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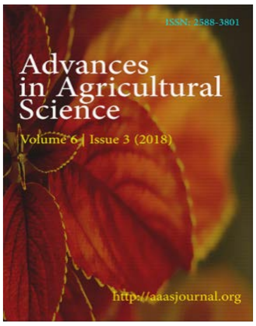

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Physico-mechanical, colour and chemical properties of selected cherry laurel genotypes of Turkey

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ABSTRACT

This study was carried out to determine the physico-mechanical (geometric, volumetric, fricitional, fruit removal force, compression force and puncture force), colour and chemical properties (titratable acidity, soluble solid content and pH) of three cherry laurel genotypes (*54 K 01*, *55 K 07* and *61 K 04*) cultivated in Turkey. The geometric properties such as geometric mean diameter and sphericity were found in the range of 13.3 to 17.4 for fruit, 8.3 to 9.6 mm for fruits pit and 6.1 to 6.9 mm for kernel of cherry laurel *54 K 01*, *55 K 07* and *61 K 04* genotypes, respectively. *54 K 01* cherry laurel genotye had the highest volumetric properties such as bulk densit and true density for fruits, whereas, *55 K 07* genotype for stone had the least values among these three cherry laurel genotypes for these properties. *54 K 01* genotype had the highest colour values for L*, a*, and b* of fruits as 24.1, 16.2, 2.4 and its stone as 40.8, 11.2, 14.3 among three cherry laurel genotypes, *54 K 01* had the lowest L*, a*and b* values for kernel of cherry laurel fruits as 42.0, 7.7 and 12.9, respectively. The fruit removal force ranged from 0.38 to 0.59 N, whereas, the puncture force for *X*-, *Y*-, *Z*- axes from 0.39 to 0.75 N; from 0.37 to 0.65 N, from 0.39 to 0.55 N, among three cherry laurel genotypes, respectively. The static friction coefficient of cherry laurel fruit, its stone and kernels changed from 0.29 to 0.72 (fruit), 0.41 to 0.93 (stone), from 0.34 to 0.60 (kernel), respectively. The coefficient of friction of cherry laurel fruit, its stone and kernels were largely influenced by the friction surfaces studied, and highest values were found genotypes. It is important to determine physico-mechanical (geometric, volumetric, frictional, fruit removal force, puncture) and rupture force, colour and chemical properties of particular fruit, its stone and kernels for selected cherry laurel genotypes which may increase fruit quality, economic value for harvest and post harvest technologies. Therefore, these properties should be considered.

Introduction

Cherry laurel (*Laurocerasus officinalis* Roem.) originated in Anatolia, West, Centre of Asia, south-eastern Europe, and cherry laurel has the potential to be exploited as a alternative food and a natural source as compounds (Ansin and Ozkan 1993). Black Sea region of Turkey has a rich gene pool of genotypes adapted to different local conditions, and cherry laurel cultivation has a long history in Turkey

(Karadeniz and Kalkisim, 1996; Bostan and Islam, 2003).

The cherry laurel tree has pleasant fruits when fully ripe and also is a valuable fruit for industrial uses. Production of this fruit has increased over time and evaluation possibilities are varied (Sulusoglu *et al.*, 2015). The cherry laurel fruits are consumed directly both fresh and dried as well as in the form of jam, pulp, marmalade, and drinks (Ayaz *et al.*, 1997).

The physico-mechanical, colour and chemical properties are important to post-harvest technologies of the agricultural materials. The physico-mechanical, colour and chemical properties engineering properties of cherry laurel fruit, its stone and kernel must be considered like cherry laurel fruit quality parameters in harvest and post-harvest applications. For cherry laurel fruit marketing, size dimension, firmness, colour and chemical properties must be considered for consumer. The knowledge of the size distribution of cherry laurel fruits, its stone and kernel is essential for the adequate design of the equipment for cleaning, grading and separation. The mechanical behaviours must be analyzed before fruits processed as jam, pulp, marmalade, and drinks (Altuntas and Ozturk, 2013). Fruit firmness is a quality parameter directly related to cherry laurel fruits shelf life (Valero *et al.*, 2007). Removal force of cherry laurel fruit from stem was an important matter for machine harvesting and preharvest drop of fruits. The lower fruit removal force causes the most economic loss (Ozkan *et al.*, 2012).

The knowledge of physico-mechanical, colour and chemical properties of the cherry laurel fruits and its stone and kernel is of importance to agricultural engineers, plant breeders, food scientists, machine manufacturers, consumers and processors (Ozturk *et al.*, 2009). Cherry laurel fruit quality is the combination of the texture, flavour and visual appearance of the fruit. The consumers demand the firmness, the optimal texture and the excellent appearance of the cherry laurel fruits. The physico-mechanical, colour and chemical properties of cherry laurel fruit must be considered like cherry laurel fruit quality parameters in harvest and post-harvest applications. Therefore, it is important to determine the physico-mechanical, colour and chemical properties of particular cherry laurel fruit, its stone and kernels which may increase its economic value.

Several researchers have investigated the physico-mechanical, colour and chemical properties for some fruits such as kiwifruit (Razavi and Parvar 2007), cherry tomato varieties (Kabas and Ozmerzi 2008); oil fruit (Kılıçkan and Güner 2008); medlar (*Mespilus germanica* L.) (Altuntas *et al.*, 2011), Japanese flowering crab apple (*Malus floribunda L.*) (Altuntas and Karaosman, 2015); service tree (*Sorbus domestica* L.) (Altuntas *et al.*, 2015); cherry laurel (Ozturk et al., 2016; Ozturk et al., 2017; Öztürk et al., 2017), respectively.

No detailed study concern the physico-mechanical such as geometric, volumetric, frictional, puncture, rupture force, fruit removal force), colour and chemical properties of selected cherry laurel genotypes of Turkey were not studied and comparatively. Therefore, physico-mechanical such as geometric, volumetric, colour and frictional, puncture, rupture force, fruit removal force) colour and chemical properties of cherry laurel fruit for three cherry laurel (*54 K 01, 55 K 07* and *61 K 04*) genotypes cultivated in Turkey were investigated in this study. In addition, the physico-mechanical and colour properties of the cherry laurel fruit's stone and kernel samples of the selected three cherry laurel genotypes were determined in this study.

Materials and Methods

This research was conducted on physico-mechanical, colour and chemical properties of three cherry laurel genotypes (*54 K 01, 55 K 07* and *61 K 04*) cultivated in Turkey. For this study, the cherry laurel genotype fruits were obtained from Black Sea Agricultural Research Institute in Samsun-city (*40° 05' and 41° 45' N latitude, 37° 08' and 34° 30' E longitude and 4 m altitude*) of Turkey. Harvested cherry laurel fruits were transferred to the laboratory in polyhthene bags to reduce water loss during transport. Fruits were picked by hand at commerical harvest criteria (skin colour) for each genotype in 2016 (15 Agust).

