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Full Length Research Paper

Basic physical properties of fruits in loquat (*Eriobotrya Japonica* (Thunb. Lindl.) cultivars and genotypes determined by both classical method and digital image processing

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In this study, dimensions, mass and shape characteristics of five commercial loquat cultivars ('Akko XIII', 'Champagne de Grasse', 'Guzelyurt 6', 'Hafifcukurgobek' and 'Sayda') and two genotypes ('KKTC3' and 'KKTC4') were determined. Physical properties such as dimension and shape were determined both by digital caliper and image processing to compare each other. Among the cultivars and genotypes tested, 'KKTC4' (58.88 mm) had the highest length while 'KKTC3' had the highest major diameter, minor diameter, mass, geometric mean diameter, surface area and volume, with a mean of 46.31 mm, 43.61 mm, 60.12 g, 48.69 mm, 74.82 cm^2, and 61.25 cm^3, respectively. The greatest value of elongation and the smallest value of sphericity were obtained from 'Akko XII' with 1.33, and 'Akko XII' was more oblong than the other cultivars and genotypes. The smallest value of elongation and the greatest value of sphericity were obtained from 'Sayda' with 1.12 and 91.16%, respectively. The results of comparison between the digital caliper and image processing showed that using the image processing method could potentially be rapid and alternative to the conventional measurement method.

Key words: *Eriobotrya japonica*, image processing, loquat, physical properties.

INTRODUCTION

The loquat (*Eriobotrya japonica* (thunb. Lindl.) is mainly cultivated in China, Japan, Korea, Mediterranean countries (Spain, Turkey, Italy, Greece, Portugal), Madagascar, Mauritius Island, United States, Brazil, Australia, Pakistan and India. Because its blossoming period is different from the other fruits, the loquat fruit is available in the market before any other fruit in spring season. Thus, the fruits of the loquat can be sold at a higher price in spring, as there are few competitive fruits in the market (Caldeira and Crane, 1999; Caballero and Fernandez, 2004; Hussain et al., 2009).

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Turkey ranks fourth place in terms of production amount of loquat after China, Japan and Spain in the world. There were 264.496 mature loquat trees yielding 12.112 tons in 2010 for Turkey (SIS, 2012). Mediterranean region has the most suitable ecological conditions for growing loquat and is particularly suitable for early production in Turkey. Approximately 60% of Turkey's loquat is produced in West Mediterranean region, with most production coming from Antalya province (Celikyurt et al., 2010; SIS, 2012). In recent years, the loquat production is carried out under protected cultivation in Antalya province since early fruits command a very high price (Celikyurt et al., 2010).

The loquat fruits, growing in clusters, are oval, rounded or pear-shaped. The loquat peel is smooth to slightly

fuzzy and light yellow to orange in color. Flesh is white or orange and soluble solids content varies from 7 to 20% (Lin et al., 1999). The loquat fruit are difficult to harvest because of the thick, tough stalk on each fruit, which does not separate readily from the cluster, and the fruits must be picked with stalk attached to avoid tearing the skin. Clusters are cut from the branch with a sharp knife or with clippers. Whole clusters are not particularly attractive on the market, therefore, the individual fruits are clipped from the cluster, the stalk is detached from each fruit and the fruits are graded for size and color to provide uniform packs. Great care is taken to avoid blemishes (Morton, 1987).

The correct determination of basic physical properties of horticultural crops including fruits in agricultural research for different purposes is necessary. These include cultivar description in application for cultivar rights and cultivar registration, evaluation of consumer performance, equipment design for harvest and processing and post-harvest operations such as cleaning, separating, sorting, sizing, packaging, shipping, conveying by air and water, storage, cooling and heating loads (Gerhard et al., 2001; Hasnain et al., 2003; Masoumi and Tabil, 2003; Kotwaliwale et al., 2004; Wilheim et al., 2004). In Turkey, sorting and quality rating in fruits of loquat is normally done by experts. In consequence, it is subjective and the results show inter and intra individual variations. To achieve objective and reproducible results, a simple assessment is needed.

The major physical properties of loquat fruits are dimension, shape, size, sphericity, surface area, volume, and mass. These properties have been studied in various agricultural products such as apple, apricot, pear, walnut, plum and medlar (Calisir et al., 2005; Hacıseferoğulları et al., 2005; Hacıseferoğulları et al., 2007). Generally, the main dimensions were determined with a digital caliper and the other physical properties were found with mathematical equations. Determination of these parameters in classical measurement by using digital caliper is subjective, slow and may depend on individual skills. However, rating based on visual comparison is more reliable because it does not require any equipment and it does not change with individual's skills. In the literature, there was limited information on physical properties of loquat fruits and there is no information about image processing to determine basic physical properties.

Recently, the use of image processing is gaining importance for physical properties determination of fruits (Rashidi and Seyfi, 2008). Rashidi et al. (2009) determined cantaloupe volume by using image processsing method. They indicated that the image processing provided an accurate, simple, and rapid method. Fıratlıgil-Durmuş et al. (2010) used image processing methods to provide geometric parameters of legume seeds. They observed that the image processing method provided fast and accurate values of physical properties of legume such as geometric parameters, volume and surface area. Omid et al. (2010) developed an image processing based technique to measure volume and mass of citrus fruit such as lemons, limes, oranges, and tangerines. They developed an algorithm, designed and implemented in Visual Basic language, and indicated that a simple procedure based on computed volume of assumed ellipsoidal shape was also proposed for estimating mass of citrus fruit. Wycislo et al. (2008) used commercially available SigmaScan software to determine some physical properties of grape. They compared computer findings with data from human raters using a simple correlation. They found that when computer findings with the human ratings were compared, results showed strong correlations.

The objective of this study was to determine some basic physical properties such as dimensions, shape, and size of five cultivars and two genotypes of loquat by using traditional method (digital caliper) and image processing to compare each other.

