Geometric properties of Kohanz apple fruits

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Abstract: Kohanz is a domestic apple variety which is grown in Iran. It is sensitive to packing conditions. Bad packages normally cause decline in its quality. Therefore, apple' s geometric properties are of important consideration in the design of the fruit' s packaging facilities. In this study, a sample of 38 freshly harvested apple fruits was obtained, 82 images of their sides were acquired and geometric dimensions were measured. Their axial dimensions, equivalent diameter and sphericity were obtained using a vernier caliper with accuracy of 0.05 mm, while the cross section area, eccentricity, perimeter and roundness were measured using a color based image processing method. Their arithmetic mean diameter was 57.6 mm, while the mean eccentricity was 0.3058, mean roundness was 0.5858 and mean sphericity was 0.9985. Therefore, the packing design must be collections of spheroid spaces with diameters of about 6.8 mm which will include all of the apples.

Keywords: eccentricity, equivalent diameter, image processing, roundness, sphericity

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1 Introduction

Among all the fruits produced in Iran, apple is the most important economical and industrial fruit (Meisami-asl et al, 2009). Kohanz apple is one of the famous Iranian domestic apple varieties. The fruits are currently filled in woody or plastic made boxes without any arrangement. The packages usually include some damaged fruits.

Bruise damage is a major cause of fruit quality loss (Zarifneshat et al., 2010). The packing method causes compression damage in which fruit are bruised as they are pushed into a bin or bag (Kupferman, 2006). Conformity of size is particularly desirable for packaging and display purposes (Studman, 2001). Therefore, apples should be sorted into categories in order to provide better markets. The sorting method can be size-based in which they are classified according to their geometric properties.

Aviara et al. (2007), Hasankhani (2008), Amiriparian et al. (2008), Meisami-asl et al. (2009), and Zarifneshat et al. (2010) worked on estimation of some agricultural products physical properties.

Application of image processing based methods in agricultural activities has been developed for years. The applications involve activities such as auto-guidance (Benson et al., 2003; Han et al., 2004), weed control (Nieuwenhuizen et al., 2007; Ghazali et al., 2009), harvesting (Lak et al., 2010; Bulanon and Kataoka, 2010), yield monitoring (Chinchuluun et al., 2007; Annamalai, 2004) and post harvest (Amiriparian et al., 2008; Rao and Renganathan, 2002; Zion et al., 1999).

Geometric properties of fruits can be investigated by machine vision based methods (Rao and Renganathan, 2002; Rashidi and Seyfi, 2007). Aviara et al. (2007) determined physical properties of guna fruits; Davies (2010) investigated the physical properties of arigo seeds; and Hasankhani (2008) studied some geometric properties (area, volume, shape, external defects such as: greening, cracks and insect attack defects) of potato using machine vision. Amiriparian et al. (2008) estimated three agricultural products' (apple (*Golden Delicious*), pistachio and onion) volume using image processing.

It is likely that consumer demand for improved quality, longer storage life and guaranteed product safety will

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continue to grow (Studman, 2001). Therefore, providing an appropriate package will promote Kohanz apple marketing.

The main objective of this study is to determine the freshly harvested Kohanz apple′ s geometric properties. The axial dimensions, namely, length L (maximum dimen sion), thickness T (medium dimension) and width W (minimum dimension) were measured manually, meanwhile, cross sectional areas (pixels included in detected feature), perimeters (pixels surrounding detected feature), eccentricities (the ratio of the distance between the foci of the ellipse and its major axis length ($0 \le \varepsilon \le 1$ and $\varepsilon_{circle}=0$) (Gonzalez, et al., 2004), equivalent diameters (the diameter of a circle with the same area as the region (Gonzalez, et al., 2004), and roundness of sides of the fruits are the properties which can be defined using image processing. Sphericity was calculated using manually measured quantities.

