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Classification of Fruit Shape in Kiwifruit Applying the Analysis of Outer Dimensions

MAJID RASHIDI[1] AND KEYVAN SEYFI
Varamin Agricultural Engineering Research Department, Agricultural Engineering Research Institute, P.O. Box 31585-845, Karaj, Iran
[1]Corresponding author's e-mails: majidrashidi81@yahoo.com; m.rashidi@aeri.ir

ABSTRACT

Fruit shape is one of the most important quality parameters for evaluation by customer preference. Additionally, misshaped fruits are generally rejected according to sorting standards of fruit. This study was carried out to determine quantitative classification algorithm for fruit shape in kiwifruit (*Actinidia deliciosa*). Physical attributes of kiwifruit such as outer dimensions, mass, volume and density were measured. To achieve objective and reproducible results, an assessment based on outer dimensions analysis was proposed and significant differences in fruit shape parameters i.e., length to width ratio (aspect ratio) and width to thickness ratio (ellipsoid ratio) were detected between fruit shapes. Finally the results of the study indicated that aspect ratio and ellipsoid ratio can be used effectively to determine normal and misshapen fruit.

Key words: Fruit grading; Fruit sorting; Physical characteristics; Kiwifruit

INTRODUCTION

Kiwifruit 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 (Abedini, 2004). 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 vitamins (A, B_1, B_2, B_6 & 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 (Mohammadian & Teimouri, 1999; Abedini, 2004).

The main commercial producers are Italy, New Zealand, Chili, France, Japan, USA, Iran, Greece, Spain and Portugal (Abedini, 2004). Iran produces 35,000 tons of kiwifruit and is ranked 7th in the world, but Iranian kiwifruit 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 (Sadrnia *et al.*, 2007). Consumers prefer fruits of equal weight and uniform shape (Waseem *et al.*, 2002). Classification of fruit can increase uniformity in size and shape, reduce packaging and transportation costs and also may provide an optimum packaging configuration (Tabatabaeefar *et al.*, 2000). Fruit shape is affected by inheritance in addition to environmental growing conditions (Sadrnia *et al.*, 2007). Description of fruit shape is often necessary in horticultural research for a range of different purposes such as cultivar descriptions in applications for plant variety rights or cultivar registers (Anonymous, 1997; Beyer *et al.*, 2002; Hasnain *et al.*, 2003), evaluation of consumer preference (Gerhard *et al.*, 2001), investigating heritability of fruit shape traits (Currie *et al.*, 2000; White *et al.*, 2000), stress distribution analysis in the fruit skin (Considine & Brown, 1981) and determining misshapen fruit (Sadrnia *et al.*, 2007).

On the other hand, the official quality definitions for fruit or vegetable are scarcely more than a measure on size and color. The USDA grade standard specifies shapes based on visual comparison of fruit shape relative to reference drawing. These drawing serve as a reference in classifying fruit shape. Ratings based on visual comparison don't require any equipment. However the method is subjective and may depend on person who executes the rating. Moreover, rating scores may be biased by confusing variables such as fruit size or color (Sadrnia *et al.*, 2007). As a result, this process runs very slowly and seems not satisfactory for fruit classification in distribution terminals.

Substitute approaches describe shape using indices calculated from outer dimensions of fruit e.g., tomato (Ku *et al.*, 1999), pear (White *et al.*, 2000) and watermelon (Sadrnia *et al.*, 2007). Since such approaches are based on direct measurement, they are objective and reproducible. In addition, necessary measurements can be performed by a caliper and no complicated equipment is needed. Therefore, present study was designed to develop a rapid procedure that permits an un-biased and reproducible quantitative description of fruit shape in kiwifruit, which is based on analysis of outer dimensions of fruit.

MATERIALS AND METHODS

Plant material. The most common commercial variety of kiwifruit cv. Hayward was considered for this study and about 100 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.

Primary investigation based on longitudinal and latitudinal cross section shapes indicated that six shapes were detectable and separable in samples. Fig. 1 shows six fruit shapes in kiwifruit such as: (I) short, (II) medium, (III) tall, (IV) round, (V) elliptical and (VI) flattened.

Experimental procedure. In order to obtain required parameters for fruit shape detection algorithm, 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 caliper. In addition, other physical properties of fruit i.e., mass and volume were measured. The mass of each kiwifruit was measured to 0.1 g accuracy on a digital balance. Its volume was obtained by water displacement method. A kiwifruit was submerged into water and the volume of water displaced was measured. Water temperature was kept at 25°C. The bulk density of each kiwifruit was then calculated from the mass divided by the measured volume. Table I shows some physical properties of kiwifruit in Hayward variety.

Fruit shape detection. An easy technique of judging based on analysis of outer dimensions of kiwifruit was used for detecting shape of fruit. Aspect ratio (A.R.) was used to detect short, medium and tall fruits. Aspect ratio is defined by Equation 1 (Mohsenin, 1986; Sadrnia *et al.*, 2007):

$$A.R. = a / b, \quad (A.R. \geq 1.0) \qquad (1)$$

Where

A.R. = aspect ratio, non-dimensional.

a, b = major and intermediate diameter, respectively (mm).