MATERIALS AND METHODS

Five loquat cultivars ('Akko XIII', 'Champagne de Grasse', 'Guzelyurt 6', 'Hafifcukurgobek' and 'Sayda') and two genotypes ('KKTC3' and 'KKTC4') grown in West-Mediterranean region of Turkey, were used for all the experiments in the present study (Figure 1). All cultivars (a variety of a plant developed from a natural species and maintained under cultivation) and genotypes (the genetic makeup, as distinguished from the physical appearance) were found in an experiment orchard in West Mediterranean Agricultural Research Institute. During the 2011 harvest season, the fruits were harvested and kept in a refrigerator until laboratory analyses were performed. For each loquat cultivar and genotype, 60 fruit samples were randomly selected from the loquat trees. All of the tests were carried out at the Biological Material Laboratory in Agricultural Machinery, Department of Atatürk University, Erzurum, Turkey. The mass of loquat cultivars and genotypes were measured by a digital balance, with an accuracy of ±0.001 g. In order to determine the dimensions of each loquat cultivars and genotypes, two methods (manual measurement with a digital caliper with accuracy of ±0.01 mm and image processing technique) were used (Table 2). Size and shape features were determined in two different orientations (vertical and horizontal) of each loquat fruit (Figure 1).

The image processing system consisted of a digital camera with USB connection, a fluorescent ring light source (32 W) and light bulb source (100 W) (Figure 2). A white fiberglass (25 × 35 cm) was placed on the light box with light bulb, to provide a white background. The digital camera (Panasonic Lumix DMC-FZ50) was placed at the center of the fluorescent ring light source. The fluorescent ring light source and digital camera were mounted on an adjustable frame. The distance between the fiberglass surface and the camera was set at 40 cm. The sixty fruits of each cultivar were divided into ten groups and positioned in two different orientations, on the white fiberglass surface. Each group was placed at the center of the camera's field of view and two RGB color images were captured before and after manually rotating the orange 90° around the lateral axis. The image area of approximately 129 × 97 cm^2 was captured in each photo. SigmaScan®Pro 5.0 software was used to determine the size and shape features with two orientations of the loquat cultivars and genotypes. In order to calibrate length in mm, a steel ruler with intervals of 0.50 mm was placed beside each of the loquat cultivars.

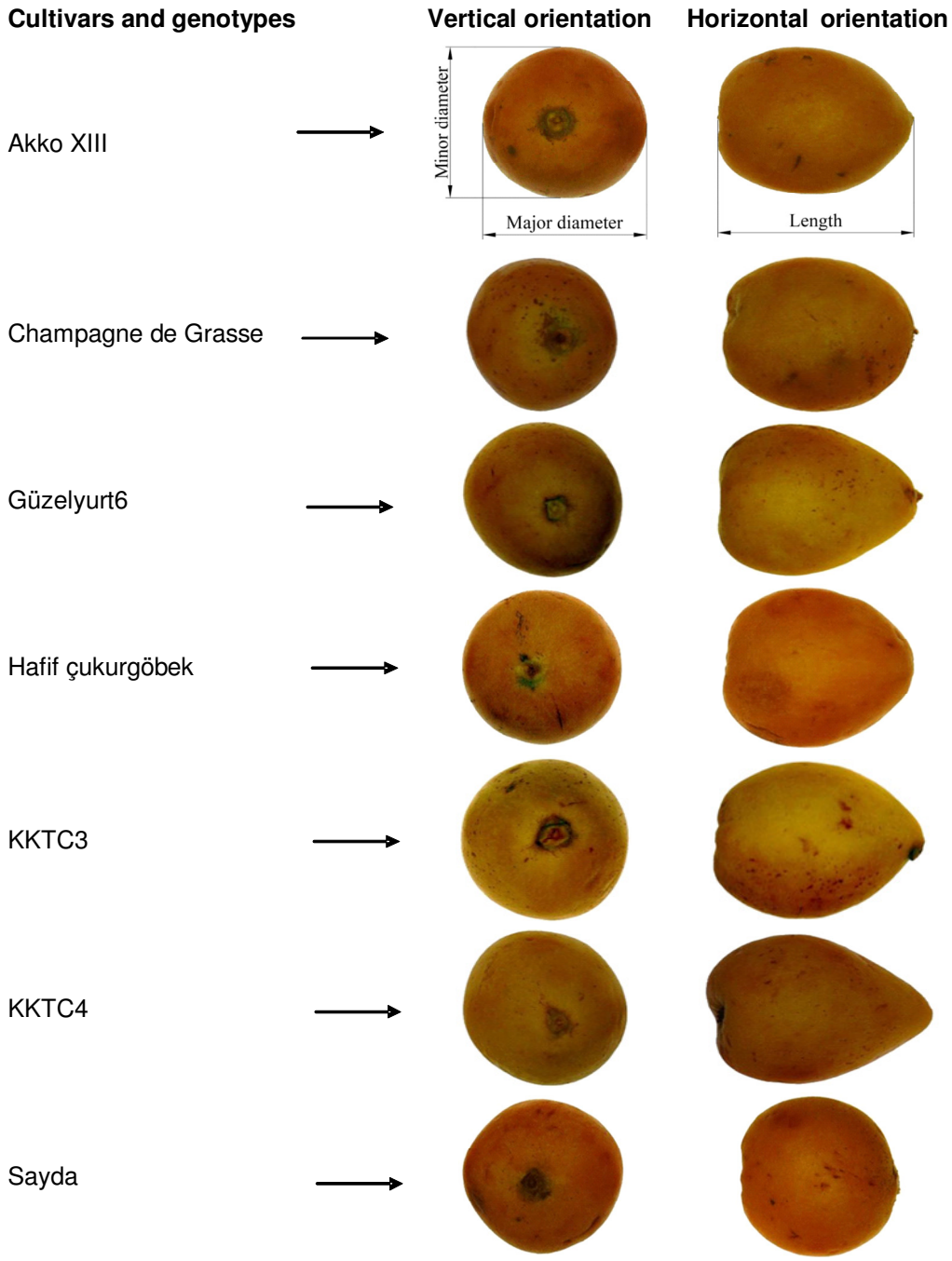

Figure 1. Orientation of photographs of loquat cultivars and genotypes.

