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Classification of Apple Size and Shape Based on Mass and Outer Dimensions

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Abstract: Fruit size and shape are the most important quality parameters. Moreover, misshapen fruits are usually rejected according to sorting standards. This study was conducted to determine quantitative classification algorithm for apple size and shape. To reach objective and reproducible results, mass and outer dimensions (height and diameter) of apple were measured and an assessment based on mass and outer dimensions was proposed. Results of the study showed that mass and aspect ratio (height to diameter ratio) of apple can be used successfully to classify apple size and shape.

Key words: Apple · Sorting · Grading · Shape · Mass · Outer dimensions

INTRODUCTION

The apple is the pomaceous fruit of the apple tree, species *Malus domestica* in the rose family (*Rosaceae*). It is one of the most widely cultivated tree fruits. There are more than 7500 known cultivars of apples [1]. At least 55 million tones of apples were grown worldwide in 2005, with a value of about $10 billion. China produced about 35% of this total. The United States is the second-leading producer, with more than 7.5% of world production. Iran is third, followed by Turkey, Russia, Italy and India [2]. Iranian apple are not exported because of variance in size and shape and lack of proper packaging [3].

Similar to other fruits, apple size and shape are the most important quality parameters. Consumers prefer fruits of equal size and shape [4, 5]. Sorting can increase uniformity in size and shape, reduce packaging and transportation costs and also may provide an optimum packaging configuration [6]. Moreover, sorting is important in meeting quality standards, increasing market value and marketing operations [7]. Sorting manually is associated with high labor costs in addition to subjectivity, tediousness and inconsistency which lower the quality of sorting [8]. However, replacing human with a machine may still be questionable where the labor cost is comparable with the sorting equipment [9]. Studies on sorting in recent years have focused on automated sorting strategies and eliminating human efforts to provide more efficient and accurate sorting systems which improve the classification success or speed up the classification process [10, 11].

Physical and geometrical properties of frits are the most important parameters in design of sorting systems. Among these properties, mass and outer dimensions are the most important ones [1, 3, 12]. The official quality definitions for sorting fruits are hardly more than a measure on size and shape. Most sorting standards specify size and shape based on visual comparison of size and shape relative to reference drawings. These drawings serve as references in classifying size and shape [4]. Although ratings based on visual comparison do not require any equipment, the method is subjective and may depend on person executing the rating. Moreover, rating scores may be biased by confusing variables such as size or shape [5]. Substitute approaches describe size and shape using indices calculated from physical and geometrical properties of fruits. Since such approaches are based on direct measurement, they are objective and reproducible. In addition, necessary measurements can be performed easily and no complicated equipment is needed [6]. Accordingly, the present study was conducted to develop a fast procedure that permits an un-biased and reproducible quantitative description of apple size and shape based on mass and outer dimensions.

MATERIALS AND METHODS

Experimental Procedure: One of the commercial varieties of apple in Iran, i.e. Damavandi (Fig. 1) was considered for this study. One hundred and fifteen randomly selected

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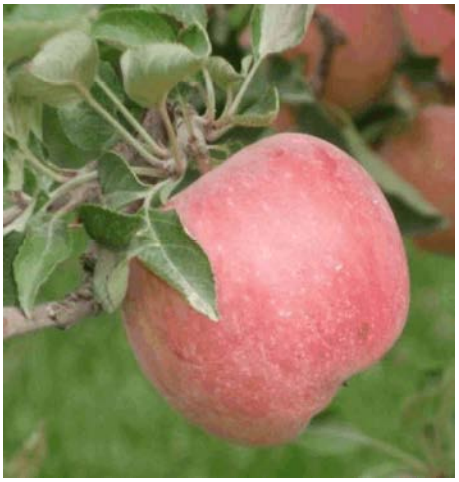

Fig. 1: Apple (Damavandi variety)

Table 1: The mean value, standard deviation (S.D.) and coefficient of variation (C.V.) of some physical and geometrical properties of the 115 randomly selected apples

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Mass, g	83.0	156.0	122.6	19.2	15.7
Height, cm	5.00	7.00	6.12	0.39	6.43
Diameter, cm	5.35	6.85	6.20	0.36	5.77
Aspect ratio	0.84	1.12	0.99	0.05	5.10

apples of various sizes were purchased from an orchard located in Damavand, Iran. Apples were selected for defects by careful visual inspection, transferred to the laboratory and held at 5±1°C and 90±5% relative humidity until experimental procedure. In order to obtain required parameters for apple size and shape detection algorithm, the mass of each apple was measured to 1.0 g accuracy on a digital balance. By assuming the general shape of apple as an oblate spheroid, the outer dimensions of each apple, i.e. height (H) and diameter (D) was measured to 0.1 cm accuracy by a digital caliper. Table 1 shows some physical and geometrical properties of the 115 randomly selected apples.

Size Detection: Primary investigation indicated that three apple sizes, i.e. small (misshapen), medium (normal) and large (normal) were detectable and separable in the samples.

