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ORIGINAL PAPER

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BIOACTIVE COMPOUNDS AND PHYSICO-MECHANICAL ATTRIBUTES OF FRUIT AND STONE OF CHERRY LAUREL (*Prunus laurocerasus*) HARVESTED AT DIFFERENT MATURITY STAGES

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ABSTRACT

In the study, physico-mechanical properties [geometric mean diameter (D_g), sphericity, surface area, weight (W), bulk and fruit density, color, fruit removal force (FRF), puncture and compression force, puncture and compression deformation, friction coefficient] and biochemical attributes [pH, soluble solids content (SSC), titratable acidity (TA), vitamin C, total phenolics (TPs), total monomeric anthocyanin (TMA) and total antioxidant capacity (TAC)] of cherry laurel fruits (*Prunus laurocerasus*) and stones were investigated. Geometric mean diameter, surface area, fruit weight, bulk and fruit density significantly increased, but L^*, a^* and b^* values significantly decreased with the progress of ripening. Fruit removal force decreased from 5.04 N to 3.09 N. On the other hand, W/FRF increased with the progress of harvest date. Static friction coefficient of fruits significantly increased over plywood and silicone surfaces and friction coefficients of stones increased over plywood, galvanized mild steel and silicone surfaces with the progress of harvest date. The pH, SSC, vitamin C, TPs, TMA and TAC (according to FRAP and TEAC assay) values significantly increased with the progress of ripening. It was concluded that fruit maturity stage at harvest had significant impact on physico-mechanical attributes and bioactive compounds of cherry laurel fruits.

Key words: antioxidant, bulk density, compression force, friction surface, fruit removal force, vitamin C

INTRODUCTION

Bio-technological characteristics of agricultural products should be taken into consideration while selection, operation, control, efficient use and analysis of harvest and post-harvest machinery, design of post-harvest facilities and to improve yields, utilizations and shelf life of such products and for sustainability of product quality along with consumer desires [Mohsenin 1986].

Cherry laurel belongs to *Prunoideae* sub-family of *Rosaeceae* family. It grows in shrub or small trees 5–6 m tall. Cherry laurel is an evergreen plant. It is widespread in eastern sections of Black Sea, Caucasus, Taurus Mountains, northern and eastern Marmora regions of Turkey. In this sense, the best cherry laurel species grow in coastal sections of Black Sea region.

Stone, leaf and fruits of cherry laurel are used for various purposes. Fruits are easily digested and give the impression of fullness, therefore can be used as a diet product in human nutrition. Fruits are freshly consumed by local people in Black Sea region. They are also used as dried product, pickles, molasses and

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jam, as an aroma and flavoring substance in cakes, pastry and fruit juices [İslam, 2002, Liyana-Pathirana et al. 2006]. What make these fruits so special are their health benefits. Fruit stones are used to expel kidney stones, in treatment of stomach ulcer and bronchitis, digestive system diseases, in strengthening the bones and establishing the acid-base balance of blood; fruits are used as diuretic, antispasmodic and antitussive agent, in treatment of eczema and hemorrhoid. Fruits have quite low Cu, Zn and etc. harmful substance and heavy metal contents and are quite abundant in antioxidants. Therefore, they are commonly used for diabetes, tissue and dermatological disorders. Fruits are also known to be quite effective in cell renewal and against cancer cells [İslam 2004, Karahalil and Şahin 2011, Yıldız et al. 2014, Demir et al. 2017].

Several studies were performed on cherry laurel for selection of superior genotypes [İslam and Odabaş 1996, İslam et al. 2010], propagation techniques were developed to widespread promising genotypes [Sülüşoğlu and Çavuşoğlu 2009]; studies were also performed about consumption method and types to increase consumptions [Temiz et al. 2014], about nutritional composition to put forth the health effects of the fruits [Kalyoncu et al. 2013, Yıldız et al. 2014, Demir et al. 2017].

However, there are no studies in literature about bio-technical characteristics of cherry laurel fruits harvested at different maturity stages. Therefore, the present study was conducted to determine the effects of different ripening stages on physico-mechanical attributes and bioactive compounds of cherry laurel fruits.