From the steel ruler and image processing measurements, a conversion factor of 1 mm to 17.3 pixels was determined. The conversion factor was used to convert units of measurement from pixels to millimeter in length. A single loquat object was selected in a photo and automatically colored red. The software automatically determined the projected area (*PA*, cm^2), equivalent diameter (*ED*, mm), perimeter (*P*, mm), length (*L*, mm), major diameter (D_1, mm), minor diameter (D_2, mm) and shape factor (*SF*) of the selected object. The geometric mean diameter (D_g, mm) and sphericity (φ, %) were calculated using the following equations (Mohsenin, 1986; Sahay and Singh, 1994):

$$D_g = (L \times D_1 \times D_2)^{(1/3)} \quad (1)$$

$$\varphi = (D_g / L) \times 100 \quad (2)$$

The surface area (*S*, cm^2) and volume (*V*, cm^3) were calculated from the equations given by McCabe et al. (1986) and cited by Olajide and Ade-Omowaye (1999):

$$S = \pi \times D_g^2 \quad (3)$$

$$V = (\pi / 6) \times D_g^3 \quad (4)$$

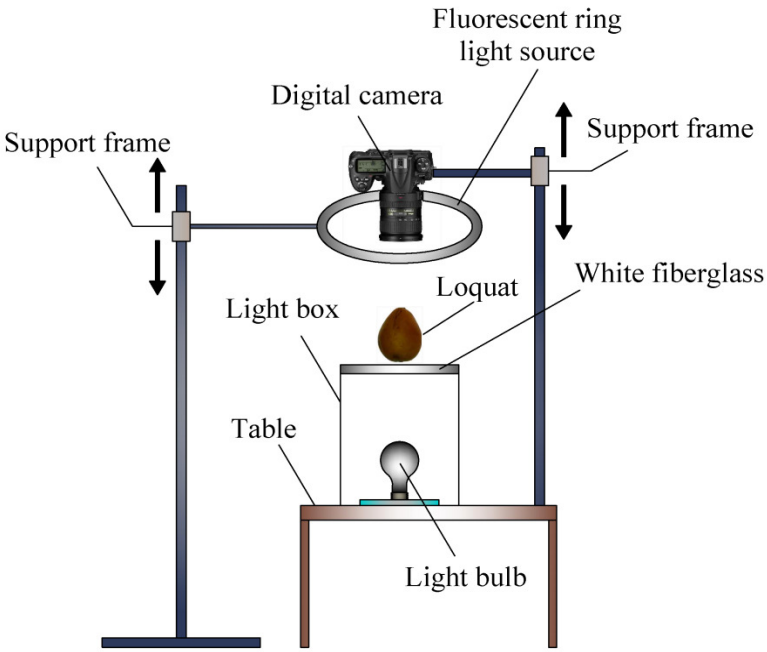

Figure 2. Image acquisition system.

Shape factor (*SF*) was calculated using the values of projected area (*PA*) and perimeter (*P*) (SigmaScan®Pro, 2004). *SF* was automatically calculated by SigmaScan software using the following equation:

$$SF = 4 \cdot \pi \cdot PA / P^2 \quad (5)$$

Elongation (*E*) was calculated by using the following equation by (Firatlıgil-Durmuş et al., 2010):

$$E = \text{Major axis length} / \text{Minor axis length} \quad (6)$$

A completely randomized design was selected for the experiment. SPSS statistical software was used for analysis of variance with a 95% confidence level ($P<0.05$) and Duncan's Multiple Comparison Test to determine significant differences (IBM SPSS® Statistics, 2010).

RESULTS AND DISCUSSION

The ranges of projected area, perimeter, equivalent diameter and shape factor obtained from the two orientations (horizontal and vertical), volume calculated by using the two methods, and mass of the five loquat cultivars and two genotypes are shown in Figure 3. The values of the projected area, equivalent diameter and perimeter obtained from the horizontal orientation skewed to right according to the vertical orientation. These tendencies showed that the outputs determined from the horizontal orientation were higher than the vertical orientation in general (Figure 3).

The mass range of the cultivars and genotypes varied from 20.89 to 84.85 g (Table 1). The mean fruit mass were determined as 60.12 g ('KKTC3'), 58.78 g ('Guzelyurt 6'), 56.31 g ('KKTC4'), 41.26 g ('Akko XIII'), 39.06 g ('Sayda'), 36.92 g ('Hafifcukurgobek') and 33.86 g ('Champagne de Grasse'). Genotype 'KKTC3' had both higher dimensions and mass than those of the others while cv. 'Champagne de Grasse' had the smallest mass. Previous studies also showed that the average fruit weight changed extremely according to growing region and cultivars (Caldeira and Crane, 1999; Hussain et al., 2009). Average fruit weight of cvs. 'Konro', 'Dr. Trabut', 'Baffico', and 'Gold Nudged' in Turkey were 25.68, 29.54, 22.55, and 25.22 g, respectively (Durgac et al., 2006). Ozdemir and Topuz (1997) reported that average fruit weight of cvs. 'Hafifcukurgöbek', 'Yuvarlakcukurgobek', 'Uzuncukurgobek', 'Sayda', 'Akko XIII', 'Gold Nugget', 'Tanaka', and 'Yabani' were 27.74, 33.11, 33.46, 30.37, 28.65, 29.42, 24.04, and 14.00 g, respectively. Average fruit weight of cvs. 'Satomi' and 'Fusahikari' in Japan were determined between 65 and 75 g (Nakai et al., 1990) and average fruit weight of cv. 'Puxiben' in China varied from 58.1 to 77.1 g (Peng et al., 2002).