Shape Detection: An easy technique of judging based on analysis of outer dimensions of apple was used for detecting shape of apple. Aspect ratio was used to detect oblate spheroid (misshapen), spheroid (normal) and oblong spheroid (misshapen) apples. Aspect ratio is defined by equation 1 [4-6, 12].

$$A.R. = H / D, (A.R. = 1.0) \quad (1)$$

Where:
A.R. = Aspect ratio, dimensionless
H = Height of apple, cm
D = Diameter of apple, cm

For mathematical describing of apple size and shape, mass and aspect ratio of apples were subjected to statistical analysis using the Microsoft Office Excel (Version 7.0 - 2003).

RESULTS

Small, Medium and Large Sizes: Mass of medium size apples ranged from 100 g to 140 g, while mass of small size apples were less than or equal to 100 g and mass of large size apples were more than or equal to 140 g. Therefore, the mass lines 100 g and 140 g can separate medium size apples from small size and large size apples as shown in Fig. 2.

Oblate Spheroid, Spheroid and Oblong Spheroid Shapes: Aspect ratio of spheroid shape apples ranged from 0.95 to 1.05, while aspect ratio of oblong spheroid shape apples were more than or equal to 1.05 and aspect ratio of oblate shape apples were less than or equal to 0.95. As a result, the aspect ratio lines 0.95 and 1.05 can separate spheroid shape apples from oblate spheroid shape and oblong spheroid shape apples as indicated in Fig. 2.

Normal and Misshapen Apples: Among nine "size and shape" combinations (three sizes × three shapes); samples with "normal size" × "normal shape" (two combinations) were considered as normal apples. Apples with other combinations (seven combinations) were considered as misshapen apples. Fig. 2 shows the mass lines 100 g and 140 g in association with the aspect ratio lines 0.95 and 1.05 can separate normal apples (two green regions) from misshapen apples (seven white regions).

DISCUSSION

In this study, mass and outer dimensions (height and diameter) of apples were analyzed to classify apples size and shape. Results of study indicated that three sizes, three shapes and consequently nine "size and shape" combinations were detectable and separable in the apples. Results of study also showed that among three sizes, frequency of medium apples was the highest (60.8%), while frequency of small apples was the lowest (17.4%).

Table 2: Size, mass range, shape, aspect ratio range, description and frequency of the 115 randomly selected apples

Size	Mass range (g)	Shape	Aspect ratio range	Description	Frequency (%)
Small	≤ 100	Oblate spheroid	≤ 0.95	Misshapen	2.60
		Spheroid	0.95 – 1.05	Misshapen	11.3
		Oblong spheroid	≥ 1.05	Misshapen	3.50
Medium	100 - 140	Oblate spheroid	≤ 0.95	Misshapen	15.7
		Spheroid	0.95 – 1.05	Normal	39.0
		Oblong spheroid	≥ 1.05	Misshapen	6.10
Large	≥ 140	Oblate spheroid	≤ 0.95	Misshapen	3.50
		Spheroid	0.95 – 1.05	Normal	15.7
		Oblong spheroid	≥ 1.05	Misshapen	2.60

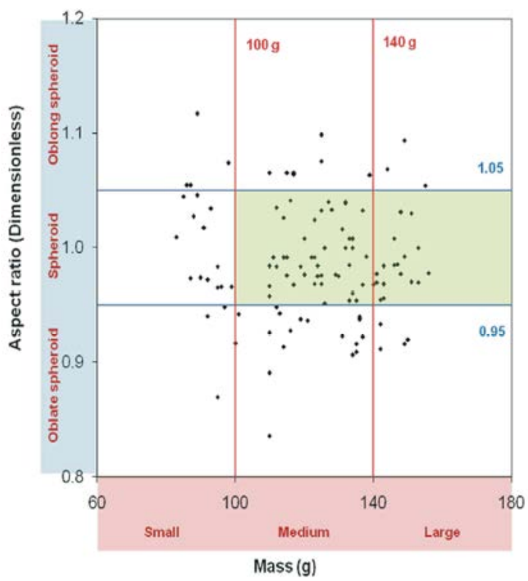

Fig. 2: Aspect ratio versus mass; green and white regions show normal and misshapen apples, respectively

Frequency of large apples was 21.8%. Besides, among three shapes, frequency of spheroid apples was the highest (66.0%), while frequency of oblong spheroid apples was the lowest (12.2%). Frequency of oblate spheroid apples was 21.8%. Moreover, frequencies of normal and misshapen apples were 54.7% and 45.3%, respectively (Table 2). These results are in agreement with those of Rashidi & Seyfi [4], Rashidi & Gholami [5] and Sadrnia *et al.* [6] who concluded that physical and geometrical properties of fruit can be used to determine normal and misshapen fruit.

CONCLUSION

It can be concluded that mass and aspect ratio of apple can be used to classify normal and misshapen apple.

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