To determine size dimension of the cherry laurel fruit, its stone and kernel samples, one hundred cherry laurel fruits from each genotypes (*54 K 01, 55 K 07* and *61 K 04*) were randomly taken and the fruits were cleaned to remove all foreign matter sand immature, decayed and spoilt fruits. The length, width and thickness of cherry laurel fruit, its stone and kernel samples were measured by using a digital-micrometer (*Model No; 3109-25A, Insize Co., China, 0.01 accuracy*), and the masses of cherry laurel fruit, its stone and kernels were measured by using a digital electronic balance (*Model No; 612-1S, Sartorius Secura, Göttingen, Germany, 0.01 g. sensitive*). The geometric mean diameter (D_g), the fruit, its stone and kernel volume of cherry laurel genotypes, sphericity (Φ) and surface area (S) were calculated using the following equation (Mohsenin, 1986):

$$D_g = (LWT)^{1/3} \quad (1)$$

$$V = \left(\frac{\pi}{6}\right) \times LWT \quad (2)$$

$$\Phi = \left[\frac{(LWT)^{1/3}}{L}\right] \times 100 \quad (3)$$

$$S = \pi D_g^{\ 2} \quad (4)$$

True density (ρ_t) and bulk density (ρ_b) of cherry laurel fruit, its stone and kernel samples for *54 K 01, 55 K 07* and *61 K 04* genotypes were determined by hectoliters standard weight method (Singh and Goswami, 1996), and the fruit density is determined by the toluene (C_7H_8) displacement method, respectively (Mohsenin, 1986). The porosity (ε) was calculated using the following equation (Mohsenin, 1986):

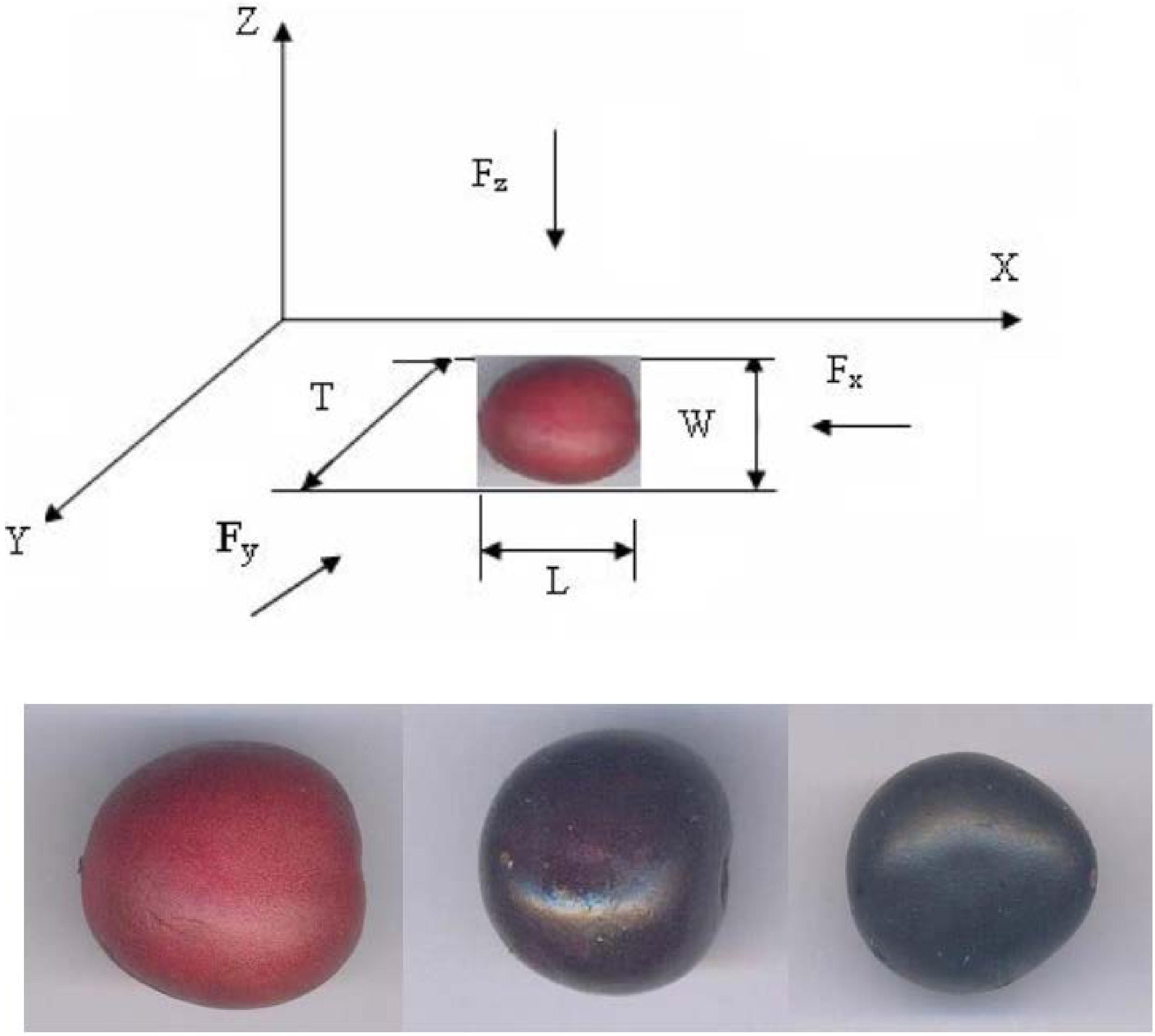
$$\varepsilon = \left[1 - \frac{\rho_b}{\rho_f}\right] \times 100 \quad (5)$$

Where, ρ_b and ρ_t the bulk density and the true density, respectively (Mohsenin, 1986).

The initial moisture content of cherry laurel fruit, its stone and kernel samples was determined by using a standard method (Brusewitz, 1975). Moisture content of fruit, its stone and kernel of the three cherry laurel genotypes are presented in Table 1.

The images and projected areas of cherry laurel fruit along X- and Y- axes, its stone and kernel samples along Z-axis have been analyzed by using *Brava! Reader v.16.0* software in this study,. For projected area measurement, each fruit, its stone and kernel of three cherry laurel genotypes should be placed on a sheet of paper and be photocopied. Then, to measure the actual fruit, its stone and kernel projected area, an image analysis software (*Brava! Reader*) were used. *Brava! Reader* is a powerful viewer developed by Informative Graphics Corporation and it's used for browsing, editing and printing photos. It has a nice GUI and an easy-to-use menu that allows the users to make the most of this piece of software. The viewer comes with basic CAD functions like measuring angles, distances, polylines and circles. What makes this piece of software different from other similar applications is the ease it provides in using common tools. One of the key features is the zoom tool that it provides, as it allows the users to zoom in and out of a picture without decreasing the quality of the photo. Also the magnifier tool is proven to be useful when one wishes to magnify just one area of the picture.