The mass, length, major diameter, minor diameter and elongation of five loquat cultivars and two genotypes measured with the digital caliper and computed with the image processing are shown in Table 1. The mean value, standard deviation, range, and coefficient of variation of each parameter are presented. There was statistically significant difference among mean dimensions of loquat cultivars and genotypes at the 5% level. The mean length, major diameter, minor diameter, and elongation of loquat cultivars and genotypes measured with the digital caliper ranged from 43.48 to 58.45, 37.11 to 44.93, 34.57

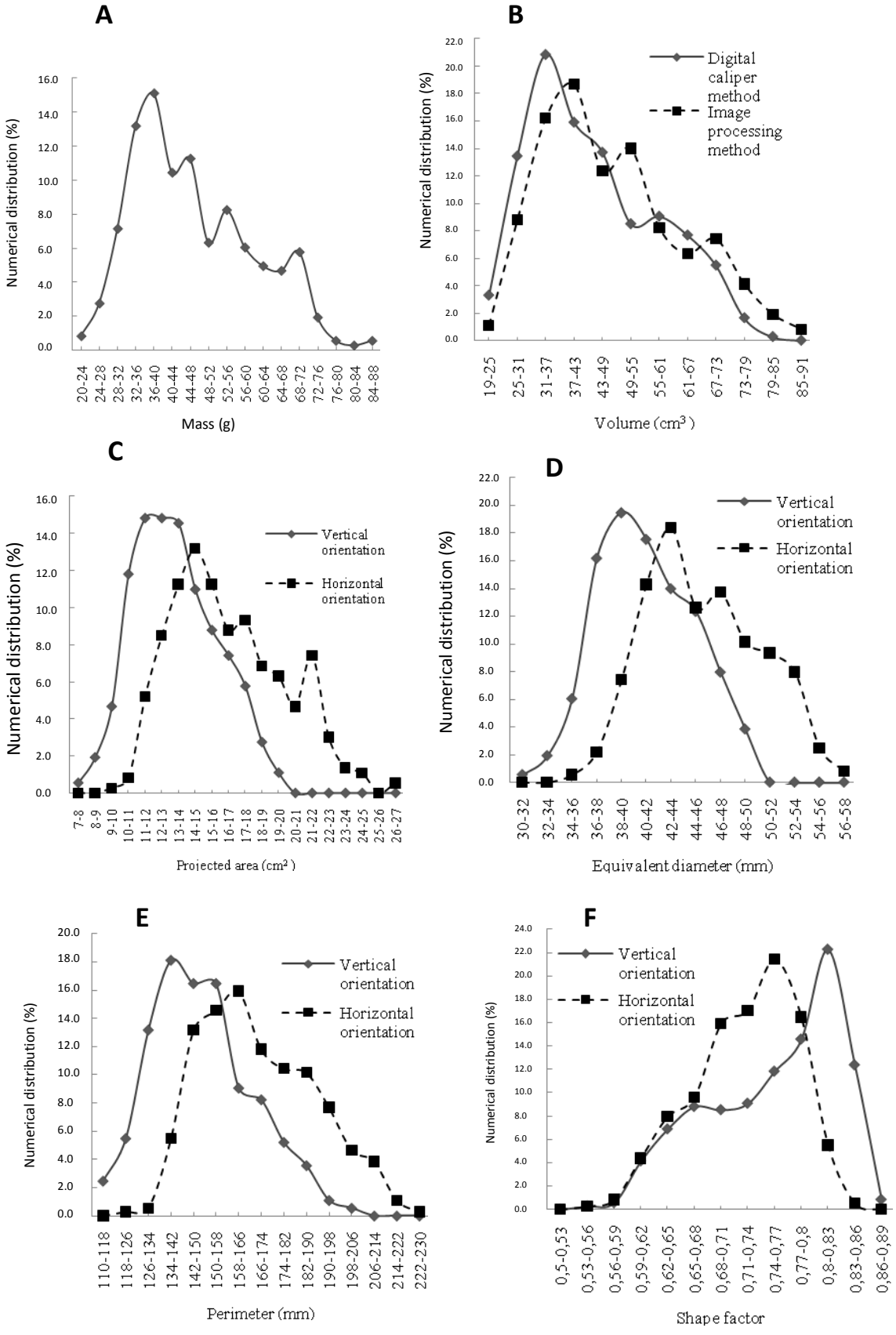

Figure 3. Numerical distribution of size and shape features of loquat cultivars and genotypes, % (n=364).

Table 1. Dimensions of loquat cultivars and genotypes measured by digital caliper (DC) and computed with image processing (IP).

Cultivars and Genotypes	Parameter	Mass (g)	Length (mm)		Major Diameter (mm)		Minor Diameter (mm)		Elongation	
			DC	IP	DC	IP	DC	IP	DC	IP
Akko XIII (n=56)	Mean±SD	41.26±8.02c[1]	52.47±4.35b[1]	53.48±4.23b	38.46±3.04d	40.23±2.93c	36.96±2.95c	38.41±2.96b	1.37±0.12a	1.33±0.09a
	Range	22.02-58.16	45.13-60.77	45.15-63.38	28.54-43.92	31.63-45.46	27.57-43.36	28.89-44.35	1.15-1.67	1.19-1.60
	CV%	19.44	8.29	7.91	7.9	7.28	7.98	7.71	8.76	6.77
Champagne de Grasse (n=48)	Mean±SD	33.86±5.17e	44.31±3.37d	46.45±3.49c	37.11±1.97e	38.64±2.20d	34.57±2.33d	35.99±2.46c	1.19±0.07c	1.20±0.06d
	Range	23.37-47.91	38.13-51.96	39.58-54.92	33.81-41.05	34.17-43	28.63-39.83	30.63-41.98	1.06-1.35	1.07-1.33
	CV%	15.27	7.61	7.51	5.31	5.69	6.74	6.84	5.88	5
Guzelyurt 6 (n=52)	Mean±SD	58.78±9.38ab	58.45±4.15a	58.48±3.99a	43.91±2.32b	45.14±2.71b	42.07±2.70a	42.84±2.87a	1.33±0.08a	1.30±0.06b
	Range	42.01-84.47	50.02-65.91	50.89-67.31	38.64-48.72	39.27-50.51	35.95-47.22	35.8-48.99	1.16-1.50	1.17-1.44
	CV%	15.96	7.1	6.82	5.28	6	6.42	6.7	6.02	4.62
Hafifcukurgobek (n=52)	Mean±SD	36.92±5.94de	46.99±3.25c	47.90±3.25c	38.35±2.19d	39.15±2.31d	36.50±2.43c	37.07±2.45c	1.23±0.10c	1.23±0.07cd
	Range	20.89-52.27	40.98-54.7	42.27-55.41	31.69-42.34	32.49-43.69	31.03-41.14	30.89-42.45	1.05-1.42	1.10-1.41
	CV%	16.09	6.92	6.78	5.71	5.9	6.66	6.61	8.13	5.69
KKTC3 (n=48)	Mean±SD	60.12±10.85a	56.89±5.77a	57.28±5.42a	44.93±2.74a	46.31±3.19a	42.50±2.56a	43.61±2.86a	1.27±0.11b	1.24±0.09c
	Range	36.14-82.25	43.97-68.48	44.87-67.45	39.04-49.93	38.37-53.29	36.9-47.66	37.54-49.06	1.10-1.56	1.06-1.46
	CV%	18.05	10.14	9.46	6.1	6.89	6.02	6.56	8.66	7.26
KKTC4 (n=56)	Mean±SD	56.31±11.13b	57.85±5.31a	58.88±5.48a	43.18±2.91b	45.35±3.10ab	41.42±2.8ab	42.85±3.25a	1.34±0.09a	1.30±0.08b
	Range	33.47-84.85	45.69-69.21	46.84-69.95	36.9-49.63	38.19-52.39	34.91-47	36.27-49.32	1.12-1.58	1.13-1.47
	CV%	19.77	9.18	9.31	6.74	6.84	6.95	7.58	6.72	6.15
Sayda (n=52)	Mean±SD	39.06±6.35cd	43.48±3.13d	46.19±3.21c	40.23±2.12c	41.25±2.27c	38.15±2.85b	39.08±2.94b	1.08±0.08d	1.12±0.06e
	Range	27.04-55.97	36.65-50.75	38.5-51.85	35.25-45.75	36.17-46.62	31.85-45.75	33.43-45.81	0.90-1.28	1.00-1.27
	CV%	16.26	7.2	6.95	5.27	5.5	7.47	7.52	7.41	5.36