MATERIAL AND METHODS

Plant material

The fruits supplied from cherry laurel genotypes naturally grown (50-years-old) in Fatsa town (41°03'N, 37°28'E, altitude 75 m) of Ordu Province in Turkey, selected in a previous project [O-44 genotype selected for TUBITAK Project (number 107 O 252)] constituted the plant material of this study. Only irrigation, but no other cultural practice, was performed.

Fruits were manually harvested at optimal harvest date (27 July 2015) and also one week before (unripe, 20 July) and one week later (over-maturity, 3 August). Peel color and firmness were considered the criteria to estimate the harvest date. About 5 kg fruits were harvested from the trees in each harvest period. The fruits free of diseases, damages and blemishes were selected. Following the harvest, fruits were instantly transferred in plastic packages to laboratory of Horticulture and Biosystems Engineering Department of Ordu and Gaziosmanpasa University Agricultural Faculty. Fruits were then randomly divided into 4 groups and physical-mechanical measurements were performed over 20 fruits of each group.

Physical and mechanical traits. Fruit and stone weight were measured with a digital balance (±0.001 g) (Kern EW 620-3 NM, Kern and Sohn GmbH, Germany), dimensional properties [length (L), width (We), thickness (T)] were measured with a digital caliper (±0.01 mm) (Model No; CD-6CSX, Mitutoyo Corp., Kawasaki, Japan). Geometric mean diameter of fruits and stones was calculated with the equation [$D_g = (LWeT)^{1/3}$], sphericity with the equation [$\phi = (D_g/L)\ 100$], surface area with the equation [$S = \pi\ (D_g)^2$], bulk density and fruit density were measured as specified by Mohsenin [1986].

Color measurements were performed over the equatorial sections of the fruits and stones with a color-meter (Konica Minolta, Inc., CR-400, Tokyo, Japan). Chromatic analyses were conducted in accordance with the Commission Internationale de l'Eclairage system. Values of *L**, *a** and *b** were used to define a three-dimensional color space.

FRF represents the force to remove the fruit from the stalk and it was determined with a digital force gauge (draft dynamometer) (Tronic HF-50, Taiwan). Fruit penetration resistance (punching) and fruit compression tests were performed with biological material test device (Sundoo, SH-50, digital force gauge, China).

About 1.2 mm stainless steel needle tip was used for penetration tests of the fruits and 73 mm diameter circular brass place was used for compression tests of fruits and stones. Biological material test device was manually operated and equipped with digital indicator, tension-compression dynamometer, measurement grid stand, fixed plate and cable connection to a computer. Force and deformation measurements were performed with these compression and penetration tests and results were expressed respectively in N and mm.

Friction coefficient. Friction coefficients of cherry laurel fruits and stones over different surfaces (plywood, galvanized mild steel, laminate and silicone) were determined with a sloped bench test set.

Bioactive compounds. For bioactive measurements, 4 groups were formed with 20 fruits in each and 3 measurements were performed for each group. Initially, fruits were washed with distilled water and deseeded. Fruits were then homogenized in a blender (Philips, Turkey). The fruit samples were kept in 50 mL tubes at –20°C for TPs, TMA and TAC analysis. For pH, TA, SSC and vitamin C analyses, homogenate was filtered through cheesecloth and fruit juice was obtained. Then, pH of the juice was measured with a pH-meter (HI9321, Hanna, Turkey); SSC was measured with a digital refractometer (Atago, PAL-1, USA) and expressed in %. For TA, 10 ml fruit juice was supplemented with 10 ml distilled water, and then the solution was titrated with NaOH until a pH of 8.1. Amount of NaOH used to bring the pH to 8.1 was expressed in g malic acid 100 mL^{-1} equivalent. Fruit juice vitamin C contents were determined with a reflectoquant set of Merck Co (Merck RQflex plus 10) and expressed as mg 100 g^{-1}.

For TPs, TMA and TAC analysis, samples were thawed at room temperature (≈21°C) and homogenized in a food grade blender. The resultant slurry was centrifuged (12,000 × g) for 30 min at 4°C to separate the juice from the pulp. Freshly obtained juice materials were diluted with distilled water, divided into multiple sample aliquots, and refrozen at –20°C until used in phenolics, antioxidant and anthocyanin assay procedures.

