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

Mehrdad Nazari and Majid Rashidi

Department of Agricultural Machinery, Takestan Branch,
Islamic Azad University, Takestan, Iran

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 plum size and shape. To reach objective and reproducible results, mass and outer dimensions (major diameter, intermediate diameter and minor diameter) of plum were measured and an assessment based on mass and outer dimensions was proposed. Results of the study showed that mass and aspect ratio (major diameter to geometrical mean of intermediate and minor diameters) of plum can be used successfully to classify plum size and shape.

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

INTRODUCTION

A plum (*Prunus domestica*) is a drupe fruit of the genus *Prunus*. The subgenus is distinguished from other subgenera (peaches, cherries, bird cherries, etc.) in the shoots having a terminal bud and solitary side buds (not clustered), the flowers in groups of one to five together on short stems and the fruit having a groove running down one side and a smooth stone (or pit). The commercially important plum trees are medium sized, usually pruned to 5-6 meters height. The tree is of medium hardiness. Fruits are usually of medium size, between 1 to 3 inches in diameter, globose to oval. The flesh is firm, juicy and mealy. The fruit's peel is smooth, with a natural waxy surface that adheres to the flesh. The fruit has a single large seed. Plum fruit tastes sweet and/or tart; the skin may be particularly tart. It is juicy and can be eaten fresh or used in jam-making or other recipes. Plums come in a wide variety of colors and sizes. Some are much firmer-fleshed than others and some have yellow, white, green or red flesh, with equally varying skin color [1]. Plums are produced around the world and China is the world's largest producer. The ten largest producers of plums are China, Romania, USA, Serbia, Chile, France, Iran, Turkey, Italy and India. Iran products nearly about 269,139 tons of plum and is ranked 7th in the world [2]. But, Iranian plums are not exported because of variability in size and shape and lack of suitable packaging [3].

Similar to other fruits, plum 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 [12-14]. The official quality

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

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 plum size and shape based on mass and outer dimensions.

MATERIALS AND METHODS

Experimental Procedure: One of the commercial varieties of plum in Iran, i.e. Golden Drop (Fig. 1) was considered for this study. One hundred and fifteen randomly selected plums of various sizes were purchased from a local market. Plums 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 plum size and shape detection algorithm, the mass of each plum was measured to 0.1 g accuracy on a digital balance. By assuming the general shape of plum as an ellipsoid (Fig. 2), the outer dimensions of each plum, i.e. major diameter (a), intermediate diameter (b) and minor diameter (c) was measured to 0.1 mm accuracy by a digital caliper. Table 1 shows some physical and geometrical properties of the 115 randomly selected plums.

Fig. 1: Plum (*Prunus domestica* cv. Golden Drop)

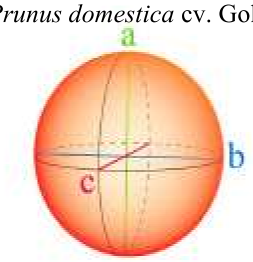

Fig. 2: The outer dimensions of a plum, i.e. major diameter (a), intermediate diameter (b) and minor diameter (c) by assuming the shape of plum as an ellipsoid

Size Detection: Primary investigation indicated that three plum 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 plum was used for detecting shape of plum. Aspect ratio was used to detect oblate-ellipsoid (misshapen) and ellipsoid (normal) plums. Aspect ratio is defined by equation 1 [4-6, 12].

$$r = \frac{a}{\sqrt{bc}} \qquad (1)$$

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 plums

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Mass (g)	42.5	68.4	52.8	5.02	9.51
Major diameter (mm)	39.3	46.4	42.2	1.54	3.64
Intermediate diameter (mm)	42.7	49.7	45.8	1.44	3.14
Minor diameter (mm)	41.5	48.8	45.1	1.48	3.27
Aspect ratio (dimensionless)	0.87	0.99	0.93	0.02	2.40

where:

r = Aspect ratio (dimensionless)
a = Major diameter of plum (mm)
b = Intermediate diameter of plum (mm)
c = Minor diameter of plum (mm)

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

RESULTS

Small, Medium and Large Size Plums: Mass of medium size plums ranged from 50 g to 60 g, while mass of small size plums were less than or equal to 50 g and mass of large size plums were more than or equal to 60 g. Therefore, the mass lines 50 g and 60 g can separate medium size plums from small size and large size plums (Fig. 3).