[1]Means followed by the same letter in the column are not different as determined by the Duncan test at a 5% significance level.

to 42.50 and 1.08 to 1.37 mm, respectively, and the dimensions and elongation of loquat cultivars and genotypes computed with the image processing ranged from 46.19 to 58.88, 38.64 to 46.31, 35.99 to 43.61 and 1.12 to 1.33 mm, respectively. When compared to results of the digital caliper and image processing, the values obtained with the two methods were close to each other. But, it was observed that the values obtained with the digital caliper were lower than the values obtained with image processing. It may be said that high force to skin of fruit with jaws of caliper to press the fruit between two jaws was applied. Thus, real dimensions of fruit changed according to force applied. That was possibly why the values obtained with the digital caliper were low. The longest loquat fruits obtained with the image processing were obtained from cvs.

Table 2. Some physical properties of loquat cultivars and genotypes measured with digital caliper (DC) and computed with image processing (IP).

Cultivars and Genotypes	Parameter	Geometric mean diameter (mm)		Sphericity (%)		Surface area (cm^2)		Volume (cm^3)	
		DC	IP	DC	IP	DC	IP	DC	IP
Akko XIII (n=56)	Mean±SD	42.06±2.93b	43.53±2.98b	80.37±4.54d	81.54±3.75c	55.84±7.63b	59.8±8.03b	39.51±7.97b	43.78±8.67b
	Range	33.47-48.31	35.54-48.72	70.23-90.02	72.17-87.78	35.20-73.31	39.69-74.56	19.64-59.02	23.51-60.54
	CV%	6.97	6.84	5.64	4.60	13.67	13.43	20.17	19.81
Champagne de Grasse (n=48)	Mean±SD	38.43±2.19d	40.10±2.40d	86.89±3.46b	86.48±3.15b	46.54±5.29d	50.7±6.08d	29.99±5.11d	34.13±6.17d
	Range	33.72-43.96	34.91-46.28	80.96-95.27	81.01-93.00	35.71-60.71	38.3-67.29	20.07-44.48	22.29-51.91
	CV%	5.69	5.98	3.98	3.64	11.36	11.99	17.05	18.07
Guzelyurt 6 (n=52)	Mean±SD	47.59±2.60a	48.34±2.86a	81.58±3.43d	82.76±2.92c	71.36±7.78a	73.66±8.71a	56.93±9.29a	59.75±10.60a
	Range	42.66-53.08	42.76-54.61	73.83-89.25	76.22-88.80	57.17-88.51	57.45-93.69	40.65-78.30	40.95-85.28
	CV%	5.47	5.92	4.20	3.53	10.90	11.83	16.31	17.73
Hafifcukurgobek (n=52)	Mean±SD	40.33±2.06c	41.1±2.29cd	86.04±4.51b	85.93±3.59b	51.24±5.22c	53.22±5.92cd	34.62±5.27c	36.68±6.10cd
	Range	34.74-45.45	34.95-46.31	78.15-96.81	79.07-93.62	37.90-64.88	38.38-67.39	21.94-49.15	22.36-52.02
	CV%	5.12	5.58	5.24	4.18	10.19	11.12	15.23	16.64
KKTC3 (n=48)	Mean±SD	47.68±3.11a	48.69±3.30a	84.18±4.63c	85.29±4.02b	71.71±9.21a	74.82±9.95a	57.45±10.91a	61.25±12.00a
	Range	40.06-54.12	40.16-54.21	73.98-93.52	76.30-91.53	50.42-92.02	50.66-92.33	33.67-83.01	33.9-83.43
	CV%	6.53	6.79	5.50	4.71	12.85	13.30	18.98	19.59
KKTC4 (n=56)	Mean±SD	46.92±3.24a	48.52±3.53a	81.33±3.64d	82.61±3.37c	69.50±9.50a	74.34±10.72a	54.85±11.12a	60.74±13.04a
	Range	39.87-52.89	40.62-55.50	73.23-91.14	75.66-90.28	49.93-87.90	51.84-96.77	33.18-77.49	35.1-89.51
	CV%	6.92	7.28	4.47	4.08	13.67	14.42	20.27	21.46
Sayda (n=52)	Mean±SD	40.53±2.25c	42.05±2.52c	93.12±4.12a	91.16±3.41a	51.76±5.72c	55.74±6.65c	35.18±5.80c	39.34±7.04c
	Range	35.78-45.70	37.17-47.38	80.99-99.90	82.74-99.17	40.23-65.62	43.40-70.52	23.99-49.99	26.88-55.68
	CV%	5.56	5.98	4.42	3.74	11.04	11.94	16.48	17.88

[1]Means followed by the same letter in the column are not different as determined by the Duncan test at a 5% significance level.

