*Int. Agrophys., 2011, 25, 141-147*

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# Modelling of raisin berries by some physical and statistical characteristics

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*Received April 25, 2010; accepted September 28, 2010*

A b s t r a c t. The relationships between mass and size and other parameters of raisin berries are needed for grading or classifying purposes. In this study, the mass of raisin berries was measured and predicted by applying different physical characteristics with 12 linear and nonlinear models in two different classifications. It is also possible to statistically characterise raisin berries on the basis of dimension for classifying and separating targets. For this reason, the Weibull distribution model was used to describe the process under study. The results showed that from the economic and agronomical point of view, a suitable grading system of raisin berries mass could be selected based on the major diameter as the nonlinear relation: $M = 0.068\ e^{0.157\,L}$, $R^2 = 0.769$. The information on statistical or physical modelling of raisin berries can be alternatively or synthetically utilized for classifying or grading targets.

K e y w o r d s: modelling, raisin, sizing, south Azerbaijan

## INTRODUCTION

Raisin is a concentrated source of carbohydrates and a nutritious snack, containing dietary fibre, antioxidants, potassium and iron (Kim *et al.*, 2008). Raisin also has low sodium content and high levels of thiamin, magnesium, phosphorus and propionic acid. The most common uses of raisin are in breakfast cereals, bakery products, confections and snacks, dairy products, food preparations and wine-making (Mandala and Daouaher, 2004; Tsakiris *et al*., 2004).

In the commercial processing of sun-dried raisins, the product is transported from the drying field to the packing house, where it is stored in bulk, before further processing. The moisture content of the dried product is about 16% (dry basis). The raisins contain stems, soil and some other pollutants which are usually removed by washing with water. The washed raisins are dried (until 16% moisture content) in air-dryers at air temperatures ranging from 70 to 120°C (usually 110°C). The dried raisins are destemmed and sorted into various sizes before packaging (Karathanos *et al*., 1995).

Physical characteristics of agricultural products are the most important parameters in the design of grading, conveying, sorting, processing and packaging systems. Among these physical characteristics, mass, volume, projected areas and centre of gravity are the most important parameters in sizing and classifying systems (Rashidi and Seyfi, 2008). The other important parameter is size (width, length and thickness) characterization (Klenin *et al*., 1986). Determining the relationships among the physical characteristics is an efficient method to grade raisin berries. For example, the relationships between mass and dimensions and volumes of berries may be useful and applicable for grading and classifying systems (Khoshnam *et al*., 2007; Malcolm *et al*., 1986; Mohsenin, 1986; Safwat, 1971; Stroshine and Hamann, 1995).

On the other hand, it is possible to classify raisin berries in terms of the length and the width in order to design, calibrate and determine the hole sizes of classifiers machinery. For this, statistical means is necessary to validate, analyse and process raisin berries dimensional information. Because of its popularity in reliability engineering, ability in modelling and utilizing by two variables and also versatility or flexibility in comparison with other types of distributions, the Weibull distribution was used as an appropriate distribution for this study (Rojano *et al*., 2004). Corzo *et al*. (2008) used the Weibull distribution for modelling of air drying of coroba slices. Voicu *et al*. (2008) utilized normal, gamma, beta and Weibull distributions for simulating and describing the variation separation intensity of seeds on sieve length of a combine cleaning system. Also, Rojano *et al*. (2004) characterized oat grains by means of the Weibull distribution.

In the case of mass modelling, Tabatabaeefar *et al*. (2000) determined models for predicting mass of Iranian grown orange for its volumes, dimensions and projected areas. They reported that among the systems that sorted oranges

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based on one dimension, the system that applies intermediate diameter is suitable with nonlinear relationship. Hassan-Beygi *et al*. (2010) studied predicting of saffron crocus corm mass models by its geometrical attributes. The results of their study showed that the appropriate grading system of saffron corm mass is based on major diameter with nonlinear relation. And also, Lorestani and Tabatabaeefar (2006) and Rashidi and Seyfi (2008) used this method for kiwi fruits.