Oblate-Ellipsoid Shape and Ellipsoid Shape Plums: Aspect ratio of oblate-ellipsoid shape plums ranged from 0.85 to 0.90, while aspect ratio of ellipsoid shape plums ranged from 0.90 to 1.00. As a result, the aspect ratio line 0.90 can separate oblate-ellipsoid shape plums from ellipsoid shape plums (Fig. 3).

Normal and Misshapen Plums: Among six "size and shape" combinations (three sizes × two shapes); samples with "normal size" × "normal shape" (two combinations) were considered as normal plums. Plums with other combinations (four combinations) were considered as misshapen plums. Fig. 3 shows the mass lines 50 g and 60 g in association with the aspect ratio line 0.90 can separate normal plums (two green regions) from misshapen plums (four white regions).

DISCUSSION

In this study, mass and outer dimensions (major diameter, intermediate diameter and minor diameter) of plums were analyzed to classify plums size and shape. Results of study indicated that three sizes, two shapes and consequently six "size and shape" combinations were detectable and separable in the plums. Results of study also showed that among three sizes, frequency of medium size plums was the highest (60.03%), while frequency of large size plums was the lowest (6.96%). Frequency of small size plums was 33.01%. Besides, between two shapes, frequency of ellipsoid shape plums was 89.56%, while frequency of oblate-ellipsoid shape plums was 10.44%. Moreover, frequencies of normal and misshapen plums were 59.16% and 40.84%, respectively (Table 2).

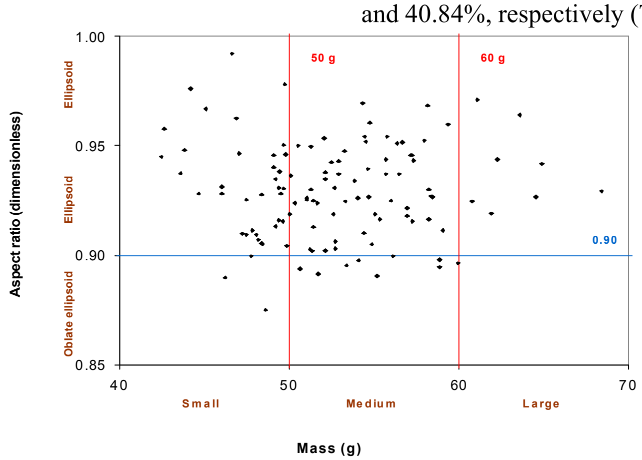

Fig. 3: Aspect ratio versus mass; green and white regions show normal and misshapen plums, respectively

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

Size	Mass range (g)	Shape	Aspect ratio range	Description	Frequency (%)
Small	≤ 50	Oblate-ellipsoid	0.85 - 0.90	Misshapen	3 - 2.61
		Ellipsoid	0.90 - 1.00	Misshapen	35 - 30.4
Medium	50 - 60	Oblate-ellipsoid	0.85 - 0.90	Misshapen	9 - 7.83
		Ellipsoid	0.90 - 1.00	Normal	60 - 52.2
Large	≥ 60	Oblate-ellipsoid	0.85 - 0.90	Misshapen	0 - 0.00
		Ellipsoid	0.90 - 1.00	Normal	8 - 6.96

These results are in agreement with those of Rashidi and Seyfi [4], Rashidi and Gholami [5], Sadrnia *et al.* [6], Keshavarzpour and Rashidi [13] and Rashidi and Keshavarzpour [14] who concluded that physical and geometrical properties of fruit can be used to determine normal and misshapen fruit [15-17].

CONCLUSION

It can be concluded that mass and aspect ratio (major diameter to geometrical mean of intermediate and minor diameters) of plum can be used to classify normal and misshapen plum.

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