The colour characteristics of the cherry laurel fruit, its stone and kernel samples for three (*54 K 01, 55 K 07, 61 K 04*) genotypes were determined by using a Minolta colourimeter (Model CR-3000, Konica Minolta, Osaka, Japan) in terms of L*, a* and b* values. *L** denotes the lightness or darkness; a* is green or red colour; b* is blue or yellow colour of the cherry laurel fruit, its stone and kernel samples for *54 K 01, 55 K 07* and *61 K 04* genotypes.



54 K 01 *55 K 07* *61 K 07*

Figure 1. Representation of the three axial forces (F_x, F_y and F_z), three perpendicular dimensions of *54 K 01* cherry laurel genotype fruit samples, and three cherry laurel genotype fruits.

The colours were measured by colourimeter for each fruit, its stone and kernel samples as the means of three replication values (Jha *et al.*, 2005).

The coefficient of friction of cherry laurel genotypes for fruit, its stone and kernel samples is defined as tangent value of the angle of slope between sliding surface and vertical and horizontal planes (Celik *et al.*, 2007). The experiment was conducted by using PVC, plywood, galvanized metal, glass and rubber friction surfaces by a friction device. To determine the mechanical behavior such as puncture force and compression force of the the cherry laurel fruit, its stone and kernel samples for three (*54 K 01*, *55 K 07* and *61 K 04*) genotypes, a biological materials test device (*Sundoo, SH–2, 500 N, China*) was used. This device has three main components: a moving platform, a driving unit and a data acquisition (load cell, PC card and software) system. The fruit sample was placed on the moving platform and loaded and pressed with a plate fixed until the cherry laurel fruit ruptured by compressed and punctured or cutted. The *X*- axis (force F_x) is the longitudinal axis (length), the *Y*- axis (force F_y) is the transverse axis (width) at right angles to the *X*- axis in the plane of the suture, and the *Z*- axis (force F_z) is the transverse axis (thickness) at right angles to the plane of the suture (Figure 1).

Removal forces of cherry laurel fruits (RF), were measured by a hand dynamometer (*Tronic; HF–10, Digital Dynamometer, 100 N, Taiwan*). To determine of RF of cherry laurel fruits, twenty sample fruits were measured for each genotype as three replicates (Jolliffe, 1975). The fruit mass of cherry laurel *RF* relationship *(M/RF)* was calculated for genotype according to the method of Sahin (2007).

For each genotype, the soluble solids content (SSC), TA (titratable acidity) and, pH of cherry laurel fruits were determined by the method of the Association of Official Analytical Chemists (Cemeroglu, 2013). A sample of juice was also taken from cherry laurel fruit samples, and SSC was measured using a digital refractometer (*PAL-1; McCormick Fruit Tech., Yakima, Wash*) and was expressed as a percentage. The pH values were measured with a pH meter (*HI9321; Hanna instruments, Padova, Italy*). Titratable acidity was determined by titrating to pH 8.1 with 0.1 N sodium hydroxide (NaOH) and was expressed as percent malic acid. The results for SSC, and titratable acidity were the average of three measurements in each replication.

The data sets were analyzed with ANOVA by using SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA) software. Tukey's range test was used to compare treatments when ANOVA showed significant differences among means. The level of significance was set as 5%.

Results and Discussion

The physico-mechanical (geometric, volumetric, frictional, mechanical behaviour) properties colour and chemical characteristics of the fruits, its stone and kernel of the different three cherry laurel genotypes (*54 K 01, 55 K 07* and *61 K 04*) were evaluated in this study.

Physical properties

Geometric and volumetric properties

The geometric and volumetric properties of fruits, its stone and kernel of the different three cherry laurel genotypes (*54 K 01, 55 K 07* and *61 K 04*) are given in Table 2, respectively. The length, width and thickness of the fruit of the three cherry laurel genotypes varied from 13.1 mm, 13.9 mm and 12.9 mm (*55 K 07* genotype) to 19.6 mm, 17.0 mm and 15.9 mm (*61 K 04* genotype), respectively. The length, width and thickness varied statisticaly significantly for all the three genotypes ($p<0.05$). The geometric mean diameter (D_g), sphericity (Φ) and surface area (*S)* of the cherry laurel genotypes ranged from 13.3 to 17.4 mm, 88.8% to 99.99%, 5.6 cm^2 to 9.54 cm^2, respectively. The highest sphericity was found of *55 K 07* cherry laurel genotype for fruit, its stone and kernel. Significant differences were found for sphericity between seed of the cherry laurel fruit, its stone and kernel samples (Table 2).

Sphericity indicated that the shape of the biological materials is spherical and thus makes it easy to roll on surface. The sphericity of the *54 K 01* genotype fruit is the low tendency of the shape towards a sphere between genotypes of the cherry laurel studied. The highest geometric mean diameter and surface area were found for fruits and kernel of *61 K 04* genotype at the moisture content 64.1% and 41.0% w.b. (wet basis), whereas, the highest geometric mean diameter and surface area for cherry laurel fruit's stone samples was found of *54 K 01* genotype at the moisture content 26.7% w.b., respectively.

Owolarafe *et al.* (2007) have reported that the sphericity of the fresh *D*ura and

Table 1. Moisture content levels (% wet basis) of cherry laurel genotypes for fruit, its stone and kernel.

Cherry laurel genotypes	***Moisture content (%)***		
	Fruits	***Stone***	***Kernel***
54 K 01	60.38±0.09 b	27.16±1.63 b	34.27±0.34 b
55 K 07	61.29±0.57 b	35.86±2.36 a	7.89±1.25 c
61 K 04	64.13±0.62 a	29.71±3.93 ab	40.79±0.56 a

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at P <0.05.

Table 2. The geometric properties of fruit, its stone and kernel of the different cherry laurel genotypes.

