

Fruit Shape Classification in Cantaloupe Using the Analysis of Geometrical Attributes

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Abstract: Fruit shape is one of the most important physical properties and quality parameters of all agricultural produce. Moreover, classification of fruit shape is vital in evaluating agricultural produce, meeting quality standards and increasing market value. It is also helpful in planning packaging, transportation and marketing operations. Misshapen fruits are generally rejected according to sorting standards of fruit. Therefore, this study was carried out to establish quantitative algorithm for classification of fruit shape in cantaloupe (*Cucumis melo*) and to determine detection algorithm for misshapen cantaloupes. Geometrical attributes and some physical characteristics of cantaloupe such as length, major diameter, minor diameter, mass, volume and density were measured. To achieve objective and reproducible results, an assessment based on geometrical attributes analysis was proposed. Significant differences in fruit shape parameters i.e. length to lateral geometric mean diameter ratio (roundness ratio) and major diameter to minor diameter ratio (ellipsoid ratio) were detected between fruit shapes. The results of the study indicated that roundness ratio and ellipsoid ratio can be used successfully to classify fruit shape and determine normal and misshapen fruit.

Key words: Cantaloupe • Fruit shape • Classification • Geometrical attributes

INTRODUCTION

Cantaloupe (*Cucumis melo*) is a subtropical fruit and belongs to the family Cucurbitaceae. Its spread from Italy to other parts of the world was rapid due to its ordinary climatic requirements. Cantaloupe is considered as one of the best fruits due to its high nutritive value. Besides a rich source of vitamin A and C, it contains a fair amount of nutrients (Calcium, Magnesium, Phosphorus, Potassium and Iron) and vitamins (B₁, B₃, B₅ and B₆). Cantaloupe contains 55-59% edible portion, 87-92% moisture, 0.1-0.2% oil, 0.60-1.0% protein and 6.3-10.3% total soluble solids [1].

Iran produces 750,000 tons of cantaloupes, but Iranian cantaloupe is not exported because of variability in size, shape and lack of proper packaging. Fruit shape is one of the most important physical properties and quality parameters of all agricultural produce [2]. Consumers prefer fruits of equal weight and uniform shape. Misshapen fruits are generally rejected according to sorting standards of fruit [3]. Classification of fruit can increase uniformity in size and shape, reduce packaging

and transportation costs and also may provide an optimum packaging configuration [4]. Moreover, classification of fruit shape is vital in evaluating agricultural produce, meeting quality standards and increasing market value. It is also helpful in planning packaging, transportation and marketing operations [5].

Fruit shape is affected by genotypic variability in addition to environmental growing conditions [6]. 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 [7, 8], evaluation of consumer preference [9], investigating heritability of fruit shape traits [6, 10], stress distribution analysis in the fruit skin [11], determining misshapen fruit in a cultivar [12], effect of orientation on the fruit size [13] and estimation of fruit volume and weight [5].

On the other hand, the official quality definitions for fruit or vegetable are scarcely more than a measure on size and color. The United States Department of Agriculture (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 [12]. As a result, this process runs very slowly and seems not satisfactory for fruit classification in distribution terminals. Substitute approaches describe fruit shape using indices calculated from geometrical attributes of fruit e.g. watermelon [5], pear [6], tomato [14] and kiwifruit [15]. 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.

The present study was thus planned to develop a rapid procedure that permits an un-biased and reproducible quantitative classification of fruit shape and to determine normal and misshapen fruit in cantaloupe.

MATERIALS AND METHODS

Plant Material: The most common commercial variety of cantaloupe cv. Samsouri was considered for this study and about 120 samples of mature cantaloupe 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 $9 \pm 5\%$ relative humidity until use.

Primary investigation based on longitudinal and lateral cross section shapes indicated that five shapes were detectable and separable in samples. Fig. 1 shows five fruit shapes in cantaloupe such as: (I) oblate, (II) regular, (III) oblong, (IV) round and (V) elliptical.