The aim of this investigation was to determine the optimum model to predict raisin berries mass by selected physical properties for designing and developing sizing systems, and also analysis of the experimental data to apply the Weibull distribution for sizing and classifying of raisin berries.

## MATERIALS AND METHODS

The examined materials were Golden Bleached Raisins (GBR) which were produced by sun drying of Thompson seedless grapes in Qurujan, South Azerbaijan. The grapes were pretreated by immersion in 2% $K_2CO_3$ solution for ruining the natural wax coating, in order to increase the speed of drying. The grapes were also treated with $SO_2$ to preserve the golden colour of the raisins (Karadeniz *et al*., 2000), prevent the enzymatic browning (Karathanos *et al*., 1995) and facilitate the drying process (Miranda *et al*., 2009; Pateraki *et al*., 2007).

The moisture content of the raisins was determined by the vacuum oven method (70°C for 48 h under vacuum) (Karathanos *et al*., 1995). It is noteworthy that in many papers determining moisture content of raisin at 70°C for 24 h under vacuum has been recommended, but by this method the moisture content of the raisin did not approach 0%, hence, this method was not selected.

The size of raisin berries was determined by measuring the dimensions of three principal axes; the major diameter ($L$) in the direction of the tail stalk (pedicel) at the end of berries was defined as the length, the intermediate diameter ($W$) was defined as the width, and the minor diameter ($T$) was defined as the thickness of the berries. The dimensions of 110 randomly selected raisin berries were measured using a digital caliper with an accuracy of 0.01 mm, and also the nut mass ($M$) of these berries was simultaneously measured using an electronic balance with an accuracy of 0.001 g. The geometric mean diameter ($D_g$), sphericity ($\phi$), surface area ($S$) and projected area ($A_p$) of the berries were calculated by the formulas presented by Mohsenin (1986). The berries shape was assumed as a regularly geometric shape *ie* oblate spheroid, prolate spheroid and ellipsoid shapes, thus, their volumes were calculated using the relationships given by Mohsenin (1986), as ($V_{osp}$), ($V_{psp}$) and ($V_{ellip}$), respectively.

The actual volume ($V_{act}$) of 50 randomly selected berries was individually calculated by the analytical balance method (Mohsenin, 1986). The bulk density of the berries was determined by pouring the berries into a calibrated container from a height of 15 cm, striking off the top level and then weighing the contents. The true density was determined using the water displacement method. Due to the short duration of the experiments and the natural waxed skin of raisin berries, the moisture adsorption was found to be negligible; therefore the berries were not coated for moisture adsorption prevention. The porosity ($\varepsilon$) was also determined by the formula of Mohsenin (1986).

In order to estimate raisin berries mass from the measured dimensions, dimension-related parameters and volumes, the following two classifications of models were considered:

– single or multiple variable regressions of raisin berries dimensional characteristics: major diameter ($L$), intermediate diameter ($W$), minor diameter ($T$), three diameters, and also the other parameters of the berries that are related to dimensions: geometric mean diameter, sphericity, surface area and projected area;
– single regression of berries volumes: actual volume and volumes of the berries assumed as oblate spheroid, prolate spheroid and ellipsoid shapes.

The Weibull distribution was used in this study to characterize raisin berries distribution. The probability density function (PDF) of Weibull has the following form:

$$f_{we}(x)=\left(\frac{\alpha}{\beta}\right)\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}\exp\left[-\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right], \qquad (1)$$

and its cumulative density function (PDF) is:

$$F_{we}(x)=1-e^{\left[-\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right]}, \qquad (2)$$

where: $\alpha$, $\beta$ and $\gamma$ are the shape, scale and location parameters of the Weibull distribution, respectively, and $x$ is the independent variable corresponding to the length, width or thickness of raisin berries.

## RESULTS AND DISCUSSION

A summary of some selected physical characteristics of the raisin berries is presented in Table 1. The moisture content at three repetitions was found to be 16±0.38% (d.b).