Total phenolics (TP) content was measured according to the procedure described by Singleton and Rossi [1965]. Briefly, fruit slurries were extracted with a buffer containing acetone, water and acetic acid (70 : 29.5 : 0.5 v/v) for 2 h at dark. Samples were replicated three times. Extracts were combined with Folin-Ciocalteu's phenol reagent and water, and incubated for 8 minutes followed by the addition of 7% sodium carbonate. After 2 h, the absorbance at 750 nm was measured in an automated UV-Vis spectrophotometer (Model T60U, PG Instruments). Gallic acid was used as the standard. The results were expressed as micrograms (µg) gallic acid equivalents (GAE) g^{-1} fresh weight (f.w.).

Trolox equivalent antioxidant capacity (TEAC) method was used to determine the total antioxidant capacity. For the standard TEAC assay, 10 mmol L^{-1} $ABTS^{+}$ diammonium salt was dissolved in acetate buffer and prepared with potassium persulfate as described in Ozgen et al. [2006]. The mixture was diluted using an acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.70 ±0.01 at 734 nm for longer stability. For the spectrophotometric assay, 2.90 mL of the $ABTS^{+}$ solution and 100 µL of fruit extract were mixed, incubated for 10 min, then the absorbance was determined at 734 nm. The results were expressed in µmol trolox equivalent (TE) g^{-1} f.w.

Total anthocyanin content was measured by the pH differential method described in Giusti et al. [1999]. Sample extracts were combined in a 1 : 20 ratio (v : v) with potassium chloride and with sodium acetate buffers (pH 1.0 and 4.5, respectively) in separate vessels. After an equilibration period (15 min), the raw absorbance of each solution was measured at 533 and 700 nm. A corrected absorbance value was calculated as (A520 – A700) pH 1.0 – (A520 – A700) pH 4.5. The anthocyanin content was calculated using the molar absorptivity (ϵ) and molecular weights (MW) of cyanidin 3-glucoside (ϵ = 26.900, MW = 449.2). Results were expressed as micrograms (µg) of cyanidin 3-glucoside equivalents (µg cy-3-glu g^{-1} f.w.).

Statistical analysis. The data sets were analyzed with ANOVA using SPSS statistical software (SPSS Inc., Chicago, IL, USA). Duncan's multiple range test was used to compare treatments when ANOVA showed significant differences among the means. Differences were considered significant at p = < 0.05 and $p < 0.01$.

RESULTS AND DISCUSSION

Physical and mechanical attributes. While harvest periods did not have significant effects on fruit geometric mean diameter and surface area, the effects of harvest periods on fruit sphericity were found to be significant at $p < 0.01$. On the other hand, effects of harvest periods on geometric mean diameters and surface areas of the stones were found to be significant at $p < 0.05$ and effects on stone sphericity were found to be significant at $p < 0.01$ (Tab. 1).

Table 1. Change in physical properties of fruit and stone of cherry laurel harvested at different maturity stages

Physical properties	Harvest dates					
	fruit			stone		
	20 July	27 July	3 August	20 July	27 July	3 August
Fruit weight (g)	4.38 ±0.08 b*	4.50 ±0.08 a	5.46 ±0.05 a	0.49 ±0.005 a*	0.44 ±0.004 b	0.39 ±0.004 c
D_g (mm)	18.60 ±0.13 ^{ns}	18.82 ±0.11 ^{ns}	19.60 ±0.10 ^{ns}	10.45 ±0.05 a*	9.99 ±0.03 ab	9.52 ±0.05 b
Sphericity	0.89 ±0.002 a**	0.89 ±0.001 a	0.88 ±0.001 b	0.62 ±0.001 c**	0.64 ±0.001 a	0.63 ±0.001 b
Surface area (cm^2)	10.87 ±0.11 ^{ns}	16.66 ±0.09 ^{ns}	17.35 ±0.08 ^{ns}	3.44 ±0.03 a*	3.14 ±0.02 ab	2.85 ±0.03 b
Bulk density (kg m^{-3})	547.52 ±3.09 ^{ns}	558.03 ±6.50 ^{ns}	569.39 ±3.54 ^{ns}	520.06 ±4.54 ^{ns}	529.00 ±6.43 ^{ns}	513.17 ±6.75 ^{ns}
Fruit density (kg m^{-3})	1039.51 ±29.91 ^{ns}	1056.99 ±14.43 ^{ns}	1059.74 ±19.23 ^{ns}	1138.34 ±78.64 ^{ns}	1147.58 ±32.51 ^{ns}	1178.93 ±50.66 ^{ns}