Cherry laurel genotypes	***Length L (mm)***	***Width W (mm)***	***Thickness T (mm)***	***Geometric mean diameter D_g (mm)***	***Sphericity Φ (%)***	***Surface area S (cm^2)***
Fruits						
54 K 01	17.38±0.12 b	17.65±0.15 a	16.86±0.14 a	17.24±0.13 a	99.17±0.28 b	9.39±0.14 a
55 K 07	13.11±0.12 c	13.94±0.11 c	12.89±0.09 c	13.27±0.10 b	99.99±0.29 a	5.56±0.09 b
61 K 04	19.63±0.13 a	17.02±0.09 b	15.93±0.09 b	17.40±0.09 a	88.80±0.28 c	9.54±0.10 a
Stone						
54 K 01	12.17±0.05 a	9.18±0.05 a	7.97±0.02 a	9.60±0.03 a	78.89±0.27 b	2.90±0.02 a
55 K 07	10.52±0.77 b	7.85±0.05 c	7.18±0.03 b	8.25±0.09 c	83.57±0.82 a	2.17±0.07 c
61K 04	12.61±0.10 a	8.24±0.06 b	7.09±0.04 b	9.01±0.06 b	71.53±0.21 c	2.56±0.03 b
Kernel						
54 K 01	9.14±0.06 a	5.61±0.04 b	5.10±0.04 b	6.37±0.04 b	69.93±0.43 b	1.28±0.02 b
55 K 07	8.88±0.71 a	5.42±0.03 c	5.09±0.04 b	6.10±0.08 c	75.35±0.92 a	1.19±0.04 c
61K 04	9.52±0.31 a	6.21±0.03 a	5.70±0.04 a	6.91±0.05 a	74.16±0.55 a	1.51±0.03 a

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at P <0.05.

fresh *Tenera* varieties of palm fruits were found to be 70.67% and 64.23%, respectively. Haciseferogullari *et al.* (2005) reported that the the geometric mean diameter and sphericity of the wild medlar were as 0.90 and 28.9 mm at 72.2% dry basis moisture content, whereas, Altuntas *et al.* (2013) reported that the mean sphericity, surface area, and fruit volume of medlar were reported as 0.97, 29.7 cm^2, and 15.3 cm^3, respectively.

Altuntas (2015) reported that the sphericity and geometric mean diameter of Juniper berries were reported as 8.30 mm, 96.7%, respectively. The mean geometric mean diameter, surface area, fruit volume, and the sphericity of Japan flowering crabapple were reported as 34.0 mm, 36.5 mm^2, 21.1 mm^3, and 97.7%, by Altuntas and Karaosman (2015), respectively. The sphericity of cherry laurel fruits stone and kernel is lower than reported for medlar (Haciseferogullari et al (2005); Altuntas *et al.* (2013), Japan flowering crabapple fruits (Altuntas and Karaosman, 2015), and Juniper berries fruits (Altuntas, 2015), while, the sphericity of the cherry laurel fruits stone and kernel was generally higher than the fresh *Dura* and *Tenera* varieties (Owolarafe *et al.*, 2007).

The relationship between length, width, thickness, geometric mean diameter, sphericity, and surface area of cherry laurel fruit, its stone and kernel samples (Table 3). The relations between L/D_g and *L/S* have been found to be statistically significant for all cherry laurel genotypes (*54 K 01*, *55 K 07* and *61 K 04*) in fruit, its stone and kernel. The correlation coefficients (R) for cherry laurel fruit, its stone and kernel samples these relations for were determined as follows:

For fruit;

54 K 01 genotype: $L = 0.99W = 1.73T = 1.01D_g = 1.87S$

55 K 07 genotype: $L = 0.94W = 1.02T = 0.99D_g = 2.38S$

61 K 04 genotype: $L = 1.15W = 1.23T = 1.13D_g = 2.07S$

For stone;

54 K 01 genotype: $L = 1.33W = 1.53T = 1.27D_g = 4.22S$

55 K 07 genotype: $L = 1.34W = 1.47T = 1.23D_g = 4.71S$

61 K 04 genotype: $L = 1.53W = 1.78T = 1.40D_g = 4.97S$

For kernel;

54 K 01 genotype: $L = 1.64W = 1.80T = 1.44D_g = 7.20S$

55 K 07 genotype: $L = 1.63W = 1.78T = 1.39D_g = 7.13S$

61 K 04 genotype: $L = 1.53W = 1.68T = 1.36D_g = 6.28S$

The projected area of three genotypes of cherry laurel fruit, its stone and kernel samples were presented in Table 4. The highest projected area was found for fruits along *X-, and Y-axes* as 27.98 cm^2 and 29.98 cm^2 in *54 K 01* genotype. For cherry laurel fruit stone samples, the projected area was found lowest and highest along *Z- axis* as 7.33 cm^2 and 5.01 cm^2 in *54 K 01* and *55 K 07* genotypes, respectively. For kernel samples of cherry laurel, the projected area was found lower along *Z- axis* as 2.88 cm^2 in 55 K 07 than those 54 K 01 and 61 K 04 genotypes.

The projected area of persimmon fruit (cv. *Fuyu*) along X- and Y-axes varied from 25.4 to 32.1 cm^2; 35.1 to 45.3 cm^2, by Altuntas *et al.*, 2011, respectively. Celik and Ercisli (2008) reported that the projected area along X- and Y- axes of persimmon (cv. *Hachiya*) were reported as 4.93, 4.59 mm^2, respectively. Altuntas *et al.* (2013) reported that the projected area along X- and Y-axes for medlar fruits were found as 7.20 cm^2 and 6.87 cm^2 at the physiological maturity, respectively. Haciseferogullari *et al.* (2005) reported that the projected area was as 9.3 cm^2 at ripening period medlar fruits. The projected areas of the cherry laurel fruits for three 54 K 01, 55 K 07 and 61 K 04 genotypes were found higher than those of Haciseferogulları *et al.* (2005), Altuntas *et al.* (2013), whereas, the projected areas of the cherry laurel fruits were found lower than that of Celik and Ercisli (2008); Altuntas *et al.* (2011), respectively.

The volumetric properties of three genotypes of cherry laurel fruit, its stone and kernel samples were presented in Table 5. The effects of genotypes on volumetric properties were statistically found significant. The unit mass of cherry laurel fruit, its stone and kernel samples were in the range of 1.63 to 4.28 g, 0.28 to 0.37 g, 0.10 to 0.16 g, whereas, unit volume of the cherry laurel genotypes were in the range of 1.25 to 2.81 cm^3 (for fruit), 0.31 to 0.47 cm^3 (for stone), 0.13 to 0.18 cm^3 (for kernel) respectively. The least unit mass and seed volume values for fruit, its stone and kernel were shown by *55 K 07* genotype, whereas, the highest unit mass and seed volume values for stone of cherry laurel fruit and its kernel were recorded for 61 K 04 genotype among three cherry laurel genotypes.

The porosity of the cherry laurel ranged from 51.26% (*54 K 01*) to 52.37% (*55 K 07*) for fruits,

Table 3. The correlation coefficient of cherry laurel genotype fruits, its stone and kernel at the different moisture content (w.b.), respectively.