Good packaging would vouch for better marketing. While, identification of fruits′ geometric properties is required to design appropriate package size. Therefore, the main goal of this study is to define the optimum spheroid packing size for Kohanz apples using its geometric properties.

2 Materials and Methods

Geometric properties of Kohanz apples were divided into two categories: parameters which could be measured using a vernier caliper; and properties that can be extracted from processed images.

2.1 Manual measured parameters

A sample of 38 apples was selected randomly from a grove in Hamedan, western Iran. The axial dimensions, namely, length L, thickness T, and width W were measured using a vernier caliper (*TAKA® Vernier Caliper*, 200 × 0.05mm). Arithmetic mean diameter D_a, and sphericity Φ were calculated using Equation (1) and (2) as follows (Kibar and Öztürk, 2008; Jain and Bal, 1997).

$$D_a=\frac{L+T+W}{3} \tag{1}$$

Where:

D_a=arithmetic mean diameter (mm), W=width (mm), T=thickness (mm), and L=length (mm)

$$\Phi=\frac{\sqrt{WT}\times(2L-\sqrt{WT})}{\sqrt[3]{L^2}} \tag{2}$$

Where:

Φ=sphericity (dimensionless)

2.2 Image processing extracted properties

A digital camera (*Sony, DSC-H5, Color CCD Camera*) was used to acquire 82 images of 38 apples′ sides. At least, two sides of each apple were imaged. Format of the images was jpeg and they were in RGB (red-green-blue) color space. Because some of the samples were not symmetric, they were imaged from more than two sides.

The images were converted to L*a*b color space. The L*a*b* space consists of a luminosity layer L*, chromaticity layer a* indicating where color falls along the red-green axis, and chromaticity layer b* indicating where the color falls along the blue-yellow axis (Matlab, 2007).

Then, they were converted to binary form, noise-reduced, labeled, and the properties were extracted. The properties were: area, eccentricity and perimeter. Area and perimeter were in terms of pixel and eccentricity was dimensionless.

Roundness was estimated using the relationship between area and perimeter (Equation (3)) and it was also dimensionless.

$$R=\frac{4\pi A}{P^2}\ \text{(MATLAB, 2007)} \tag{3}$$

Where:

R=roundness (dimensionless), A=area (pixel), and P =perimeter (pixel).

3 Results and Discussion

Apples′ length, thickness and width were measured; therefore their equivalent diameter and sphericity were calculated by the data. Table 1 shows the descriptive statistics of properties which were measured by means of a caliper.

All the apples were imaged at least with two sides (Figure 1). First, the images were converted to L*a*b color space (Figure 2), then they were converted to binary form (Figure 3). Finally, they were noise-reduced and some properties were extracted (Figure 4). Area, eccentricity and perimeter were the properties extracted from processed images. The roundness was calculated by using a function between area and perimeter (Equation (3)).