D_g: geometric mean diameter, $n = 80$ for fruit weight, D_g, sphericity, surface area, bulk and fruit density (20 fruits × 4 replications)
The difference between mean values shown in the same line with the same letter is not significant (*$p < 0.05$; **$p < 0.01$)
^{ns}: non-significant
Numbers following ± are standard error of the mean

Considering the variations in physical characteristics (geometric mean diameter, sphericity and surface area) of cherry laurel fruits with harvest periods, it was observed that there was an increase in geometric mean diameter and surface areas with the progress of harvest period and a relative decrease was observed in sphericity values of the 3rd as compared to the 1st and 2nd harvest periods. Stone diameter and surface area decreased with the progress of harvest. From the first to last harvest, fruit geometric mean diameters increased by 5.5% and surface areas increased by 59.61%.

Sayıncı et al. [2015] reported geometric mean diameters of cherry laurel fruits as between 17.3–22.8 mm, sphericity between 90.7%–97.8% and surface areas between 9.5–16.4 cm^2. Çalışır and Aydın [2004] reported geometric mean diameter and sphericity of cherry laurel fruits respectively as 12.71 mm and 0.98 mm. Present geometric mean diameters and surface areas of cherry laurel fruits were similar with the ones reported by Sayıncı et al. [2015]. However, present geometric mean diameter values were higher and sphericity values were lower than the ones reported by Çalışır and Aydın [2004]. The differences in sphericity were mostly resulted from the genotype of the fruits, climate and soil conditions of the growing site and other cultural practices (irrigation, pruning, fertigation etc.).

While harvest periods did not have significant effects on fruit density and bulk density of cherry laurel fruits and stones, the effects of harvest periods on fruit and stone weight were found to be significant ($p < 0.05$). Volumetric characteristics and fruit weight values increased with the progress of harvest period. Stone densities also increased with the progress of harvest period. However, stone weight values decreased significantly. On the other hand, stone bulk density initially increased, then decreased. From the first to last harvest, fruit weight increased by 25%, bulk density by 4% and fruit density by 2%; stone weight decreased by 20.41% and stone bulk density decreased by 1.32%; on the other hand, stone density increased by 3.56% (Tab. 1).

Fruits usually have an increasing volume and weight over the tree based on growth and development. A similar case was observed in present study for cherry laurel fruits. Çalışır and Aydın [2004] reported fruit density of cherry laurel fruits as between 950–1050 kg m^{-3} and bulk density values between 450–615 kg m^{-3}. Fruit weight values of different cherry laurel genotypes between 1.08–5.33 g by Beyhan [2010]; between 1.87–4.01 g by Celik et al. [2011]; between 1.15–5.22 g by Sulusoglu [2011]. Stone weight values were reported as between 0.26–0.39 g by Sulusoglu [2011]; between 0.37–0.45 g by Deligöz and Islam [2012]. Kalyoncu et al. [2013] reported fruit weight of cherry laurel fruits as 5.35 g and stone weight as 0.41 g. Present findings comply with the earlier ones.

Color characteristics. Effects of harvest periods on skin color parameters ($L*$, $a*$ and $b*$) of cherry laurel fruits were found to be significant at $p < 0.01$.

Similarly, significant differences were observed in flesh color parameters (L^* and a^*) of harvest periods ($p < 0.01$). From the first to last harvest, all fruit skin color parameters decreased. However, only fruit flesh L^* value and stone a* and b* values decreased. Fruit skin L^* values varied between 10.54–29.55, a* values between 13.72–23.72 and b* values between 18.11–42.02 (Tab. 2).