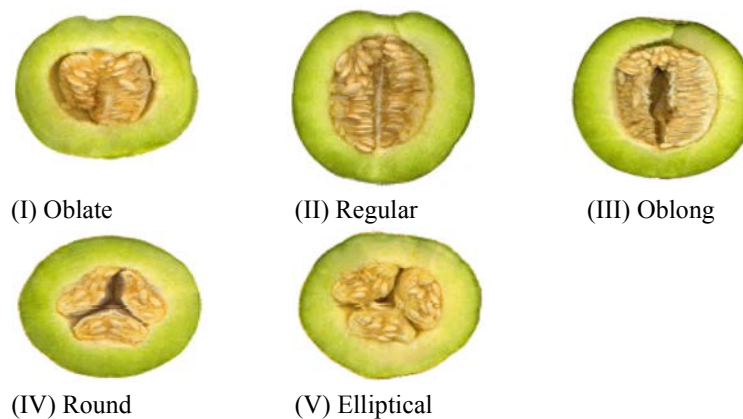


Fig. 1: Five fruit shapes in cantaloupe based on longitudinal and lateral cross section of fruits

Experimental Procedure: In order to obtain required parameters for fruit shape detection algorithm, three mutually perpendicular axes, length (L), major diameter (D_1 ; longest intercept normal to L) and minor diameter (D_2 ; longest intercept normal to L and D_1) as shown in Fig. 2 were measured using a digital caliper with ± 1.0 mm accuracy. In addition, some physical properties of fruit i.e. mass and volume were measured. The mass of each cantaloupe was measured using a three-digit precision scale with ± 5.0 g accuracy. The volume of each cantaloupe was measured using the water displacement method. Each cantaloupe was submerged in a container full of water. The volume of the displaced water was directly measured using a 1000 ml capacity graduated cylinder. Water temperature was kept at 25°C. The density of each cantaloupe was then calculated from the mass divided by the measured volume. Table 1 shows geometrical attributes and some physical properties of cantaloupe in Samsouri variety.

Fruit Shape Detection: An easy technique of judging based on analysis of geometrical attributes of cantaloupe was used for detecting shape of fruit. Roundness ratio was used to detect oblate, regular and oblong fruits. Roundness ratio is defined by equation 1 [16, 17]:

$$R.R. = \frac{L}{\sqrt{D_1 D_2}} \quad (1)$$

where:

R.R. = Roundness ratio, non-dimensional

L = Length, mm

$\sqrt{D_1 D_2}$ = Lateral geometric mean diameter, mm

Another parameter, ellipsoid ratio, was used to detect round and elliptical fruits. Ellipsoid ratio is defined by equation 2 [16, 17]:

Table 1: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of the geometric attributes, mass, volume and density of cantaloupe cv. Samsouri

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Longitudinal diameter (mm)	95	185	134	18.8	14.0
Major lateral diameter (mm)	106	205	147	21.3	14.4
Minor lateral diameter (mm)	101	190	140	20.5	14.7
Mass (g)	510	3380	1397	549	39.32
Volume (cm ³)	538	3654	1528	640	41.86
Density (g cm ⁻³)	0.776	1.070	0.924	0.06	6.34

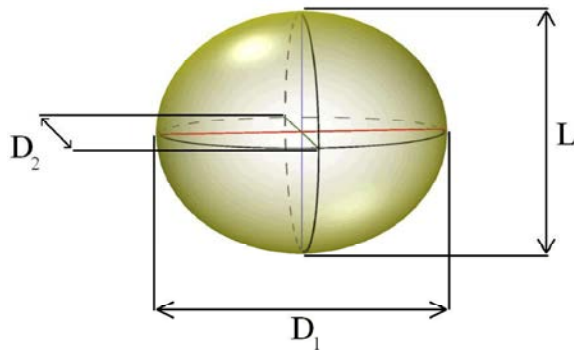


Fig. 2: The dimensions of a cantaloupe

$$E.R. = \frac{D_1}{D_2} \quad (2)$$

where:

E.R. = Ellipsoid ratio, non-dimensional

D₁ = Major diameter, mm

D₂ = Minor diameter, mm

For mathematical describing of fruit shape and to determine detection algorithm for normal shape and misshapen cantaloupe, geometrical attributes of fruits, roundness ratio values and ellipsoid ratio values were subjected to statistical analysis using the Microsoft EXCEL (Version 2003).