'Guzelyurt-6' (58.48 mm), 'KKTC4' (58.88 mm), and 'KKTC3' (57.28 mm) and the shortest fruits obtained from cvs. 'Champagne de Grasse' (46.45 mm) and 'Sayda' (46.19 mm). 'KKTC3' (46.31 mm) and 'KKTC4' (45.35 mm) had the highest major diameters and the lowest diameters were in cvs. 'Champagne de Grasse' (38.64 mm) and 'Hafifcukurgobek' (39.15 mm). Loquats produced by the cv. 'Guzelyurt 6' (42.84 mm), and genotypes 'KKTC3' (43.61 mm) and 'KKTC4' (42.85 mm) were the highest minor diameter. Cvs. 'Champagne de Grasse' (35.99 mm) and 'Hafifcukurgobek' (37.07 mm) had the lowest minor diameter. Three dimensions obtain from genotypes'KKTC3' and 'KKTC4' were higher than

those of the other cultivars. Durgac et al. (2006) determined average fruit width and length as 33.40 and 44.35 mm for cv. 'Konro', 36.51 and 43.79 mm for cv. 'Dr. Trabut', 32.83 and 33.84 mm for cv. 'Baffico', and 35.59 and 37.80 mm for cv. 'Gold Nudged' loquat cultivars grown in Turkey, respectively. Ozdemir and Topuz (1997) found that average fruit width and length was 34.93 and 42.46 mm for cv. 'Hafifcukurgobek', 37.48 and 36.61 mm for cv. 'Yuvarlakcukurgobek', 34.94 and 47.19 mm for cv. 'Uzuncukurgobek', 34.76 and 46.52 mm for cv. 'Sayda', 34.75 and 39.38 mm for cv. 'Akko XIII', 36.38 and 34.79 mm for cv. 'Gold Nudged', 33.21 and 37.69 mm for cv. 'Tanaka', and 27.43 and 29.30 mm for cv. 'Yabani' in Turkey, respectively. In our study, the mean elongation values of loquat cultivars and genotypes were found both with the digital caliper and image processing. The mean elongation values determined with image processing ranged from 1.12 to 1.33. The greatest value of elongation was obtained from cv. 'Akko XIII' (1.33), and was more oblong than the others. The smallest value of elongation was obtained from cv. 'Sayda' (1.12). It was observed that cv. 'Sayda' was inclined to round. Visual inspection supported the SigmaScan analysis (Figure 1). Similarly, Caldeira and Crane (1999) studied 13 loquat cultivars and observed that loquat fruits were either pear-shaped or rounded.

Geometric mean diameter, sphericity, surface area and volume which were calculated both with the digital caliper and image processing showed that the values obtained with the digital caliper was lower than the values obtained with image processing. However, there was no great difference between the two methods. But, it can be said that image processing method gives more correct result because it minimizes human errors. Geometric mean diameter, sphericity, surface area and volume of the loquat cultivars computed with image processing ranged from 40.10 to 48.69 mm, 81.54 to 91.16%, 50.70 to 74.82 cm^2 and 34.13 to 61.25 cm^3, respectively. The average values of the geometric mean diameter were calculated as 48.69 mm ('KKTC3'), 48.52 mm ('KKTC4'), 48.34 mm ('Guzelyurt 6'), 43.53 mm ('Akko XIII'), 42.05 mm ('Sayda'), 41.10 mm ('Hafifcukurgobek') and 40.10 mm ('Champagne de Grasse'). The geometric mean diameter value of 'KKTC3' (48.69 mm) was greater than those of the other cultivars. Cv. 'Champagne de Grasse' also had smaller geometric mean diameter value. The highest value of sphericity was obtained from cv. 'Sayda' (91.16%), followed by cvs. 'Champagne de Grasse' (86.48%), 'Hafifcukurgobek' (85.93%) and 'KKTC3' (85.29%), while cv. 'Akko XIII' (81.54%) had the smallest sphericity value. 'Sayda' cultivar tended toward round rather than elongated. Surface area and volume values of the loquat cultivars and genotypes were parallel to each other. Surface area and volume values of the loquat cultivars and genotypes were found as 74.82 and 61.25 cm^3 for genotype 'KKTC3', 74.34 and 60.74 cm^3 for genotype 'KKTC4', 73.66 and 59.75 cm^3 for cv. 'Guzelyurt 6', 59.80 and 43.78 cm^3 for cv. 'Akko XIII', 55.74 and 39.34 cm^3 for cv. 'Sayda', 53.22 and 36.68 cm^3 for cv. 'Hafifcukurgobek' and 50.70 and 34.13 cm^3 for cv. 'Champagne de Grasse', respectively. 'KKTC3' genotype had the highest surface area and volume values, while cv. 'Champagne de Grasse' had the lowest surface area and volume values.

Projected area, equivalent diameter, perimeter and shape factor of the loquat cultivars and genotypes were determined for both vertical orientation and horizontal orientation with image processing (Table 3). The mean value, standard deviation, range and coefficient of variation of each parameter are shown in Table 3. This size and shape values of the loquat cultivars and genotypes were found to be statistically significant at the 5% level. The average values of projected area, equivalent diameter and perimeter of the loquat cultivars and genotypes ranged from 10.89 to15.81 cm^2, 37.17 to 44.78 mm, and 132.40 to 167.00 mm, respectively in the vertical, and 13.47 to 19.59 cm^2, 41.35 to 49.81 mm, and 149.93 to 186.50 mm, respectively in the horizontal orientation. It was observed that the values obtained from genotype 'KKTC3' was highest for projected area, equivalent diameter, and perimeter, with a mean of 15.81 cm^2, 44.78 mm, and 167 mm, respectively in the vertical orientation. But, in the horizontal orientation, genotype 'KKTC4' had the highest values of projected area and equivalent diameter, with a mean of 19.59 cm^2, and 49.81 mm, respectively. However, the highest perimeter value was obtained from cv. 'Guzelyurt 6' (186.66 mm). Cv. 'Champagne de Grasse' had the lowest values of projected area, equivalent diameter, and perimeter, with a mean of 10.89 cm^2, 37.17 mm, and 132.40 mm, respectively in the vertical orientation, and 13.47 cm^2, 37.17 mm, 149.93 mm, respectively in the horizontal orientation.