The L^*, a^* and b^* values of different cherry laurel genotypes were reported respectively as between 18.43–23.62, 0.81–14.87 and 0.60–6.26 by Halilova and Ercisli [2010]; between 18.71–32.43, 3.41–19.84 and 1.14–10.2 by Sulusoglu [2011]; between 17.63–25.10, 0.90–11.52 and 0.01–2.58 by İslam and Deligöz [2012]. Present findings on color parameters were either similar with some of those earlier ones or different from the others. The differences were mainly because of cultivar/genotypes, environmental conditions, irrigation, fertilization and nutritional composition of the orchard.

Mechanical attributes. Effects of harvest periods on fruit removal forces were found to be significant at $p < 0.01$. Generally, a decrease was observed in fruit removal forces with the progress of harvest period (Tab. 3). Such decreases were because of ripening and resultant cell membrane degradation around the fruit removal section. Göksel and Aksoy [2014] reported the fruit removal force of different cherry cultivars (*Prunus avium*) as 4.80 N for 0900 Ziraat cherry cultivar, 4.52 N for Sweetheart and 4.33 N for Regina cultivar. Okur [2011] reported the fruit removal force of 4 different cherry cultivars as 2.579 N for ‘0900 Ziraat’, 2.187 N for Starks Gold, 2.246 N for Merton Late and 1.530 N for Lambert cultivar. The fruit removal forces at the last harvest date were lower than values reported by Göksel and Aksoy [2014], but higher than those reported by Okur [2011].

Puncture force and deformation. Effects of harvest periods on puncture forces along X (length) axis and Z (thickness) axis of cherry laurel fruits were not found to be significant, but the effects of harvest periods on puncture force along Y (width) axis were found to be significant at $p < 0.05$. While the effects of harvest periods on puncture deformations along X and Y-axis were not found to be significant, the effects on deformations along Z-axis were found to be significant at $p < 0.05$.

Table 2. Change in color characteristics of fruit and stone of cherry laurel harvested at different maturity stages

Color Properties	Harvest dates					
	skin of fruit			flesh of fruit		
	20 July	27 July	3 August	25 July	1 August	7 August
L	29.55 ±0.76 a**	15.61 ±0.43 b	10.54 ±0.35 c	58.34 ±0.87 a**	48.86 ±0.87 b	41.79 ±0.79 c
*a**	23.72 ±0.57 a**	18.86 ±0.71b	13.72 ±0.57 c	–1.77 ±0.15 c**	0.43 ±0.22 b	3.53 ±0.39 a
*b**	42.02 ±0.69 a**	26.88 ±0.73 b	18.11 ±0.60 c	24.49 ±0.53 ^{ns}	23.23 ±0.73 ^{ns}	24.23 ±0.79 ^{ns}
	stone of fruit					
L	49.97 ±1.05 b*	54.71 ±1.57 ab	56.58 ±1.45 a	–	–	–
*a**	12.52 ±1.05 a*	9.70 ±0.82 b	8.64 ±0.70 c	–	–	–
*b**	66.70 ±0.49 a**	56.88 ±2.72 b	52.91 ±1.87 c	–	–	–

$n = 80$ for color characteristics (20 fruits × 4 replications)
The difference between mean values shown in the same line with the same letter is not significant (*$p < 0.05$; **$p < 0.01$)
^{ns}: non-significant
Numbers following ± are standard error of the mean

Table 3. Change in mechanical properties of fruit and stone of cherry laurel harvested at different maturity stages