RESULTS

Oblate, Regular and Oblong Fruit Shapes: Statistical results show that the mean roundness ratio value of regular fruits is 0.97, while the mean roundness ratio values of oblate and oblong fruits are 0.86 and 1.14, respectively. Results also show that roundness ratio value for regular fruits ranged from 0.90 to 1.10, while roundness ratio value for oblate fruits ranged from 0.74 to 0.89 and for oblong fruits from 1.13 to 1.18 (Table 2). Therefore, the roundness ratio lines 1: 0.90 and 1: 1.10 can be used as separating indicators. Fig. 3 demonstrates the roundness ratio lines 1: 0.90 and 1: 1.10 can separate regular fruits from oblate and oblong fruits.

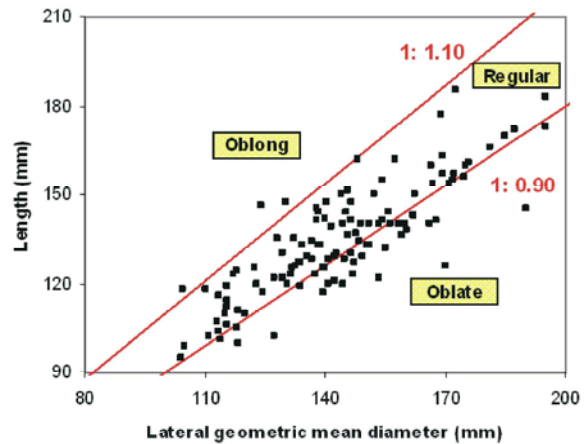


Fig. 3: Length versus lateral geometric mean diameter and separator lines of regular fruits from oblate and oblong fruits

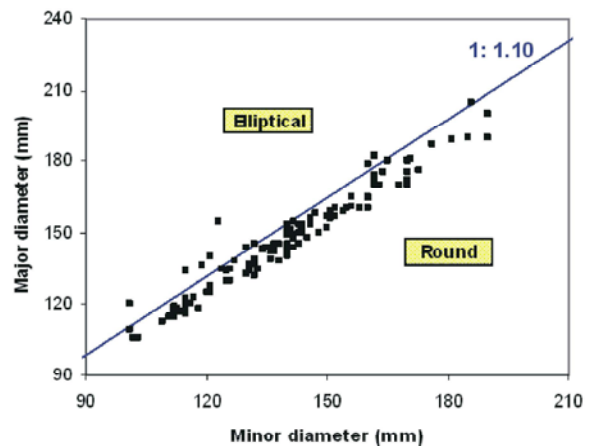


Fig. 4: Major diameter versus minor diameter and separator line of round fruits from elliptical fruits

Round and Elliptical Fruit Shapes: Statistical results of the study also indicate that the mean ellipsoid ratio value of round fruits is 1.04, while the mean ellipsoid ratio value of elliptical fruits is 1.15. Results also indicate that ellipsoid ratio value for round fruits ranged from 1.0 to 1.09, while ellipsoid ratio value for elliptical fruits ranged from 1.10 to 1.26 (Table 3). Therefore, the ellipsoid ratio

Table 2: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of the roundness ratio of oblong, regular and oblate shapes of cantaloupe cv. Samsouri (shapes based on longitudinal cross section of fruits)

Shape	Minimum	Maximum	Mean	S.D.	C.V. (%)
Oblate	0.74	0.89	0.86	0.04	4.35
Regular	0.90	1.10	0.97	0.05	5.29
Oblong	1.13	1.18	1.14	0.03	2.36

Table 3: The mean values, standard deviation (S.D.) and coefficient of variation (C.V.) of the ellipsoid ratio of round and elliptical shapes of cantaloupe cv. Samsouri (shapes based on lateral cross section of fruits)

Shape	Minimum	Maximum	Mean	S.D.	C.V. (%)
Round	1.0	1.09	1.04	0.02	2.27
Elliptical	1.10	1.26	1.15	0.05	3.53