For mathematical mass modelling, all the data were subjected to regression analysis using the Microsoft EXCEL program (Version 2007). All the regression models based on the selected variables are shown in Table 2. All of the models in this table are divided two classifications:

– among the first classification models, Nos 1 to 8 shown in Table 2, model No. 5 had the highest $R^2$, while for this model measurement of three diameters is needed, which makes the sizing mechanism more tedious, complex and expensive. Therefore, among the first classification models, the one-variable model No. 1 based on the major diameter ($L$) was selected as the best raisin berries mass model as shown in Fig. 1;

**T a b l e 1.** Some physical characteristics of raisin berries

| Characteristics | Replication number | Mean value | Range of values | Standard deviation |
|---|---|---|---|---|
| Major (mm) | 110 | 14.01 | 7.4-17.38 | 2.13 |
| Intermediate (mm) | 110 | 9.59 | 5.36-14.16 | 1.50 |
| Minor (mm) | 110 | 6.93 | 4.01-10.38 | 1.26 |
| Geometric mean (mm) | 110 | 9.69 | 6.33-12.37 | 1.32 |
| Sphericity (%) | 110 | 68.98 | 60.24-99.03 | 6.35 |
| Projected area ($mm^2$) | 110 | 73.92 | 31.53-120.26 | 19.08 |
| Surface area ($mm^2$) | 110 | 298.05 | 126.13-481.05 | 76.51 |
| Ellipsoid ($mm^3$) | 110 | 484.23 | 163.24-938.38 | 109.15 |
| Oblate spheroid ($mm^3$) | 110 | 983.58 | 198.2-1614.31 | 250.01 |
| Prolate spheroid ($mm^3$) | 110 | 670.13 | 171.96-1307.11 | 183.62 |
| Mass (g) | 110 | 0.621 | 0.31-1.25 | 0.28 |
| Bulk density (kg $m^{-3}$) | 10 | 763.23 | 755.45-771.25 | 11.25 |
| True density (kg $m^{-3}$) | 10 | 1306.36 | 1251.41-1342.86 | 19.84 |
| Porosity (%) | 10 | 41.53 | 39.81-43.03 | 2.08 |
| Actual volume ($mm^3$) | 50 | 406.27 | 132.19-764.64 | 45.48 |

**T a b l e 2.** Raisin berries mass models based on selected independent variables

| Classification | No. | Model | $R^2$ |
|---|---|---|---|
| First | 1 | $M = 0.068\ e^{0.157L}$ | 0.769 |
| | 2 | $M = 0.073\ e^{0.197W}$ | 0.659 |
| | 3 | $M = 0.073\ T^{1.42}$ | 0.526 |
| | 4 | $M = 0.039\ L + 0.043\ W + 0.045\ T - 0.7$ | 0.854 |
| | 5 | $M = 0.068\ e^{0.157Dg}$ | 0.918 |
| | 6 | $M = 7.21\ \phi^{-0.62}$ | 0.112 |
| | 7 | $M = 0.136\ e^{0.018Ap}$ | 0.891 |
| | 8 | $M = 0.136\ e^{0.004S}$ | 0.892 |
| Second | 9 | $M = 0.001 Vact + 0.021$ | 0.927 |
| | 10 | $M = 0.001 Vellip + 0.074$ | 0.875 |
| | 11 | $M = 0.001 Vosp + 0.102$ | 0.831 |
| | 12 | $M = 0.001 Vpsp + 0.122$ | 0.808 |