Another parameter, ellipsoid ratio (E.R.), was used to detect flattened fruits. Ellipsoid ratio is defined by Equation 2 (Mohsenin, 1986):

$$E.R. = b / c, \quad (E.R. \geq 1.0) \qquad (2)$$

Where

E.R. = ellipsoid ratio, non-dimensional.

b, c = intermediate and minor diameter, respectively (mm).

For mathematical description of normal shape and misshapen kiwifruit, outer dimensions of fruits, aspect ratio values, and ellipsoid ratio values were subjected to statistical analysis using Microsoft EXCEL program (Version, 2003).

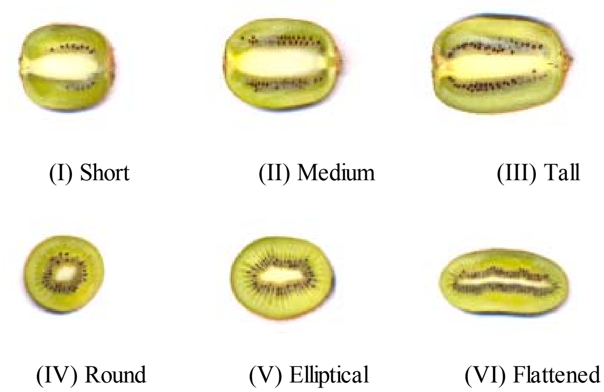
RESULTS

Short, medium and tall fruit shapes. Statistical results show that the mean aspect ratio value of medium fruits is 1.29, while the mean aspect ratio values of short and tall fruits are 1.13 and 1.48, respectively. Results also show that aspect ratio for medium fruits ranged from 1.20 to 1.40, while this ratio for short fruits ranged from 1.0 to 1.19 and for tall fruits from 1.41 to 1.63 (Table II). Therefore, the aspect ratio lines 1:1.19 and 1:1.41 can be used as separating indicators. The aspect ratio lines 1:1.19 and 1:1.41 can separate medium fruits from short and tall ones (Fig. 2).

Table I. The mean values, S.D., and C.V. of the dimensions (a, b, and c), mass, volume, and density of kiwifruit

Parameter	Mean	Minimum	Maximum	S.D.	C.V.
a (mm)	60.3	45	77	7.65	12.68
b (mm)	47.5	38	63	4.69	9.87
c (mm)	42.6	33	53	3.35	7.87
Mass (g)	72.7	42.4	123.9	19.44	26.74
Volume (cm^3)	70.0	39.6	121.2	18.95	27.07
Density ($g\ cm^{-3}$)	1.040	0.974	1.114	0.02	1.92

Fig. 1. Six fruit shapes in kiwifruit based on longitudinal and latitudinal cross section of fruits



Round, elliptical and flattened fruit shapes. Statistical results of the study also indicate that the mean ellipsoid ratio of round and elliptical fruits are 1.06 and 1.16, respectively while the mean ellipsoid ratio of flattened fruits was 1.35. Results also indicated that ellipsoid ratio value for round fruits ranged from 1.0 to 1.09 and for elliptical fruits from 1.10 to 1.23, while ellipsoid ratio for flattened fruits ranged from 1.30 to 1.43 (Table III). Thus, the ellipsoid ratio lines 1:1.09 and 1:1.30 can be employed as separating indicators. Fig. 3 demonstrated the ellipsoid lines 1:1.09 and 1.30 can separate elliptical fruits from round and flattened fruits.

Normal and misshapen fruit shapes. Results of the study demonstrated that aspect ratio value for normal fruit shapes ranged from 1.20 to 1.40 and ellipsoid ratio value for them ranged from 1.0 to 1.23 (Table IV). Therefore, aspect ratio lines 1:1.19 and 1:1.41, together with the ellipsoid ratio lines 1:1.0 and 1:1.23 can be used as separator of normal fruits from misshapen fruits. Aspect ratio lines 1:1.19 and 1:1.41, in conjunction with the ellipsoid ratio lines 1: 1.0 and 1: 1.23 can separate normal fruits from misshapen fruits (Fig. 4). Results of the study also indicated that aspect ratio value for small kind of misshaped fruits was less than or equal to 1.19 ($A.R \leq 1.19$) and for tall kind of misshaped fruits is more than or equal to 1.41 ($A.R \geq 1.41$). Moreover, ellipsoid

Fig. 2. Major diameter versus intermediate diameter and separator lines of medium fruits from short and tall fruits

