American-Eurasian J. Agric. & Environ. Sci., 3 (1): 26-29, 2008
ISSN 1818-6769

Modeling of Kiwifruit Mass Based on Outer Dimensions and Projected Areas

[1]Majid Rashidi and [2]Keyvan Seyfi

[1]Department of Agricultural Machinery,
Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran
[2]Varamin Agricultural Engineering Research Department, Agricultural Engineering Research Institute, Iran

Abstract: Fruits are often graded on the basis of size, but it may be more suitable and economical to develop a system which grades by mass. Therefore, a relationship between mass and size of fruits is needed. In this study, eighth models for predicting mass of kiwifruit (*Actinidia deliciosa*) from its outer dimensions and projected areas were identified. Models were divided into two classifications: 1- Single and multiple variable regressions of kiwifruit outer dimensions (first classification models). 2- Single and multiple variable regressions of kiwifruit projected areas (second classification models). The most common commercial variety of kiwifruit cv. Hayward was selected for this study. About 125 samples of kiwifruit were picked up at random and physical attributes of kiwifruit such as mass, outer dimensions and projected areas were measured. The results of the study indicated that second classification models had higher performance. However, second classification models need electronic systems with cameras, whereas first classification models, except multiple variable one, are used in the simple mechanical systems. The results of the study also indicated that in order to predict mass of kiwifruit based on outer dimensions, the mass model based on the major diameter as $M = 2.19\ a - 59.36$ with $R^2 = 0.74$ is recommended. Also, to predict mass of kiwifruit based on projected areas, the mass model based on the first projected area as $M = 4.06\ PA_1 - 19.35$ with $R^2 = 0.94$ can be suggested.

Key words: Mass models · outer dimensions · projected areas · kiwifruit · sorting

INTRODUCTION

Kiwifruit (*Actinidia deliciosa*) is a subtropical fruit and belongs to the family Actinidiaceae. Its spread from China to other parts of the world was rapid due to its ordinary climatic requirements [1]. It is considered as one of the best fruits due to its high nutritive value. Besides a rich source of vitamin C, kiwifruit contains a fair amount of nutrients (Calcium, Magnesium, Nitrogen, Phosphorus, Potassium, Iron, Sodium, Manganese, Zinc, Copper and Boron) and vitamins (A, B_1, B_2, B_6 and E). Kiwifruit contains 90-95% edible portion, 80-88% moisture, 1.0-1.6% acid, 0.7-0.9% oil, 0.11-1.2% protein, 0.45-0.74% ash, 1.1-3.3% fiber, 17.5% carbohydrate and 12-18% total soluble solids [1, 2].

The main commercial producers are Italy, New Zealand, Chili, France, Japan, USA, Iran, Greece, Spain and Portugal [1]. Iran produces 35,000 tons of kiwifruit and is ranked 7^{th} in the world (Iranian Ministry of Agriculture, Statistical Yearbook, 2005), but Iranian fruits are not exported because of variability in size and shape and lack of proper packaging.

Fruit shape is one of the most important quality parameters for evaluation by consumer preference. Consumers prefer fruits of equal weight and uniform shape [3]. Sorting of fruit can increase uniformity in size and shape, reduce packaging and transportation costs and also may provide an optimum packaging configuration. Sorting fruits manually is associated with high labour costs in addition to subjectivity, tediousness and inconsistency which lower the quality of sorting [4]. However, replacing human with a machine may still be questionable where the labour cost is comparable with the sorting equipment [5]. Studies on fruit sorting in recent years have focused on automated sorting strategies (eliminating human efforts) to provide more efficient and accurate sorting systems which improve the classification success or speed up the classification process [6, 7].

Physical characteristics of agricultural products are the most important parameters in design of sorting systems. Among these physical characteristics, mass, projected area and center of the gravity are the most important ones in sizing systems [8]. Other important parameters are outer dimensions (length, width and thickness) [9-11].