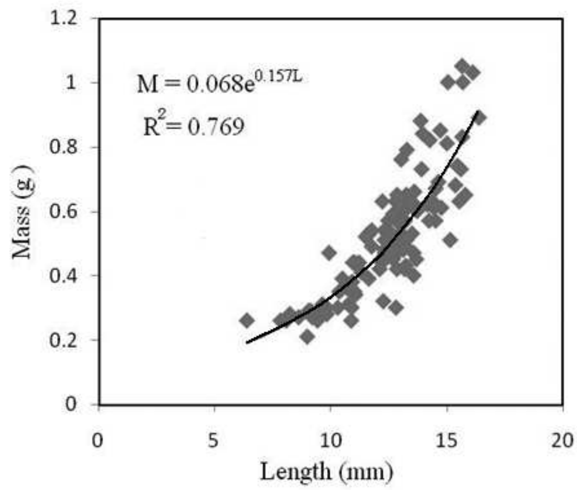


**Fig. 1.** Raisin berries mass model based on the major diameter.

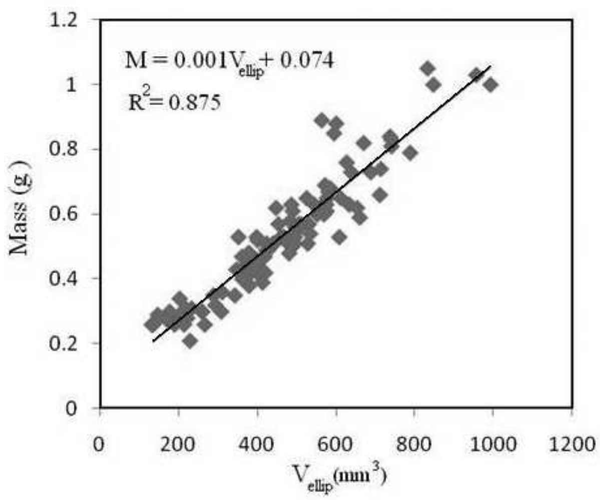


**Fig. 2.** Raisin berries mass model based on the volume of assumed ellipsoid.

**T a b l e 3.** Kolmogorov-Smirnov testing proof for comparing distributions

| Dimension | Normal | Weibull (3P) |
|---|---|---|
| Length | 0.09 | 0.06 |
| Width | 0.06 | 0.05 |

**T a b l e 4.** Weibull parameters

| Dimension | Alfa | Beta | Gama |
|---|---|---|---|
| Length | 7.13 | 13.00 | 0.28 |
| Width | 3.79 | 5.72 | 4.41 |

– among the models in the second classification (models Nos 9 to 12 shown in Table 2), the $R^2$ of model No. 9 had the maximum value for the actual volume. Among the assumed shapes models (models Nos 10 to 12), the model No. 10 for ellipsoid assumed model had the highest $R^2$ value. Measuring of actual volume is time consuming work, therefore, mass modelling based on actual volume is not reasonable; consequently, it seems suitable that mass modelling of berries be accomplished based on volume of assumed ellipsoid shape as shown in Fig. 2.

Using "Easy fit" as a tool program of Kolmogorov-Smirnov testing proof for the raisin berries depicted that the Weibull distribution has higher and better fit than the normal distribution (Table 3). The main parameters of the Weibull distribution for each dimension (length and width) to give the empirical models are shown in Table 4. These parameters have been obtained from "Easy fit". A comparison of the Weibull and normal distributions of the length and the width dimensions by applying Matlab (R2008 a) as a tool program, respectively, is graphically represented in Figs 3 and 4.

Cumulative density function (CDF) of the Weibull distribution for the length ($l_i$) and the width ($w_i$) is:

$$F_{we}(l_i) = 1 - e^{\left[-\left(\frac{l-0.28}{13}\right)^{7.13}\right]}, \quad (3)$$

$$F_{we}(w_i) = 1 - e^{\left[-\left(\frac{w-4.41}{5.72}\right)^{3.79}\right]}. \quad (4)$$

Cumulative frequencies and cumulative Weibull and normal distributions in terms of the length ($l_i$) and the width ($w_i$) of raisin berries by using intervals of 1 mm, are comparatively shown in Table 5.