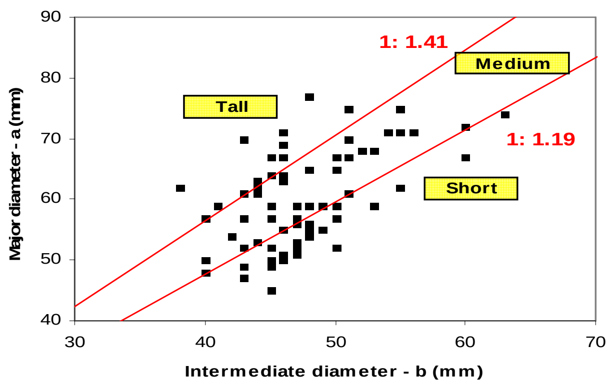


Fig. 3. Intermediate diameter versus minor diameter and separator line of flattened fruits from round and elliptical fruits

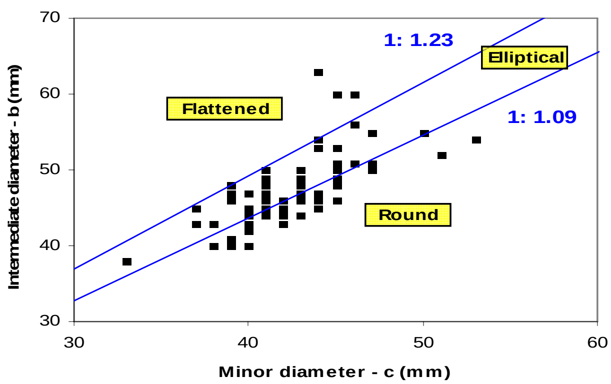
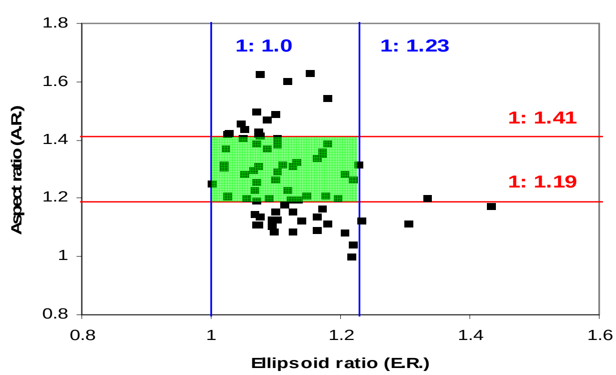


Fig. 4. Aspect ratio versus ellipsoid ratio and separator lines of normal fruits from misshapen fruits



ratio value for flattened kind of misshapen fruits is more than or equal to 1.30 (E.R ≥ 1.30).

DISCUSSION

In this study, the outer dimensions of kiwifruit i.e., major, intermediate and minor diameters, were analyzed to classify fruit shape. The study indicated that six shapes i.e., short (misshapen), medium (normal), tall (misshapen), round (normal), elliptical (normal) and flattened (misshapen), were detectable and separable in fruits. The results of the study also indicated that among all kinds of misshapen fruits, number of short kind followed by tall kind was the highest, while number of flattened kind was the lowest. In addition, amount of normal shape fruits and all kinds of misshapen fruits were in the order of normal (50.0%) > short (28.0%) > tall (18.0%) > flattened (4.0%). These results are in line with those of Sadrnia *et al.* (2007) who reported that aspect ratio and ellipsoid ratio can be used effectively to determine normal and misshapen fruit, and quite in agreement with those of Ku *et al.* (1999) and White *et al.* (2000) who concluded that classification of fruit shape using indices calculated from outer dimensions of fruit can increase uniformity in size and shape.

Table II. The mean values, S.D., and C.V. of aspect ratio of short, medium, and tall shapes of kiwifruit (shapes based on longitudinal cross section of fruits)

Shape	Mean	Minimum	Maximum	S.D.	C.V.
Short	1.13	1.0	1.19	0.05	4.11
Medium	1.29	1.20	1.40	0.06	4.84
Tall	1.48	1.41	1.63	0.08	5.31

Table III. The mean values, S.D., and C.V. of ellipsoid ratio of round, elliptical, and flattened shapes of kiwifruit (shapes based on latitudinal cross section of fruits)

Shape	Mean	Minimum	Maximum	S.D.	C.V.
Round	1.06	1.0	1.09	0.03	2.48
Elliptical	1.16	1.10	1.23	0.04	3.53
Flattened	1.35	1.30	1.43	0.07	4.93

Table IV. Description, aspect ratio range, and ellipsoid ratio range of normal shape and misshapen kiwifruit

Shape	Description	Aspect ratio range	Ellipsoid ratio range
Normal	Medium and not flattened	1.20 – 1.40	1.0 – 1.23
Misshapen	Short	≤ 1.19	-----
Misshapen	Tall	≥ 1.41	-----
Misshapen	Flattened	-----	≥ 1.30

CONCLUSIONS

To achieve objective and reproducible results, an assessment based on outer dimensions analysis was proposed and significant differences in fruit shape parameters i.e., aspect ratio and ellipsoid ratio were detected between normal and misshapen fruit shapes. Finally, aspect ratio and ellipsoid ratio were effectively used to determine normal and misshapen fruit. This method can also be adapted and applied to other products with the same physical features.

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