Particulars Genotypes	Ratio	D.F	R	Particulars Genotypes	Ratio	D.F	R	Particulars Genotypes	Ratio	D.F	R
Fruits				**Stone**				**Kernel**			
54 K 01	**(60.38% w.b.)**			***54 K 01***	**(26.72% w.b.)**			***54 K 01***	**(34.29% w.b.)**		
L/W	0.9869	98	0.8395 **	L/W	1.3291	98	0.2162 ^{ns}	L/W	1.6377	98	0.2223 ^{ns}
L/T	1.0337	98	0.8080 **	L/T	1.5293	98	0.0917 ^{ns}	L/T	1.8015	98	0.2792 ^{ns}
L/D_g	1.0091	98	0.9274 **	L/D_g	1.2690	98	0.5713 *	L/D_g	1.4351	98	0.6373 *
L/ Φ	0.1754	98	-0.0114 ^{ns}	L/ Φ	0.1546	98	-0.6544 *	L/ Φ	0.1314	98	-0.6521 *
L/S	1.8760	98	0.9303 **	L/S	4.2151	98	0.5694 *	L/S	7.1975	98	0.6161 *
55 K 07	**(61.29% w.b.)**			***55 K 07***	**(36.51% w.b.)**			***55 K 07***	**(48.48% w.b.)**		
L/W	0.9398	98	0.8722 **	L/W	1.3438	98	0.0332 ^{ns}	L/W	1.6299	98	0.1661 ^{ns}
L/T	1.0173	98	0.8072 **	L/T	1.4680	98	0.0249 ^{ns}	L/T	1.7787	98	-0.1756 ^{ns}
L/D_g	0.9873	98	0.9513 **	L/D_g	1.2320	98	0.9089 **	L/D_g	1.3878	98	0.9504 **
L/ Φ	0.1296	98	-0.6148 *	L/ Φ	0.1607	98	-0.8634 **	L/ Φ	0.1611	98	-0.9006 **
L/S	2.3797	98	0.9506 **	L/S	4.7055	98	0.9625 **	L/S	7.1304	98	0.9758 **
61 K 04	**(64.13% w.b)**			***61 K 04***	**(28.448% w.b.)**			***61 K 04***	**(40.97% w.b.)**		
L/W	1.1539	98	0.5878 *	L/W	1.5317	98	0.8170 **	L/W	1.5344	98	0.1020 ^{ns}
L/T	1.2323	98	0.7019 **	L/T	1.7788	98	0.8091 **	L/T	1.6780	98	-0.0654 ^{ns}
L/D_g	1.1273	98	0.8869 **	L/D_g	1.3993	98	0.9359 **	L/D_g	1.3647	98	0.8867 **
L/ Φ	0.2215	98	-0.6464 *	L/ Φ	0.1767	98	-0.5766 *	L/ Φ	0.1370	98	-0.8898 **
L/S	2.0666	98	0.8898 **	L/S	4.9652	98	0.9384 **	L/S	6.2771	98	0.9307 **

D.F: Degress of freedom; R: Correlation coefficient; ^{ns} non significant, ** Significant at 1% level, * Significant at 5% level.

Table 4. The projected area of the fruit, its stone and kernel of the different cherry laurel genotypes (cm^2).

Cherry laurel genotypes	***Fruit***		***Stone***	***Kernel***
	X- axis	***Y- axis***	***Z- axis***	***Z- axis***
54 K 01	27.98±0.50 a	29.98±0.61 a	7.33±0.09 a	3.53±0.07 b
55 K 07	15.83±0.48 c	16.01±0.63 c	5.01±0.19 c	2.88±0.06 c
61 K 04	23.23±0.44 b	27.78±0.50 b	6.87±0.12 b	3.97±0.05 a

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at P <0.05.

from 39.13% (*54 K 01*) to 50.21 (*61 K 04*) for its stone, 33.42% (*54 K 01*) to 39.94% (*55 K 07*) for kernel, respectively. Porosity values were found lower in *54 K 01* genotype than the other genotypes for fruit, its stone and kernel samples. This may be due to differences of the volumetric properties of *54 K 01* genotype. The effect of species on porosity of cherry laurel fruit, its stone and kernels was found significantly ($p<0.05$).

The true densities of cherry laurel fruit, stone and kernels for the selected genotypes studied were changed from 1104.3 to 1149.1 kg m^{-3} (for fruit), 875.2 to 1072.6 kg m^{-3} (for stone), 991.2 to 1005.7 kg m^{-3} (for kernel), respectively. The lowest true density for stone and its kernel of the cherry laurel fruit was observed for *61 K 04* genotype, whereas, the lowest true density for fruit of cherry laurel was obtained from *55 K 07* genotype. The true density values for cherry laurel fruit, its stone and kernel for three genotypes were statistically found significant ($p<0.05$) (Table 5). The highest bulk density of cherry laurel fruit and kernel samples was found for

54 K 01 genotype (559.5 and 665.8 kg m^{-3}) and the lowest (525.4 and 599.4 kg m^{-3}) was observed for *55 K 07* genotype.

In this study, the unit masses for the cherry laurel fruit (ranged from 1.63 to 4.28 g), its stone (ranged from 0.28 to 0.32 g), and kernel (0.10 to 0.16 g) were found lower than reported by Owolarafe *et al.* (2007), which was 7.66 and 8.50 g for the fresh *Dura* and fresh *Tenera* varieties of palm fruits. The fruit volume of Japan flowering crabapple and date fruit (cv. *Dairi*) have been reported as 21.1 cm^3 and 5.49 cm^3 were reported by Altuntas and Karaosman (2015); Jahromi *et al.* (2008), respectively. The fruit volume of the cherry laurel fruits stone and kernel was generally lower than Japan flowering crabapple (Altuntas and Karaosman, 2015); the fresh *Dura* and *Tenera* varieties for fresh palm (Owolarafe *et al.*, 2007).

The fruit density of *Dura* and *Tenera* varieties for fresh palm as 1112.5 and 995.7 kg $m^{-3;}$ the bulk density of *Dura* and *Tenera* varieties as 659.4 and 611.0 kg m^{-3}; the porosity of *Dura* and *Tenera* varieties as 40.7 and 38.6% were reported by Owolarafe *et al.* (2007). that fruit and bulk densities; the porosity of date fruit (cv. *Dairi*) were reported as 970 kg m^{-3}, 490 kg m^{-3} and 49.14% by Jahromi *et al.* (2008), respectively. In this study, the similar results for the fruit and bulk densities, the porosity of the cherry laurel fruits stone and kernel have also been reported by Owolarafe *et al.* (2007). The fruit density and the porosity of the cherry laurel fruit among three cherry laurel genotypes were generally found higher than fresh palm varieties and date fruit (cv. *Dairi*) (Owolarafe *et al.* (2007); Jahromi *et al.* (2008), respectively. The porosity for the cherry laurel fruits among the selected genotypes (*54 K 01, 55 K 07* and *61 K 04)* is lower than reported for medlar, service tree and Juniper berries fruits (Altuntas *et al.* 2013; Altuntas *et al.*, 2015; Altuntas and Karaosman, 2015).