The shape factor values in the vertical and horizontal orientation ranged from 0.72 to 0.78 and 0.69 to 0.75, respectively. The loquat cultivars and genotypes tended toward round rather than elongated. Cv. 'Sayda' and 'Champagne de Grasse' had higher shape factor value than those of the other loquat cultivars and genotypes in both vertical and horizontal orientation. Thus, it was observed that cv. 'Sayda' and 'Champagne de Grasse' was more round than the others (Figure 1). 'Güzelyurt-6' cultivar had lower shape factor value (0.69) in horizontal orientation, and cv. 'KKTC3' had lower shape factor value in the vertical orientation. Because the loquat cultivars and genotypes in the vertical orientation was more sphere appearance than horizontal orientation, the shape factor ranges in the vertical orientation was found close to 1, indicating accurate sphere.

The results of comparison between the digital caliper and image processing are shown in Figure 4. The co-efficient of determination (R^2) for geometric mean diameter, sphericity, surface area and volume were 0.97, 0.90, 0.97 and 0.96, respectively. It is observed that the

Table 3. Size and shape features of loquat cultivars and genotypes computed with image processing.

Cultivars and genotypes	Parameter	Vertical orientation			
		Projected area (cm^2)	Equivalent diameter (mm)	Perimeter (mm)	Shape factor
Akko XIII (n=56)	Mean±SD	12.08±1.74c[1]	39.11±2.89b	141.78±13.8c	0.76±0.07ab
	Range	7.18-15.54	30.23-44.48	110.75-175.57	0.60-0.86
	CV%	14.40	7.39	9.73	9.21
Champagne de Grasse (n=48)	Mean±SD	10.89±1.25d	37.17±2.14c	132.40±10.10d	0.78±0.06a
	Range	8.40-13.84	32.70-41.97	111.8-155.36	0.62-0.87
	CV%	11.48	5.76	7.63	7.69
Guzelyurt 6 (n=52)	Mean±SD	15.11±1.76b	43.79±2.55a	161.89±14.33ab	0.73±0.07bc
	Range	11.8-19.4	38.77-49.7	136.11-191.02	0.60-0.83
	CV%	11.65	5.82	8.85	9.59
Hafifcukurgobek (n=52)	Mean±SD	11.36±1.36d	37.97±2.29c	138.37±11.04c	0.75±0.07b
	Range	7.78-14.06	31.47-42.31	110.25-165.89	0.61-0.86
	CV%	11.97	6.03	7.98	9.33
KKTC3 (n=48)	Mean±SD	15.81±1.98a	44.78±2.85a	167.00±15.86a	0.72±0.08c
	Range	11.19-19.62	37.74-49.98	131.22-200.16	0.55-0.85
	CV%	12.52	6.36	9.50	11.11
KKTC4 (n=56)	Mean±SD	15.26±2.06ab	43.97±2.99a	159.61±14.99b	0.76±0.08ab
	Range	11.09-19.56	37.58-49.9	132.19-192.42	0.61-0.86
	CV%	13.50	6.80	9.39	10.53
Sayda (n=52)	Mean±SD	12.65±1.49c	40.07±2.36b	142.87±11.38c	0.78±0.06a
	Range	9.47-16.51	34.72-45.84	120.28-170.98	0.62-0.86
	CV%	11.78	5.89	7.97	7.69
		Horizontal orientation			
Akko XIII (n=56)	Mean±SD	15.69±2.15b	44.58±3.1b	166.56±14.46b	0.71±0.06bc
	Range	11.12-19.79	37.63-50.19	139.31-194.03	0.55-0.80
	CV%	13.70	6.95	8.68	8.45
Champagne de Grasse (n=48)	Mean±SD	13.47±1.57c	41.35±2.40c	149.93±9.50c	0.75±0.05a
	Range	10.17-17.46	35.99-47.15	124.4-176.01	0.61-0.85
	CV%	11.66	5.80	6.34	6.67
Güzelyurt-6 (n=52)	Mean±SD	19.22±2.17a	49.40±2.79a	186.66±12.68a	0.69±0.05c
	Range	14.8-24.89	43.41-56.30	158.48-212.61	0.62-0.79
	CV%	11.29	5.65	6.79	7.25
Hafifçukurgöbek (n=52)	Mean±SD	13.80±1.52c	41.85±2.34c	155.28±10.03c	0.72±0.05b
	Range	9.64-17.51	35.04-47.21	136.23-175.26	0.60-0.80
	CV%	11.01	5.59	6.46	6.94
KKTC3 (n=48)	Mean±SD	19.35±2.69a	49.51±3.52a	186.50±18.49a	0.70±0.07bc
	Range	12.93-24.43	40.58-55.77	146.73-221.98	0.58-0.82
	CV%	13.90	7.11	9.91	10.00
KKTC4 (n=56)	Mean±SD	19.59±2.89a	49.81±3.70a	184.42±17.17a	0.72±0.05b
	Range	13.51-26.30	41.47-57.87	145.41-223.42	0.63-0.81
	CV%	14.75	7.43	9.31	6.94
Sayda (n=52)	Mean±SD	14.18±1.58c	42.42±2.38c	153.98±10.74c	0.75±0.05a
	Range	10.86-17.41	37.18-47.08	133.8-176.68	0.60-0.84
	CV%	11.14	5.61	6.97	6.67

[1]Means followed by the same letter in the column are not different as determined by the Duncan test at a 5% significance level.