Table 4: Description, roundness ratio range and ellipsoid ratio range of normal shape and misshapen cantaloupe cv. Samsouri

Shape	Description	Roundness ratio range	Ellipsoid ratio range
Normal	Round and regular	0.90 – 1.10	1.0 – 1.10
Misshapen	Oblate	< 0.90	----
Misshapen	Oblong	> 1.10	----
Misshapen	Elliptical	----	> 1.10

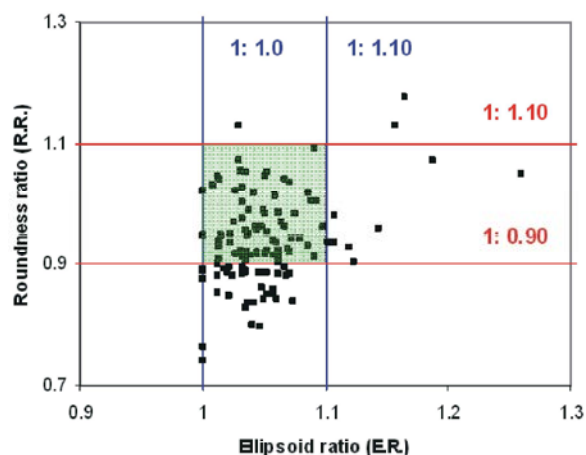


Fig. 5: Roundness ratio versus ellipsoid ratio and separator lines of normal fruits from misshapen fruits

line 1: 1.10 can be employed as separating indicator. Fig. 4 demonstrates the ellipsoid line 1: 1.10 can separate round fruits from elliptical fruits.

Normal and Misshapen Fruit Shapes: Results of the study show that roundness ratio value for normal fruit shapes ranged from 0.90 to 1.10 and ellipsoid ratio value for them ranged from 1.0 to 1.10 (Table 4). Therefore, roundness ratio lines 1: 0.90 and 1: 1.10, together with the ellipsoid ratio lines 1: 1.0 and 1: 1.10 can be used as separator of normal fruits from misshapen fruits. Fig. 5 shows the roundness ratio lines 1: 0.90 and 1: 1.10 in conjunction with the ellipsoid ratio lines 1: 1.0 and 1: 1.10

can separate normal fruits from misshapen fruits. Results of the study also indicated that roundness ratio value for oblate kind of misshapen fruits is less than 0.90 (R.R. < 0.90) and for oblong kind of misshapen fruits is more than 1.10 (R.R. > 1.10). Moreover, ellipsoid ratio value for ellipsoid kind of misshapen fruits is more than 1.10 (E.R. > 1.10).

DISCUSSION

In this study, the geometrical attributes of cantaloupe, i.e. length, major diameter and minor diameter, were analyzed to classify fruit shape. The study indicated that five shapes, i.e. oblate (misshapen), round (normal), oblong (misshapen), round (normal) and elliptical (misshapen), were detectable and separable in fruits. The results of the study also indicated that among all kinds of misshapen fruits, number of oblate kind was the highest, while number of oblong kind was the lowest. In addition, amount of normal shape fruits and all kinds of misshapen fruits were in the order of normal (60.0%) > oblate (31.0%) > elliptical (7.0%) > oblong (2.0%). These results are in line with those of Sadrnia *et al.* [12] and Rashidi and Seyfi [15] who reported that fruit shape parameters can be used effectively to determine normal and misshapen fruit and quite in agreement with those of Kavdir and Guyer [2], Koc [5], White *et al.* [6] and Ku *et al.* [14] who concluded that classification of fruit shape using indices calculated from geometrical attributes of fruit, can increase uniformity in size and shape.

CONCLUSIONS

Primary investigation based on longitudinal and lateral cross section shapes indicated that five shapes were detectable and separable in samples. To achieve objective and reproducible results, a judgment based on geometrical attributes analysis was proposed and significant differences in fruit shape parameters i.e. roundness ratio and ellipsoid ratio were detected between five fruit shapes. Finally, roundness ratio and ellipsoid ratio were effectively used to classify fruit shape and 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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