Colour characteristics

Colour characteristic (lightness, redness, and yellowness) values of the different cherry laurel genotypes for fruit, stone and kernel samples were presented in Table 6. The maximum lightness (L*) for fruit and its stone was found to be 24.08 and 40.78 for *54 K 01* cherry laurel genotype, whereas minimum L* value was recorded as 15.49 and 37.40 for *61 K 04* genotype, respectively. Significant differences ($p<0.05$) were found between cherry laurel fruit, stone and kernel among the cherry laurel genotypes for colour characterictics such as lightness, redness and yellowness.

Altuntas and Karaosman (2015) have reported the colour characteristics such as L*, a* and b* values of Japan flowering crab apple varied from 36.19 to 39.42; 22.67 to 26.30 and 20.02 to 23.92 for skin fruits, respectively. L*, a* and b* colour values were reported as 37.3 to 47.6; 5.0 to 11.7 and 19.5 to 26.0 at physiological maturity for skin medlar fruits, by Altuntas *et al.* (2013), respectively. Altuntas *et al.* (2015) have reported L*, a* and b* colour characteristics were found as 61.31; -8.92 and 30.64 at physiological maturity for skin service tree fruits, respectively. The skin colour of kiwifruit was found as L*, a* and b* values of 43.94, 5.51 and 24.04 by Celik *et al.* (2007), while the flesh colour of kiwi fruit as L* of 56.41, a* of -17.47 and b* of 32.35 reported by Beirão-da-Costa *et al.* (2006).

Lightness was found statistically different in between cherry laurel fruit genotypes for fruit, its stone and kernel samples. Ozkan *et al.* (2012) reported that the skin colour characteristics (L*, a* and b*) of Braeburn apple were as 44.21, 30.47, and 25.93, respectively. According to these results, our results related L* for cherry laurel fruits stone for each genotypes were similar to that reported for Japan flowering crab apple and medlar fruits by Altuntas and Karaosman (2015); Altuntas *et al.* (2013). The colour characteristics (L* and b*) of cherry laurel fruits are lower than reported for Braeburn apple (Ozkan *et al.* 2012), for Japan flowering crab apple Altuntas and Karaosman (2015), for service tree (Altuntas *et al.* (2015) respectively.

Table 5. The volumetric properties of the fruit, its stone and kernel of the different cherry laurel genotypes.

Cherry laurel genotypes	*Unit mass, M (g)*	*Volume, V (cm³)*	*Bulk density, ρ_f (kg m⁻³)*	*True density, ρ_f (kg m⁻³)*	*Porosity ε (%)*
Fruits					
54 K 01	4.280±0.060 a	2.751±0.061 a	559.50±4.9 a	1149.08±16.3 a	51.26±0.46 a
55 K 07	1.632±0.045 c	1.254±0.030 b	525.39±52.3 a	1104.34±17.8 b	52.37±4.84 a
61 K 04	3.372±0.043 b	2.805±0.042 a	543.44±3.7 a	1134.82±8.1 ab	52.10±0.29 a
Stone					
54 K 01	0.371±0.003 a	0.467±0.004 a	529.72±3.8 b	875.2±22.7 c	39.13±1.53 b
55 K 07	0.278±0.004 c	0.312±0.022 c	544.30±3.0 a	1072.55±24.9 a	48.96±1.42 a
61K 04	0.299±0.004 b	0.390±0.008 b	475.82±2.5 c	962.85±27.9 b	50.21±1.46 a
Kernel					
54 K 01	0.137±0.001 b	0.138±0.002 b	665.82±42.1 a	1005.67±23.2 a	33.42±2.18 b
55 K 07	0.100±0.002 c	0.128±0.010 b	599.51±14.7 b	999.79±14.0 a	39.94±0.90 a
61K 04	0.163±0.002 a	0.176±0.006 a	616.53±3.6 b	991.21±25.3 a	37.41±1.76 ab

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at $P < 0.05$.

Table 6. The colour characteristics properties of the fruit, its stone and kernel of the different cherry laurel genotypes.

Cherry laurel genotypes	L*	a*	b*
Fruits			
54 K 01	24.08±0.34 a	16.20±0.92 a	2.37±0.33 a
55 K 07	18.17±0.36 b	6.06±0.50 b	1.13±0.11 b
61 K 04	15.49±0.54 c	7.27±0.50 b	1.05±0.08 b
Stone			
54 K 01	40.78±0.79 a	11.18±0.16 a	14.33±0.33 a
55 K 07	39.76±0.75 a	11.18±0.13 a	11.41±0.53 b
61K 04	37.40±0.77 b	11.46±0.20 a	9.93±0.52 c
Kernel			
54 K 01	42.01±0.44 c	7.658±0.12 b	12.92±0.30 a
55 K 07	44.44±0.49 b	8.73±0.19 a	13.75±0.36 a
61K 04	46.74±0.69 a	8.81±0.21 a	13.69±0.40 a

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at $P < 0.05$.

As shown in Table 6 the lightness value (L*) of all types of fruits and kernel are statistically different. But *54 K 01* and *55 K 07* genotypes stones are statistically same. The most important colour value of cherry laurel genotypes is b* yellowness value. The positive b* values represent yellowness and negative b* values represent blueness. The b* values of all genotypes of kernel are the same. But the b* values of all genotypes stone are statistically different. According to the colour of the fruit a* and b* values of *54 K 01* are different from the other types. The a* and b* values of *55 K 07* and *61 K 04* are not statistically different. The reason of this is the colour of the *54 K 01*.

Frictional properties

The frictional properties (static coefficient of friction) of the fruit, its stone and kernel of the cherry laurel genotypes were given in Table 7. The static coefficient of friction for the fruit, its stone and kernel of three cherry laurel genotypes was determined on the plywood, galvanized metal, PVC, rubber, and glass surfaces. The static coefficient of friction was the lowest and the highest for the fruit, on rubber friciton surface as 0.724 and 0.598 for fruit and kernel in *55 K 07*, as 0.929 for its stone in *61 K 04* among cherry laurel genotypes, respectively. Cherry laurel fruit and its stone showed the highest static coefficient of friction for rubber surface among five surfaces, respectively. This may be due to more adhesion surface of than the other test surfaces. Static friction coefficient of the cherry laurel fruit, stone and kernel species largely influenced by friction surfaces. The static coefficient of friction for fruit ranged from 0.29 to 0.72 (for fruit), 0.413 to 0.929 (for its stone), 0.342 to 0.598 (for kernel) for studied friction surfaces, among the three cherry laurel genotypes, respectively. There were significant differences of the static friction coefficients among the cherry laurel genotypes on the five different surfaces statistically ($p<0.05$) (Table 7).