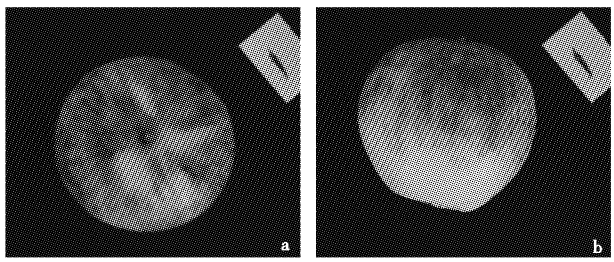

Figure 1 Typical original images acquired from two sides of apples

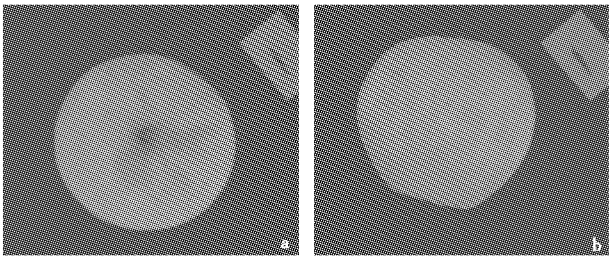

Figure 2 Images in L*a*b color space

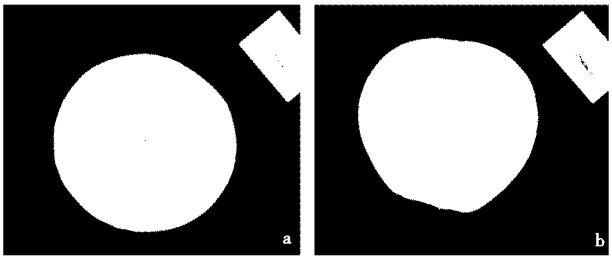

Figure 3 Binary images

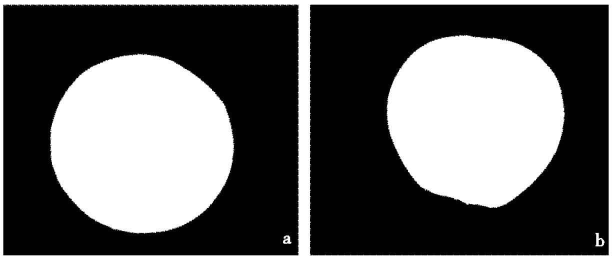

Figure 4 Noise-reduced binary images

The descriptive statistics of apples' properties which obtained from image processing are listed in Table 2.

Table 1 Descriptive statistics of manually measured properties of apples

Properties	Na	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Lb	82	17.45	49.65	67.10	60.05	3.0189	9.114
Tc	82	15.50	49.50	65.00	57.99	2.9438	8.666
Wd	82	13.50	47.00	60.50	54.83	3.1641	10.011
Dae	82	15.48	48.72	64.20	57.62	1.7572	3.088

a Sample size

b Length in millimeter

c Thickness in millimeter

d Width in millimeter

e Arithmetic mean diameter in millimeter

Mean and range of length, thickness, width, eccentricity, equivalent diameter, roundness and sphericity were 60.05 [49.65 67.10], 57.99 [49.50 65.00], 54.83 [47.00 60.50], 0.3058 [0.0446 0.7204], 57.63 [48.72 63.75], 0.5858 [0.0526 0.8407], and 0.9985 [0.9948 0.9999] respectively (Table 1 and Table 2).

Extracted geometric properties of Kohanz apples

Table 2 Descriptive statistics of the properties measured by image processing

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Area (pixels)	82	1014172	1044468	2058640	1494828.10	204750.905	4.192E10
Eccentricity (pixels)	82	0.6758	0.0446	0.7204	0.3058	0.1116	0.012
Equivalent Diameter (pixels)	82	15.03	48.72	63.75	57.63	2.8285	8.000
Perimeter (pixels)	82	13130.5	4080.5	17211.0	6321.7	2239.0	5013152.3
Roundness (dimensionless)	82	0.7881	0.0526	0.8407	0.5858	0.2396	0.057
Sphericity (dimensionless)	82	0.0051	0.9948	0.9999	0.9985	0.0012	0.000

were of at least two sides of each apple, therefore, the properties involve three dimension properties of them. The maximum, mean and minimum diameters of Golab apple were 65.04, 53.50 and 35.14 mm respectively (Meisami-asl, 2009); meanwhile the measures were 64.20, 57.62, and 48.72 mm for Kohanz variety.

The apples' sphericity ranges show that the apples can be considered as spheres with diameters equal to equivalent diameters. On the other hand, their maximum dimension is their length. Therefore, their packing design must be collections of spheroid spaces with diameters of about 68 mm which includes all of them.

4 Conclusions

This paper considered Kohanz apple' s geometric properties. Their length, thickness and width were measured by caliper. Their equivalent diameters and sphericity were calculated. Their area, perimeter and eccentricity were extracted by image processing and roundness was computed by a function with area and perimeter.

Finally it was determined that a collection of spheroid spaces with diameters of about 68 mm will be the most appropriate package design.

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