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Classification and Analysis of Fruit Shapes in Long Type Watermelon Using Image Processing

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ABSTRACT

Fruit shape is one of the most important quality parameters for evaluation by consumer performance. Also misshapen fruits are usually rejected according to grading standards of fruit. This case is more considered for watermelons, because of large size and sensitive skin. This study was carried out to determine "detection algorithm" for misshapen watermelons. Physical characteristics of watermelon such as mass, volume, dimensions, density, spherical coefficient and geometric mean diameter were measured. Relations and correlations coefficient obtained between above characteristics for normal and non-standard fruit shape. It was found that weight of normal watermelon could be determined by image analysis with error 2.42%. In addition fruit shape of long type watermelon (Charleston Gray cv.) in front view was well-described by an ellipsoid model with $R^2 = 0.97$. Finally, the results indicated that length to width ratio and fruit area (2D) to background area ratio can be used to determine misshapen fruit.

Key Words: Physical characteristics; Fruits grading; Image analysis; Fruits shape; Quality; Watermelon

INTRODUCTION

Shape is one of the most important quality parameters of fruits. Fruit shape is affected by inheritance in addition to environmental growing conditions. In some fruits as watermelon, sensitive skin is cause of deformation in fruit shape when confronted with other object, also insufficient pollination results in misshapen melons. Recently, some researchers produced cube and pyramid watermelons by using this attribute.

Essentially, description of fruit shape is often necessary in horticulture research for a range of different purposes including cultivar descriptions in applications for plant variety rights or cultivar registers (Anonymous, 1997; Beyer *et al*., 2002; Hasnain *et al*., 2003), evaluation of consumer performance (Gerhard *et al*., 2001), investigating heritability of fruit shape traits (Currie *et al*., 2000; White *et al*., 2000), analysis stress distribution in the fruit skin (Considine & Brown, 1981), parameters using in packaging and shipping, or determining misshapen fruit in a cultivar, etc.

In other side official quality definitions for fruit or vegetables are hardly more than a rough ration on size and colour. Where the USDA grade standard for watermelons (USDA, 1997) specifies two shapes in three classifications (U.S. Fancy, U.S. No. 1, U.S. No. 2) based on visual comparison of fruit shape relative to reference drawing. These drawing serve as reference in classifying cultivars and normal for fruit shape. Ratings based on visual comparison do not require any equipment. However, the method is subjective and may depend on individual performing the rating. Also, rating scores may be biased by confounding variables such as fruit size or fruit colour. Therefore this procedure run very slowly and seam not sufficient for classification fruit in distribution terminals. Alternative approaches characterize fruit shape using indices calculated from outer dimensions of fruit (e.g. tomato, Ku *et al*., 1999; pear, White *et al*., 2000). Since based on direct measurement, the approach is objective and expected to be reproducible. Further, if measurement were performed by caliper, no sophisticated equipment would be needed; while useful in some applications, other applications may require a continuous description of the fruit shape.

The main objective of our research is to develop a fast procedure that allows an un-biased and reproducible quantitative description of fruit shape in watermelon that is based on image analysis and utilizing of standard software for data handling and analysis.

MATERIALS AND METHODS

Plant material. Mature watermelon fruit (Charleston Gray cv.) were obtained of commercial field located near Varamine, Tehran, Iran. Sixty watermelon samples were randomly (without consideration misshapen fruit) taken from the field. Fruit were selected for freedom from defects by careful visual inspection, transferred to the laboratory and held at 5 ± 1°C, 90 ± 5% relative humidity until use.

Primary investigation was showed that four types misshapen were detectable and separable in samples. The USDA standards for grades of watermelons were described two ill-shaped (misshapen) watermelons of long type: (i) bottleneck, (ii) gourdneck.

Fig. 1 shows four types misshapen fruit in long watermelons such as: (i) bottleneck, (ii) gourdneck, (iii) curvy shape and (iv) flattened.

Acquisition of fruit shape data. A standard colour camera, frame grabber, a PC and the ADOBE PHOTOSHOP™ Program are used for image analysis to obtain digitized fruit shape. Images were taken from above fruits. The x-coordinate defined the position of the fruits length and y-coordinate the position on width (Fig. 2).