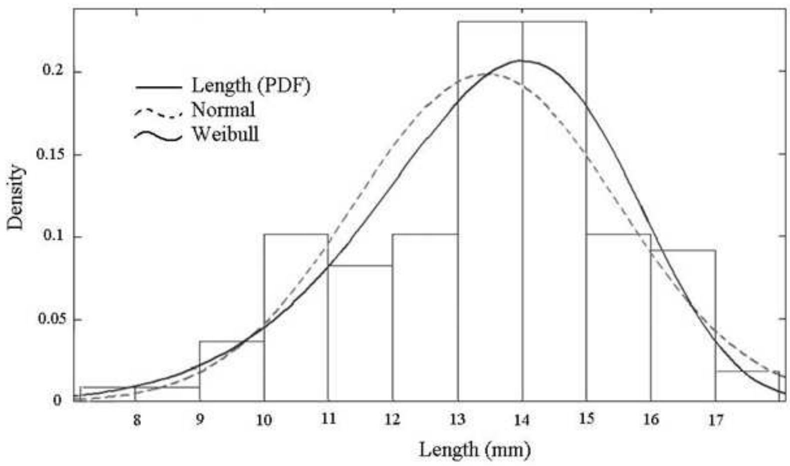


**Fig. 3.** Histogram of probability density function for length of raisin berries by comparing its fitting behaviour between normal and Weibull (3P) distributions (at the %16 (d.b) moisture content).

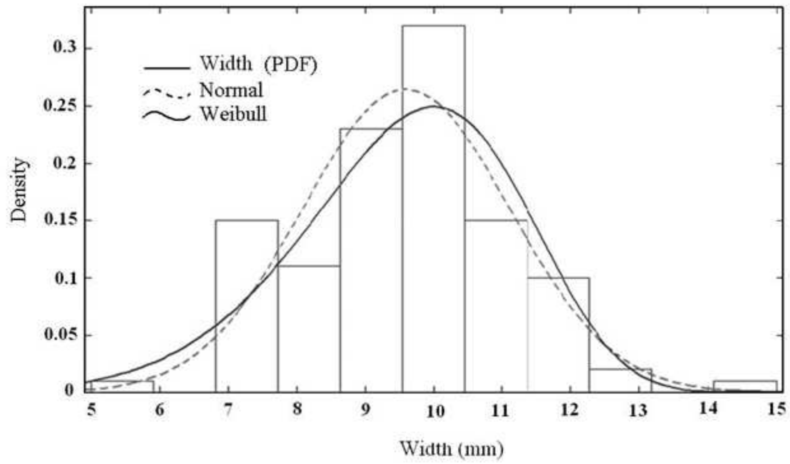


**Fig. 4.** Histogram of raisin berries probability density function for width dimension by comparing its fitting behaviour between normal and Weibull distributions (at the %16 (d.b) moisture content).

**T a b l e 5.** Cumulative frequency, cumulative Weibull distribution and cumulative normal distributions for the length and width of berries

| Length (mm) $l_i$ | Cumulative | | | Width (mm) $w_i$ | Cumulative | | |
|---|---|---|---|---|---|---|---|
| | Frequency | Weibull distribution | Normal distribution | | Frequency | Weibull distribution | Normal distribution |
| 7.4 | 1 | 0.46 | 0.14 | 5.36 | 1 | 0.11 | 0.23 |
| 8.4 | 1 | 1.35 | 0.64 | 6.36 | 1 | 1.67 | 1.53 |
| 9.4 | 4 | 3.42 | 2.3 | 7.36 | 12 | 7.80 | 6.76 |
| 10.4 | 9 | 7.67 | 6.64 | 8.36 | 22 | 21.79 | 20.42 |
| 11.4 | 19 | 15.43 | 15.62 | 9.36 | 48 | 43.90 | 43.64 |
| 12.4 | 31 | 27.98 | 30.25 | 10.36 | 76 | 68.68 | 69.38 |
| 13.4 | 46 | 45.48 | 49.01 | 11.36 | 97 | 87.65 | 87.96 |
| 14.4 | 77 | 65.62 | 68.01 | 12.36 | 107 | 96.92 | 96.71 |
| 15.4 | 91 | 83.51 | 83.16 | 13.36 | 109 | 99.57 | 99.39 |
| 16.4 | 101 | 94.69 | 92.69 | 14.36 | 110 | 99.97 | 99.92 |
| 17.4 | 110 | 99.02 | 97.41 | – | – | – | – |