Corresponding Author: Dr. Majid Rashidi, Department of Agricultural Machinery, Faculty of Agriculture, Islamic Azad University, Takestan Branch, Iran

Sorting by weighing mechanism is recommended for the irregular shape products [12]. Since electrical mechanisms with strain gauges are expensive and mechanical mechanisms react poorly, dimensional method can be used. Therefore, modeling of kiwifruit mass based on outer dimensions and projected areas may be useful and applicable [11, 12]. The aim of this study was to determine optimum mass model (s) based on outer dimensions and projected areas for kiwifruit cv. Hayward. This information can be used to design and develop sizing systems.

MATERIALS AND METHODS

Plant material: The most common commercial variety of kiwifruit cv. Hayward was considered for this study and about 125 samples of mature kiwifruit were picked up at random (without consideration fruit shape) from their storage piles. Fruits were selected for freedom from defects by careful visual inspection, transferred to the laboratory and held at 5±1°C and 90±5% relative humidity until use.

Experimental procedure: In order to obtain required parameters for modeling of kiwifruit mass, outer dimensions of fruit i.e. three mutually perpendicular axes, major (a, longest intercept), intermediate (b, longest intercept normal to a) and minor (c longest intercept normal to a, b) were measured. Three mutually perpendicular axes were measured to 0.1 mm accuracy by a digital caliper. The mass of each kiwifruit was measured to 0.1 g accuracy on a digital balance. Besides, other physical properties of fruit i.e. volume and density were determined. Its volume was obtained by water displacement method. A kiwifruit was submerged into water and the volume of water displaced was measured.

Table 1: The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of the dimensions (a, b and c), projected areas (PA1, PA2 and PA3), mass, volume and density of kiwifruit cv. Hayward

Parameter	Min.	Max.	Mean	S.D.	C.V.(%)
Major diameter, a (mm)	45.1	77.5	60.3	7.6	12.7
Intermediate diameter, b (mm)	38.6	63.3	47.5	4.7	9.9
Minor diameter, c(mm)	33.2	53.1	42.6	3.4	7.9
First projected area, PA_1 (cm^2)	15.1	36.6	22.7	4.6	20.4
Second projected area, PA_2(cm^2)	13.1	29.6	20.3	3.7	18.2
Third projected area, PA_3 (cm^2)	9.8	22.5	16.0	2.7	16.7
Mass, M (g)	42.4	123.9	72.7	19.4	26.7
Volume, V (cm^3)	39.6	121.2	70.0	19.0	27.1
Density, ρ (g cm^{-3})	0.974	1.114	1.040	0.02	1.9

Water temperature was kept at 25°C. The density of each kiwifruit was then calculated from the mass divided by the measured volume. Also, three mutually perpendicular areas, PA_1, PA_2 and PA_3 were measured by an area meter, MK2 model from UK. Table 1 shows physical properties of kiwifruit cv. Hayward.

Regression models: A typical linear multiple regression model is shown in the following equation:

$$Y = a_1X_1 + a_2X_2 + \ldots + a_nX_n + a_0 \quad (1)$$

where:

Y = Dependent variable, for example mass

$X_1, X_2, \ldots, X_n$ = Independent variable, for example outer dimensions or projected areas

$a_0, a_1, a_2, \ldots, a_n$ = Regression coefficients

In order to estimate the kiwifruit mass from outer dimensions or projected areas; the following two classifications of mass models were suggested:

Regression of each and multiple variables of outer dimensions: In the first classification mass models, the independent variables are three mutually perpendicular diameters and the mass can be estimated as a function of one or three dimensions.

$$M = k_1a + k_2b + k_3c + k_0 \quad (2)$$

where:

M = Mass of kiwifruit, g

a, b, c = Major, intermediate and minor diameter, respectively, mm

k_0, k_1, k_2, k_3 = Regression coefficients

Regression of each and multiple variables of projected areas: In the second classification mass models, the independent variables are three mutually perpendicular areas and the mass can be estimated as a function of one or three projected areas.

$$M = k_1 PA_1 + k_2 PA_2 + k_3 PA_3 + k_0 \quad (3)$$

where:

M = Mass of kiwifruit, g

PA_1, PA_2, PA_3 = First, second and third projected areas, respectively, cm^2

k_0, k_1, k_2, k_3 = Regression coefficients

RESULTS

For mathematical describing linear mass models, all the data were subjected to linear regression analysis using the Microsoft EXCEL program (Version 2003). Table 2 shows a total of 8 linear regression mass models which have been categorized in two different classifications. The coefficient of determination (R^2) and Coefficient of Variation (C.V.) of all the mass models are also shown in Table 2.