Altuntas (2015) have reported the static coefficient of friction of Juniper berries was found as 0.31 for chipboard; 0.22 for galvanized steel, 0.29 for mild steel; 0.26 for plywood; 0.54 for rubber surfaces, respectively. Demir and Kalyoncu (2003), reported that the static coefficient of friction of the cornelian cherry was reported between 0.96 for rubber; 0.91 for plywood; 0.85 for steel surfaces, respectively. Owolarafe *et al.* (2007) reported that the coefficient of static friction of of fresh palm fruit varieties (*cv. Dura* and *cv. Tenera*) were as 0.58 and 0.52 for plywood, 0.53 and 0.52 for aluminium, 0.56 and 0.52 for mild steel sheet, 0.56 and 0.53 for galvanized steel sheet respectively. The static coefficient of friction of Japan flowering crabapple fruits was found as 0.397 (laminate); 0.456 (plywood); 0.461 (chipboard) and 0.459 (rubber), respectively. Similar results related the highest static coefficient of frictions in rubber friction surface of the cherry laurel fruit (for *55 K 07),* its stone (for *61 K 07*) and kernel (for *55 K 07*) among all the selected genotypes were found for cornelian cherry and Juniper berries reported by Demir and Kalyoncu (2003), Altuntas (2015), respectively.

Mechanical properties

The fruit removal force, puncture force and rupture force of three cherry laurel fruits were presented in Table 8. The fruit removal force values 0.593 N for *54 K 01*, 0.375 N for *55 K 07*, and 0.438 N for *61 K 04* genotype samples. The fruit removal force of *55 K 07* and *61 K 04* genotypes showed statistically similar. Among three cherry laurel fruits, the the highest fruit removal force was found in *54 K 01* genotype at the same time, and also, it has been seen that *55 K 07* genotype has the lowest fruit removal force. Significant differences ($p<0.05$) were found between cherry laurel fruits among the cherry laurel genotypes for fruit removal force. The fruit removal force for *Golden Delicious* was as 16.57 N reported.by Gezer *et al.* (2000). The fruit removal force of three apples was 14.57 N for *Golden Delicious*, 9.86 N for *Starking Delicious*, by reported Sahin (2007). Our findings were found the lower than those reported by researchers.

The puncture force (skin firmness) of three cherry laurel genotypes such as *54 K 01*, *55 K 07 and 61 K 04* genotypes fruits punctured using with 1.2 mm needle probe along X-axis ranged from 0.385 N to 0.748 N. The skin puncture force for *55 K 07* genotype fruits was higher than those cherry laurel genotypes. The puncture forces among three cherry laurel genotypes, *54 K 01* ranged from 0.365 N and 0.388 N for *Y- and Z-* axes, respectively. For 55 K 07 genotype fruits the puncture forces along *X-, Y-, and Z-axes* were higher among the three cherry laurel genotypes. Altuntas et al. (2015) reported that the puncture force of service tree fruits along *X-* and *Y-axes* using with needle probe varied from 2.804 N at the physiological maturity. Altuntas and Karaosman (2015) reported that the puncture force

Table 7. The frictional properties of the fruit, its stone and kernel of the different cherry laurel genotypes.

Cherry laurel genotypes	**Static friction coefficient**				
	Plywood	**Galvanized metal**	**PVC**	**Rubber**	**Glass**
Fruits					
54 K 01	0.536±0.026 a	0.407±0.018 c	0.285±0.018 c	0.494±0.012 b	0.539±0.021 b
55 K 07	0.486±0.022 ab	0.674±0.020 a	0.523±0.027 a	0.724±0.019 a	0.626±0.013 a
61 K 04	0.412±0.019 b	0.585±0.022 b	0.416±0.016 b	0.442±0.022 b	0.489±0.018 b
Stone					
54 K 01	0.514±0.020 b	0.458±0.012 b	0.427±0.009 b	0.680±0.011 b	0.413±0.014 b
55 K 07	0.720±0.007 a	0.642±0.012 a	0.444±0.008 b	0.761±0.035 b	0.609±0.008 a
61K 04	0.791±0.017 a	0.650±0.022 a	0.613±0.019 a	0.929±0.024 a	0.664±0.023 a
Kernel					
54 K 01	0.493±0.012 a	0.435±0.004 a	0.423±0.011 ab	0.583±0.013 a	0.588±0.038 a
55 K 07	0.583±0.019 a	0.342±0.003 b	0.453±0.013 a	0.598±0.017 a	0.471±0.005 a
61K 04	0.494±0.012 a	0.359±0.005 ab	0.406±0.006 b	0.554±0.013 a	0.494±0.017 a

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at P <0.05.

of Japan flowering crabapple fruits using with 1.2 mm needle probe along *X*- and *Y-axes* ranged from 6.5 to 11.1 N and 6.5 to 12.9 N mm, respectively. Altuntas *et al.* (2013) reported that the puncture force of medlar fruits punctured using with needle probe at the physiological maturity was found as 28.2 N. According to these results, our results related rupture force of three cherry laurel genotypes fruits lower than the reported for previous studies (Altuntas *et al.*, 2013; Altuntas and Karaosman, 2015; Altuntas *et al.*, 2015).

Rupture force of the three cherry laurel fruits, its stone and kernels were presented Japan flowering crabapple fruits compressin Table 8. The rupture force of the three cherry laurel fruits, its stone and kernels using with cylindirical plate along *X*-, *Y*-, *and Z- axes* ranged from 0.413 to 0.740 N for fruits, from 1.684 to 2.970 N for fruits stone samples, and from 0.396 to 0.931 N for kernel of cherry laurel stones, respectively. The rupture force for cherry laurel fruits for *Y-axis* (0.740 N in *61 K 01* genotype) was higher than *X-, and Z-axes*. The rupture force for cherry laurel fruits stone and kernel samples for *X-axis* (2.970 in *54 K 01* and 0.931 N in *61 K 04* genotype) was higher than *Y*-, and *Z-axes*. Among three cherry laurel fruits, its stone and kernel samples, the the lowest rupture force was found in *55 K 07* genotype as 0.413 for fruits along *X- axis*, 1.684 N along *Y-axis*, and 0.396 N along *Z-axis*, respectively. Significant differences (p<0.05) were found between cherry laurel fruits, its stone and kernel among the cherry laurel genotypes for puncture force and rupture forces.