Physical properties of normal fruits. In order to obtain required parameters for detection algorithm and calibration images, physical properties e.g. three mutually perpendicular axes, major (a, longest intercept), intermediate (b, longest intercept normal to a) and minor (c, longest intercept normal to a & b) mass, volume were measured. Table I shows some physical properties of watermelon in Charleston Gray cultivar.

The area is computed from the 2D image of watermelon and so an estimate of the watermelon's mass/volume is achieved (Fig. 3). The highest degree of correlation was found between area measured by image analysis and mass measured using a scale:

$$M = 0.8638A^{1.4114} \qquad R^2 = 0.99 \qquad (1).$$

Where

A is the area (cm^2) and M is the mass (g) [Eq. (1)]. Using the above relationship, the mean absolute error of weighing a watermelon by determining the area using image analysis would be 2.42% (approximately 156 g for 6000 g watermelon). Thus, size and size distribution or mass and mass distribution can be recorded automatically with a high degree of accuracy by image analysis.

For mathematical describing of normal shape long type watermelon, image data was subjected to regression analysis. Non-linear regression based ellipsoid shape were carried out using the SPSS program package (SPSS, Version 8.0, SPSS Inc., Chicago, IL, USA):

$$A_{est} = K\,\frac{a \times b}{4} \qquad (2)$$

Where

A_{est} is estimated area (cm^2), a is the longest intercept and b is the longest intercept normal to a. Parameter K was calculated with using initial value 3.1415 and after run the model K was achieved 3.3347 on R-square 0.97. Fig. 4 shows comparison of measured and calculated (from regression equation).

Detecte misshapen fruits. A simple method of judging based on ellipsoid shape of long watermelon was used for detecting of some misshapen fruits. Ellipsoid ratio (E) shows fruit area to background area, which is measured for all samples. This ratio for normal shape long watermelon on based of Eq. (2) is about 5.25. Another parameter, aspect ratio, was used to detect flattened fruits. Aspect ratio was defined by Eq. (3) (Mohsenin, 1986):

Fig. 1. Four types misshapen fruit in long watermelons (i) bottlenecks, (ii) gourdnecks, (iii) curvy shape, and (iv) flattened

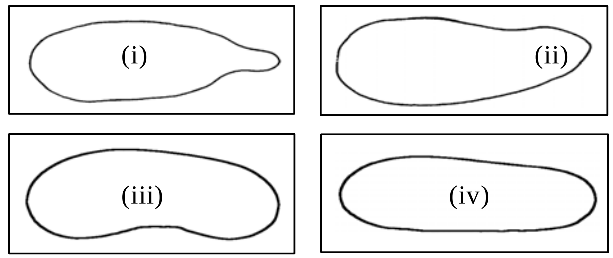


Fig. 2. Method for acquisition of fruit shape data

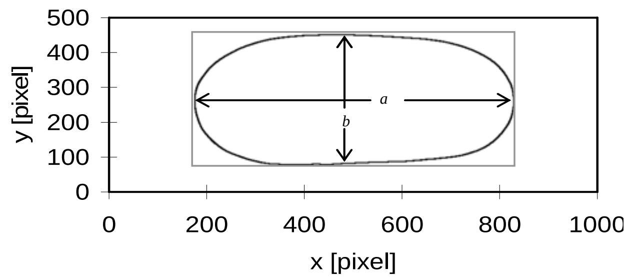


Fig. 3. Relationship between the area measured by image analysis and weight measured using a scale for watermelons of different size

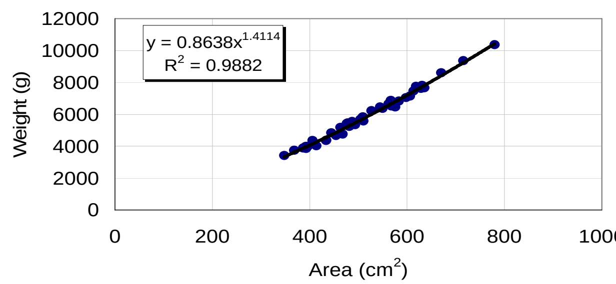
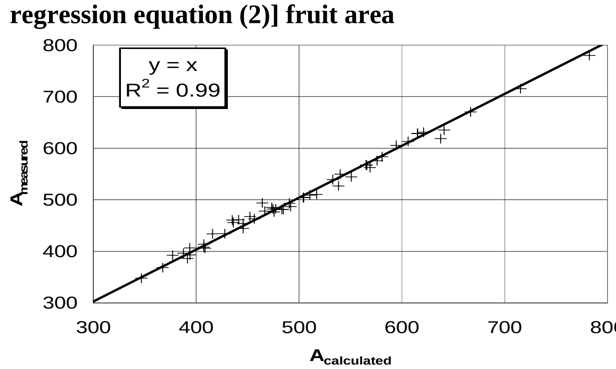