Table 3 shows the mean R^2 values and the mean C.V. values in the two different classification models. The mean R^2 and C.V. value of the first classification models is 0.77 and 9.0%, respectively, while the means R^2 and C.V. value of the second classification models is 0.91 and 5.7%, respectively. Results show that the first classification models have lower mean R^2 value and higher mean C.V. value, while the second classification models have higher mean R^2 value and lower mean C.V. value. Therefore, the second classification models have higher performance.

DISCUSSION

First classification models: Among the first classification models (models No. 1, 2, 3 and 4 shown in Table 1), model 4 where all the three diameters were considered had the highest R^2 value and the lowest C.V. However, all three diameters must be measured for this model, which make the sizing mechanism more complicated and expensive. The mass model of kiwifruit based on three diameters (model 4) was given in Eq. (4).

$$M = 1.33\,a + 1.46\,b + 1.58\,c - 144.0,\ R^2 = 0.97 \quad (4)$$

Table 2: Linear regression mass models, coefficient of determination (R^2) and Coefficient of Variation (C.V.)

No	Models	R^2	C.V.(%)
1	$M = k_1 a + k_0$	0.74	9.9
2	$M = k_2 b + k_0$	0.71	10.6
3	$M = k_3 c + k_0$	0.64	11.7
4	$M = k_1 a + k_2 b + k_3 c + k_0$	0.97	3.7
5	$M = k_1 PA_1 + k_0$	0.94	5.0
6	$M = k_2 PA_2 + k_0$	0.92	5.5
7	$M = k_3 PA_3 + k_0$	0.80	8.9
8	$M = k_1 PA_1 + k_2 PA_2 + k_3 PA_3 + k_0$	0.97	3.2

Table 3: The mean R^2 and C.V. values in the two different classification mass models

Model	Mean R^2 value	Mean C.V. value (%)
First classification	0.77	9.0
Second classification	0.91	5.7

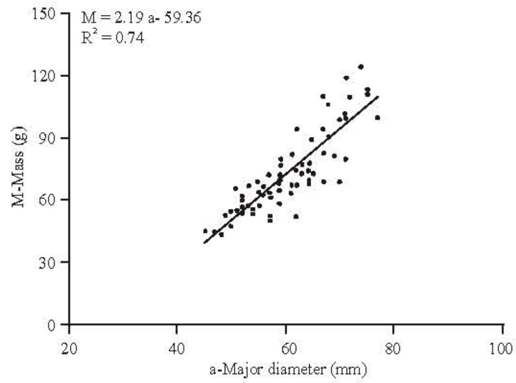

Fig. 1: Mass model of kiwifruit based on major diameter

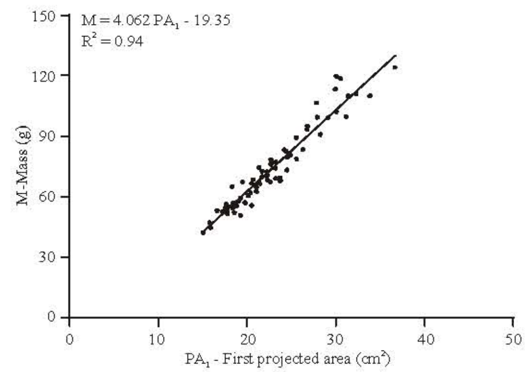

Fig. 2: Mass model of kiwifruit based on first projected areas

Among the models 1, 2 and 3, model 1 had the highest R^2 value and the lowest C.V. whereas, models 2 and 3 had lower R^2 values and higher C.V. Therefore, among the three single variable models, model 1 with major diameter as independent variable was selected as the best choice as shown in Fig. 1. The mass model of kiwifruit based on the major diameter (model 1) was given in Eq. (5).