By using relations Nos 3 and 4, and information from Table 5, it is possible to write the model with nonlinear equations including both of the variables (the length and the width) as a cumulative distribution function (Rojano *et al.*, 2004):

$$F(l, w) = F(l)\,F(w) \tag{5}$$

$$F(l,w)=\left(1-e^{\left[-\left(\frac{l-0.28}{13}\right)^{7.13}\right]}\right)\left(1-e^{\left[-\left(\frac{w-4.41}{5.72}\right)^{3.79}\right]}\right),$$

and the final model is:

$$F(l,w) = 1.9615 \times (m.n.e^{b}.e^{c}), \tag{6}$$

where:

$$b=-\left(\frac{l-0.28}{13}\right)^{7.13},\qquad c=-\left(\frac{w-4.41}{5.72}\right)^{3.79},$$

$$m=-\left(\frac{l-0.28}{13}\right)^{6.13},\quad n=-\left(\frac{w-4.41}{5.72}\right)^{2.79}.$$

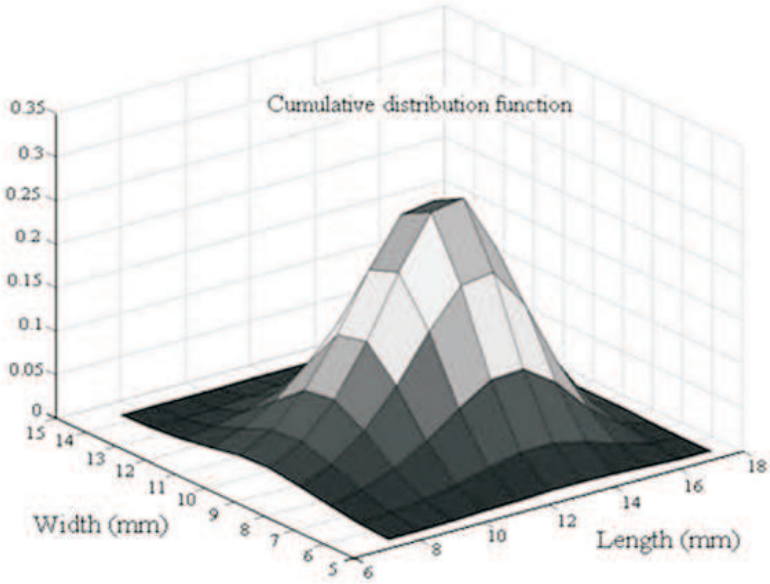


**Fig. 5.** Bivariable cumulative distribution function for raisin berries.

The results of relation No. 6 are graphically presented in Fig. 5. These results are beneficial in: selecting machinery, designing, validating and determining the holes sizes of raisin berries classifiers.

## CONCLUSIONS

1. The data of physical properties of raisin berries could be used for designing and developing raisin berries handling, storing, grading and packaging equipments.

2. There was a very good relationship between the mass and actual volume of raisin berries (model No. 9 in Table 2) with $R^2$ of 0.927 (the highest $R^2$ value among all models, from Nos 1 to 12 in Table 2).

3. The mass model based on geometric mean diameter (model No. 5 in Table 2) had the highest $R^2$ among all the models based on dimensional parameters (first classification).

4. The model which predicts the mass of raisin berries based on actual volume (model No. 9 in Table 2) had the highest $R^2$ among all the mass models based on volume (second classification).

5. The recommended equation in the first classification was the mass model based on the major diameter, whereas in the second classification, the mass model based on the volume of assumed ellipsoid shape was recommended.

6. From the economic and agricultural standpoint, the mass model No. 1 is recommended among the entire range of models (models Nos 1 to 12 in Table 2) as a nonlinear form: $M= 0.068\,e^{0.157L}$, $R^2 = 0.769$, because measuring only one parameter (major diameter) is time saving, simple and inexpensive.

7. The size distribution for the two dimensions (length and width) of raisin berries was followed as the Weibull distribution.

8. Raisin berries characterization as a function of two variables, namely width and length, made by the Weibull distribution is the best computational tool in giving practical results.

9. Finally, from the viewpoint of the possibility and potentiality at a plant or factory, the information of statistical and mass modelling of raisin berries can be used in the design and development of sizing and grading systems and other raisin post-harvest processing machines.