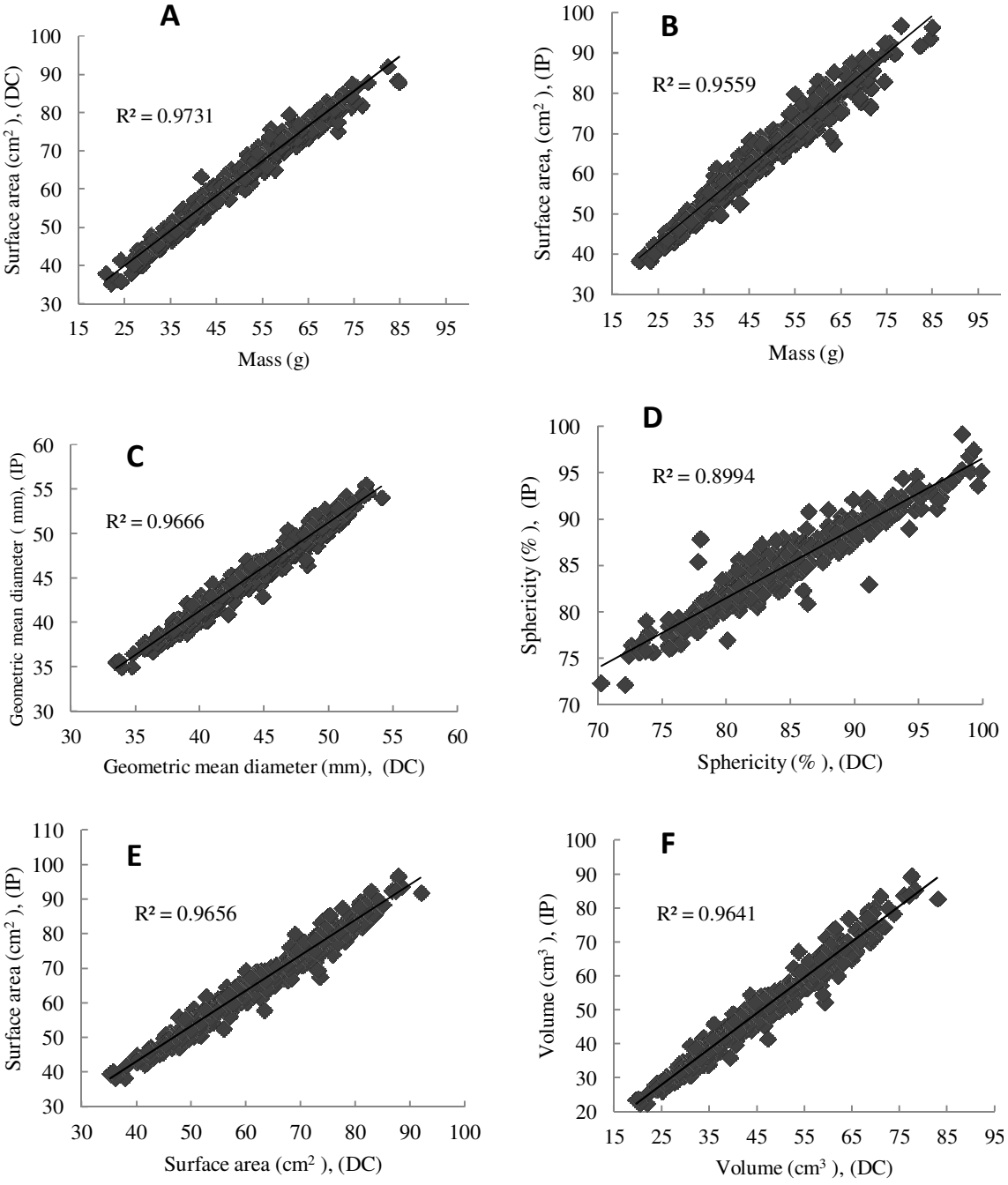

Figure 4. Comparison of computed and measured some physical properties of loquat cultivars and genotypes with digital caliper (DC) and image processing method (IP) (n=364).

results obtained from the image processing and digital caliper are very close to each other. The higher the R^2 values, the closer the image processing results are to digital caliper results. Besides, correlation plot of mass by surface area for both digital caliper and image processing are shown in Figure 4. The relationships between the mass and surface area were determined, and a high correlation was found for both methods. The R^2 values of these methods were 0.97 and 0.95, respectively. If the fruit density is assumed to be constant, then mass of fruit can readily be estimated from its surface area. The high R^2 values show that image processing may be adequate for designing and developing a specific sizing system for loquat and genotypes based on their masses and volumes, and for estimating the surface area and geometric mean diameter of the loquat cultivars and

genotypes. Khoshnam et al. (2007) stated that real –time measurement of fruit mass is a time consuming task, however, a volume based sorting system may provide an alternative and more efficient method than weight sorting. Koc (2007) compared volume of watermelons (‘*Citrullus lanatus*’) measured by using image processing with water displacement method. He stated that the difference between the volumes estimated by image processing and water displacement was not statically significant. Similarly, Omid et al. (2010) estimated volume and mass of citrus fruits by using image processing and water displacement method. They determined that the coefficient of determination (R^2) for citrus fruits ranged from 0.96 to 0.99.

Conclusions

Some physical properties of the five loquat cultivars and two genotypes were determined by using the digital caliper and image processing. Projected area, equivalent diameter, perimeter, and shape factors were obtained from vertical and horizontal. Length, major diameter, minor diameter, elongation, geometric mean diameter, sphericty, surface area, and volume are very important in distinguishing the loquat cultivars and genotypes in terms of gravimetric and dimensional. Loquat cultivars and genotypes showed dimensional and gravimetric properties different from each other; while ‘Güzelyurt 6’, ‘KKTC3’, and ‘KKTC4’ had the highest dimension and gravimetric, ‘Champagne de Grasse’ had the lowest values. When compared to results of the digital caliper and image processing, the values obtained with the digital caliper and image processing was close to each other. The high R^2 values obtained from this research ranged from 0.90 to 0.97. The results of comparison between the digital caliper and image processing showed that using the image processing method could potentially be rapid and alternative to the conventional measurement methods. The size and shape features obtained in the present study for the five loquat cultivars and two genotypes can be used to distinguish cultivars and genotypes from each other and can also be used to determine the parameters for sorting and post-harvest processing that should be incorporated in the equipment design.

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