,\ R^2 = 0.742$$

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

4. Conclusions

Some physical properties and their relationships of mass of Castor seed are presented in this study. From this study it can be concluded that:

1. All properties considered in the current study were found to be statistically significant at the 1% probability level.
2. The best model for prediction the mass of Castor seed among the dimensional models was Quadratic as: $M = 5.648 - 0.805\ L + 0.036\ L^2\ ,\quad R^2 = 0.771$
3. The best model for prediction the mass of Castor seed was based on second projected area which perpendicular to W direction of Castor seed and it was Quadratic form as $M = -5.165 + 0.096\ PA_2 + 0.000\ PA_2^2\ ,\ R^2 = 0.82$, and the worst was based on first projected area of Castor seed and it was Linear form as $M = -0.262 + 0.011\ PA_1,\ R^2 = 0.757$.
4. At last, mass model based on second projected area from economical standpoint is recommended.

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 Castor seed 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.

Nomenclature

M= fruit mass, g; V= fruit Volume, cm^3; D_g = geometric mean diameter, mm; S= surface area, mm^2; L= length of fruits, mm; W= width of fruit, mm; T= thickness of fruit, mm; PA_1 = first projected area, mm^2; PA_2 = second projected area, mm^2; PA_3 = third projected area, mm^2; CPA= criteria projected area, mm^2; b_0,b_1,b_2 = curve fitting parameters; X= independent parameter.

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