## REFERENCES

**Corzo O., Bracho N., Pereira A., and Va'squez A., 2008.** Weibull distribution for modeling air drying of coroba slices. Food Sci. Technol., 41, 2023-2028.

**Hassan-Beygi S.R., Ghanbarian D., and Farahmand D., 2010**. Prediction of saffron crocus corn mass by geometrical attributes. Sci. Hort., 124, 109-115.

**Karadeniz F., Durst R.W., and Wrolstad R.E., 2000.** Polyphenolic composition of raisins. J. Agric. Food Chem., 48, 5343-5350.

**Karathanos V.T., Karanikolas T., Kostaropoulos A.E., and Saravacos G.D., 1995.** Non enzymatic browning in air-drying of washed raisins. Develop. Food Sci., 37, 1057-1064.

**Khoshnam F., Tabatabaeefar A., Ghasemi Varnamkhasti M., and Borghei A.M., 2007.** Mass modeling of pomegranate (*Punica granatum* L.) fruit with some physical characteristics. Sci. Hort., 114, 21-26.

**Kim Y., Hertzler S.R., Byrne H.K., and Mattern C.O., 2008.** Raisins area low to moderate glycemic index food with a correspondingly low insulin index. Nutr. Res., 28, 304-308.

**Klenin N.I., Popov I.F., and Sakun V.A., 1986.** Agricultural Machines: Theory of Operation, Computation of Controlling Parameters and the Condition of Operation. Balkema Press, Rotterdam, the Netherlands.

**Lorestani A.N. and Tabatabaeefar A., 2006.** Modeling the mass of kiwi fruit by geometrical attributes. Int. Agrophysics, 20, 135-139.

**Malcolm E.W., Tappan J.H., and Sister F.E., 1986.** The size and shape of typical sweet potatoes. Trans. ASAE, 29, 678-682.

**Mandala I.G. and Daouaher M., 2004.** Effect of addition of low sugar raisin (LSR) on physical properties of cakes during storage. J. Food Process Eng., 27, 229-245.

**Miranda G., Berna A., Salazar D., and Mulet A., 2009.** Sulphur dioxide evolution during dried apricot storage. Food Sci. Technol., 42, 531-533.

**Mohsenin N.N., 1986.** Physical Properties of Plant and Animal Material. Gordon and Breach Press, New York, USA.

**Pateraki M., Dekanea A., Mitchell D., Lydakis D., and Magan N., 2007.** Influence of sulphur dioxide, controlled atmospheres and water availability on in vitro germination, growth and ochratoxin a production by strains of *Aspergillus carbonarius* isolated from grapes. Postharvest Biol. Technol., 44, 141-149.

**Rashidi M. and Seyfi K., 2008.** Modeling of kiwifruit mass based on outer dimensions and projected areas. Am.-Eur. J. Agric. Environ. Sci., 3, 26-29.

**Rojano A., Salazar R., and Galicia R., 2004.** Oat characterization by means of Weibull distribution. Proc. ASAE/CSAE Annual Int. Meeting, August 1-4, St. Joseph, MI, USA.

**Safwat M.A., 1971.** Theoretical prediction of volume, surface area, and center of gravity for agricultural products. Trans. ASAE, 14, 549-553.

**Stroshine R. and Hamann D., 1995.** Physical properties of agricultural materials and food products. FAO Press, West Lafayette, IN, USA.

**Tabatabaeefar A., Vefagh-Nematolahee A., and Rajabipour A., 2000.** Modeling of orange mass based on dimensions (in Farsi). Agric. Sci. Tech., 2, 299-305 .

**Tsakiris A., Bekatorou A., Psarianos C., Koutinas A.A., Marchant R., and Banat I.M., 2004.** Immobilization of yeast on dried raisin berries for use in dry white winemaking. Food Chem., 87, 11-15.

**Voicu H., Casandroiu T., and Tarcolea C., 2008.** Testing stochastic models for simulating the seeds separation process on the sieves of a cleaning system, and a comparison with experimental data. Agric. Conspectus Sci., 73(2), 95-101.