Fig. 1. Comparison of measured and calculated [from regression equation (2)] fruit area



$$Aspect\ ratio = \frac{Major\,diameter\,(a)}{Intermediat\,diameter\,(b)} \qquad (3)$$

RESULTS AND DISCUSSION

Table II shows E values for bottleneck, gourdneck, curvy and normal shapes. The mean E value of normal fruits is 5.27, while the means E value of curvy shapes, gourdnecks and bottlenecks are respectively 4.4, 3.7 and 2.5. It is found that E values can be considered as a separated indicator. Fig. 5 shows line 1:4.5 can separate normal fruits from above three misshapen fruits.

Table III shows the mean values, SD and CV of aspect ratio for flattened and normal fruits. The mean aspect ratio of normal fruits is 2.10, while the mean aspect ratio of flattened fruits is 2.57. Results show that aspect ratio for normal fruits is ranged from 2.52 to 2.62 and for flattened fruits from 1.83 to 2.20. Therefore line 1:2.5 can used as a separator of normal fruits from flattened fruits. Fig. 5 shows the separated line for flattened fruits.

CONCLUSIONS

Sorting and quality rating is normally done by experts. In consequence it is subjective and the results show inter and intra individual variations. To achieve objective and reproducible results, a simple assessment based on measured image data and regression analysis is proposed. Significantly differences in fruit shape parameters e.g. ellipsoid and aspect ratio were detected between normal and misshapen fruits. This method can be adapted and applied to other product too.

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Table III. The mean, SD, and CV of the dimensions (a, b and c), mass and volume of Charleston Gray cultivar

Parameters	Dimensions			Mass	Volume	Density
	A (mm)	B (mm)	C (mm)	(gr)	(cm^3)	(gr/cm^3)
Large	177.5	183.45	395.65	7343.5	7693.5	0.956
Medium	163.3	167.1	356.1	5395	5641.5	0.9561
Small	154.4	159.1	313.5	4289.7	4482.5	0.957
Mean	165	170	352	5730	5998	0.956
SD	12.38	12.84	43.37	1517	1611	0.010
CV%	7.48	7.54	12.31	26.47	26.86	1.07

Table III The mean, SD, and CV of E value of curvy shapes, gourdnecks, bottlenecks, and normal shapes

Shape	SD	CV%	Mean	Maximum	Minimum
Bottleneck	0.24	10.43	2.5	2.1	2.3
Gourdneck	0.196	5.9	3.7	3.2	3.3
Curvy	0.18	4.2	4.4	4.01	4.2
Normal	0.331	6.27	5.87	4.72	5.27

Table III. The mean, SD, and CV of E value of flattened and normal shapes

Shape	SD	CV%	Mean	Minimum	Maximum
flattened	0.12	4.67	2.57	2.52	2.62
Normal	0.19	7.09	2.1	1.83	2.2

Fig. 5. Separator line of normal fruits from three misshapen fruits (bottlenecks, gourdnecks, curvy shape)

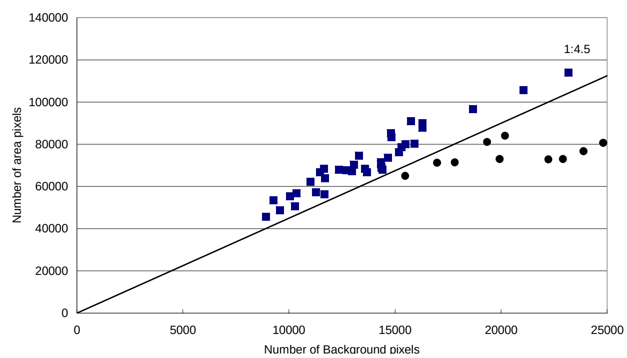

Fig. 2. Separator line of normal fruits from flattened fruits