$$M = 2.19\,a - 59.36,\ R^2 = 0.74 \quad (5)$$

Second classification models: Among the second classification models (models No. 5, 6, 7 and 8 shown in Table 1), model 8 where all the three projected areas were considered had the highest R^2 value and the lowest C.V. However, this model needs to have three cameras, in order to take all the three projected areas for each one kiwifruit, which make the sizing mechanism much more complicated and expensive. The mass model of kiwifruit based on three projected areas (model 8) was given in Eq. (6).

$$M = 1.74\,PA_1 + 2.09\,PA_2 + 1.57\,PA_3 - 34.18,\ R^2 = 0.97 \quad (6)$$

Among the models 5, 6 and 7, models 5 had the highest R^2 value and the lowest C.V. whereas, model 7 had the lowest R^2 value and the highest C.V. Therefore, among the three single variable models, model 5 with first projected area as independent variable was selected as the best choice as shown in Fig. 2. The mass model of kiwifruit based on the first projected areas (model 5) was given in Eq. (7).

$$M = 4.06\ PA_1 - 19.35,\ R^2 = 0.94 \qquad (7)$$

CONCLUSIONS

At the end it may be concluded that in order to predict mass of kiwifruit based on outer dimensions, the mass model based on the major diameter as M = 2.19 a-59.36 with $R^2 = 0.74$ is recommended. Also, to predict mass of kiwifruit based on projected areas, the mass model based on the first projected area as $M = 4.06\ PA_1 - 19.35$ with $R^2 = 0.94$ can be suggested.

ACKNOWLEDGMENTS

The financial support provided by the Varamin Agricultural Engineering Research Department of Agricultural Engineering Research Institute of Iran is gratefully acknowledged.

REFERENCES

1. Abedini, J., 2004. Post Harvest Physiology and Technology of Kiwifruit. Danesh-Negar Publishers, Tehran, Iran.
2. Mohammadian, M.A. and R.E. Teimouri, 1999. Agro, Management and Nutritious Value of Kiwifruit. Bank Melli Iran Publishers, Tehran, Iran.
3. Sadrnia, H., A. Rajabipour, A. Jafary, A. Javadi and Y. Mostofi, 2007. Classification and analysis of fruit shapes in long type watermelon using image processing. Intl. J. Agric. Biol., 1: 68-70.
4. Wen, Z. and Y. Tao, 1999. Building a rule-based machine-vision system for defect inspection on apple sorting and packing lines. Expert Systems with Application, 16: 307-313.
5. Kavdir, I. and D.E. Guyer, 2004. Comparison of artificial neural networks and statistical classifiers in apple sorting using textural features. Biosys. Eng., 89 (3): 331-344.
6. Kleynen, O., V. Leemans and M.F. Destain, 2003. Selection of the most effective wavelength bands for 'Jonagold' apple sorting. Postharvest Biology and Technology, 30: 221-232.
7. Polder, G., G.W.A.M. van der Heijden and I.T. Young, 2003. Tomato sorting using independent component analysis on spectral images. Real-Time Imaging, 9: 253-259.
8. Malcolm, E.W., J.H. Toppan and F.E. Sister, 1986. The size and shape of typical sweet potatoes. TRANS. ASAE, 19 (3): 678-682.
9. Carrion, J., A. Torregrosa, E. Orti and E. Molto, 1998. First result of an automatic citrus sorting machine based on an unsupervised vision system. In the Proceeding of Euro. Agr. Eng., 1998. Olsa. Paper 98-F-019.
10. Khojastapour, M., 1996. Design and fabrication method of potato sorting machine according to Iran conditions. M.Sc. thesis, Tehran University, Iran.
11. Marvin, J.P., G.M. Hyde and R.P. Cavalieri, 1987. Modeling potato tuber mass with tuber dimensions. TRANS. ASAE, 30 (4): 1154-1159.
12. Stroshine, R. and D.D. Hamann, 1994. Physical Properties of Agricultural Material and Food products. Course Manual, Purdue University, West Lafayette, Indiana.