Altuntas *et al.* (2013) reported that the rupture force of medlar compressed using with cylindirical probe along *X*- axis ranged from 77.9 N at the physciological maturity. The rupture forces required when loading along the *X*- and *Y*- axes were found to be 46.85 and 35.45 N for service tree fruits by Altuntas *et al.* (2015). Our results related the rupture forces of cherry laurel fruits lower than the reported for previous studies (Altuntas *et al.*, 2013; Altuntas *et al.*, 2015).

Chemical properties

The effect of different genotypes on chemical properties (TA, SSC, and pH) were presented in Table 9. The effect of different genotypes on SSC, pH, TA of cherry laurel fruits were statistically significant (p<0.05). SSC of cherry laurel fruits was as 13.70%, 10.77% and 12.04% for different

Table 8. The mechanical characteristics of fruit, its stone and kernel of the different cherry laurel genotypes.

Cherry laurel genotypes	*Fruit removal Force (N)*	*Puncture force (N)* **(by 1.2 mm needle probe)**			*Rupture force (N)* **(by 79 mm circular table)**		
		X axis	***Y axis***	***Z axis***	***X axis***	***Y axis***	***Z axis***
Fruits							
54 K 01	0.593±0.025 a	0.385±0.038 b	0.365±0.020 b	0.388±0.037 b	0.523±0.050 a	0.560±0.064 a	0.578±0.074 a
55 K 07	0.375±0.025 b	0.748±0.080 a	0.648±0.094 a	0.551±0.047 a	0.413±0.045 a	0.545±0.065 a	0.460±0.048 a
61 K 04	0.438±0.024 b	0.346±0.022 b	0.416±0.016 b	0.371±0.021 b	0.525±0.054 a	0.740±0.120 a	0.517±0.071 a
Stone							
54 K 01	-	-	-	-	2.970±0.279 a	1.722±0.138 a	1.868±0.149 a
55 K 07	-	-	-	-	2.007±0.246 b	1.684±0.229 a	1.701±0.193 a
61K 04	-	-	-	-	2.638±0.225 ab	2.015±0.201 a	2.012±0.285 a
Kernel							
54 K 01	-	-	-	-	0.732±0.044 b	0.742±0.061 a	0.696±0.070 a
55 K 07	-	-	-	-	0.501±0.046 c	0.453±0.033 b	0.396±0.027 b
61K 04	-	-	-	-	0.931±0.064 a	0.715±0.044 a	0.725±0.044 a

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at P <0.05.

Table 9. The effect of different genotypes on chemical properties (TA, SSC, and pH).

Cherry laurel genotypes	**Chemical characteristics**		
	TA (g malic acid 100 g^{-1})	**SSC (%)**	**pH**
54 K 01	0.70±0.016 a	13.70±0.06 a	4.04±0.006 a
55 K 07	0.67±0.004 a	10.77±0.17 c	3.53±0.032 c
61 K 04	0.51±0.010 b	12.04±0.04b	3.68±0.015 b

The difference between mean values shown on the same column with same letter is not significant according to Duncan's Multiple Range test at P <0.05.

genotypes from *54 K 01, 55 K 07 and 61 K 04*, respectively.

pH and TA values of cherry laurel fruits were as 4.04 and 0.70 g 100 g^{-1} (*54 K 01*), 3.53 and 0.67 g 100 g^{-1} (*55 K 07*), 3.68 and 0.51 g 100 g^{-1} (*61 K 04*), respectively. Sulusoglu (2011) reported that the total soluble solid contents of different genotypes varied from 12.46% to 24.40% and titratable acidity contents varied from 0.12% to 0.62%. Macit and Demirsoy (2012) reported that TSS contents of cherry laurel genotypes were found to be between 13.5 and 26.7%. TSS contents of the promising genotypes in our study were similar to those of the other studies in Turkey.

Conclusion

The physico-mechanical, colour and chemical properties of selected cherry laurel genotypes of Turkey such as *54 K 01, 55 K 07* and *61 K 04* may be useful in designing of the related equipment for postharvest handling and processing operations (harvesting, separating, processing, packing, and transportation). will serve to design the equipment used in postharvest treatment and processing of the different cherry laurel fruit, stone and kernel samples. The following conclusions are drawn from the investigation on physico-mechanical, colour and chemical properties of three cherry laurel fruit, stone and kernel samples.

1. The highest geometric mean diameter and surface area were found for fruits and kernel of stone of *61 K 04* cherry laurel genotype at the moisture content 64.1% and 41.0% w.b., whereas, the highest geometric mean diameter and surface area for cherry laurel fruit’s stone samples were found was found of *54 K 01* cherry laurel genotype at the moisture content 26.7% w.b., respectively. The relations between L/D_g and *L/S* have been found to be statistically significant for all cherry laurel genotypes (*54 K 01, 55 K 07* and *61 K 04*) in fruit, its stone and kernel.

2. The least unit mass and seed volume values for fruit, its stone and kernel were shown by *55 K 07* cherry laurel genotype, whereas, the highest unit mass and seed volume values for stone of cherry laurel fruit and its kernel were recorded for *61 K 04* genotype among three cherry laurel genotypes. The lowest true density for stone and its kernel of the cherry laurel fruit was observed for *61 K 04* genotype, whereas, the lowest true density for fruit of cherry laurel was obtained from *55 K 07* genotype.

3. The maximum lightness (L*) for fruit and its stone was found to be 24.08 and 40.78 for *54 K 01* cherry laurel genotype, whereas minimum L* value was recorded as 15.49 and 37.40 for *61 K 04* genotype, respectively.

4. The static coefficient of friction was the lowest and the highest for the fruit, on rubber friciton surface as 0.724 and 0.598 for fruit and kernel in *55 K 07*, as 0.929 for its stone in *61 K 04* among cherry laurel genotypes, respectively. Cherry laurel fruit and its stone showed the highest static coefficient of friction for rubber surface among five surfaces.

5. Among three cherry laurel fruits, the highest fruit removal force was found in *54 K 01* genotype at the same time, and also, it has been seen that *55 K 07* genotype has the lowest fruit removal force. For *55 K 07* genotype fruits the puncture forces along *X*-, *Y*-, and *Z-axes* were higher among the three cherry laurel genotypes. The rupture force for cherry laurel fruits for *Y-axis* (0.740 N in 61 K 01 genotype) was higher than *X*- and *Z-axes*. The rupture force for cherry laurel fruits stone and kernel samples for *X-axis* (2.970 in *54 K 01* genotype, and 0.931 N in *61 K 04* genotype) was higher than *Y- and Z-axes.*

6. In this study the highest SSC and pH values was found in *54 K 01* genotype and also, it has been seen that *55 K 07* genotype has the lowest SSC and pH values. It can be said that the highest TA values are determined in *54 K 01* genotype and

the lowest TA values are determined in *61 K 04* genotype.

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