Mechanical properties	Fruit			Stone		
	harvest dates			harvest dates		
	25 July	1 August	7 August	25 July	1 August	7 August
Fruit removal force (N)	5.04 ±0.20 a**	3.51 ±0.19 b	3.09 ±0.16 c	–	–	–
Weight/Fruit removal force (W/FRF)	1.860 ±0.16 b	2.202 ±0.23 b	11.474 ±2.11 a	–	–	–
Puncture force (N) (X axis)	0.35 ±0.01 ^{ns}	0.32 ±0.003 ^{ns}	0.31 ±0.004 ^{ns}	–	–	–
(Y axis)	0.41 ±0.02 a*	0.31 ±0.004 b	0.28 ±0.01b	–	–	–
(Z axis)	0.41 ±0.03 ^{ns}	0.31 ±0.008 ^{ns}	0.31 ±0.006 ^{ns}	–	–	–
Compression force (N) (X xis)	28.84 ±3.26 ^{ns}	27.46 ±4.17 ^{ns}	25.77 ±2.33 ^{ns}	124.0 ±11.51 ^{ns}	117.27 ±5.32 ^{ns}	105.2 ±5.63 ^{ns}
(Y axis)	32.60 ±2.48 ^{ns}	27.35 ±2.09 ^{ns}	25.99 ±3.08 ^{ns}	86.05 ±4.97a**	70.63 ±3.99 b	58.62 ±6.76 c
(Z axis)	32.83 ±1.76 ^{ns}	27.76 ±1.42 ^{ns}	25.95 ±3.84 ^{ns}	83.82 ±3.90 ^{ns}	82.03 ±8.97 ^{ns}	73.42 ±7.87 ^{ns}
Puncture deformation (mm) (X axis)	3.81 ±0.26 ^{ns}	5.67 ±1.07 ^{ns}	10.27 ±1.66 ^{ns}	–	–	–
(Y axis)	6.03 ±0.45 ^{ns}	6.27 ±0.69 ^{ns}	5.57 ±0.63 ^{ns}	–	–	–
(Z axis)	4.79 ±0.59 b*	5.33 ±0.63 ab	6.86 ±0.89 a	–	–	–
Compression deformation (mm) (X axis)	11.09 ±0.56 ^{ns}	12.58 ±0.701 ^{ns}	11.37 ±0.33 ^{ns}	1.97 ±0.36 ^{ns}	2.36 ±0.12 ^{ns}	2.36 ±0.15 ^{ns}
(Y axis)	10.07 ±0.23 ^{ns}	10.10 ±0.49 ^{ns}	10.06 ±0.33 ^{ns}	1.36 ±0.24 ^{ns}	1.03 ±0.23 ^{ns}	0.91 ±0.18 ^{ns}
(Z axis)	9.18 ±0.49 ^{ns}	8.99 ±0.49 ^{ns}	9.22 ±0.34 ^{ns}	1.47 ±0.13 ^{ns}	1.28 ±0.08 ^{ns}	1.20 ±0.04 ^{ns}

n = 80 for mechanical properties (20 fruits × 4 replications)
The difference between mean values shown in the same line with the same letter is not significant ($*p < 0.05$; $**p < 0.01$)
^{ns}: non-significant
Numbers following ± are standard error of the mean

Puncture force along X, Y and Z-axis decreased with the progress of harvest period (Tab. 3). The decrease in puncture forces from the 1st to 3rd harvest period was 12.90% along X-axis, 46.43% along Y-axis and 24.39% along Z-axis. Considering the deformations, there was an increase in deformation values along X and Z-axis with the progress of harvest period. Based on dimensional characteristics, deformation values also increased along X and Z-axis.

Compression force and deformation. The effects of harvest periods on compression force and deformation values along X, Y and Z-axis were not found to be significant. Test results revealed decreasing rupture/compression force values along X, Y and Z-axis. The decrease was 10.64% along X-axis, 20.28% along Y-axis and 20.96% along Z-axis. The decrease in rupture forces of harvest periods were because of physiological ripening of the fruits with the progress of harvest period. Deformation values along X, Y and Z-axis of cherry laurel fruits were not much different and quite close to one another. Compression force along X, Y and Z-axis of cherry laurel stones decreased respectively by 15.16%, 31.88% and 12.41% and the greatest decrease was observed along Y-axis. Cherry laurel stones exhibited greater resistance along X-axis and the lowest values were observed along Y-axis, especially remarkable in the 3rd harvest period. Compression force along X, Y and Z-axis decreased with the progress of harvest period.

The effects of harvest periods on deformations along X, Y and Z-axis of cherry laurel stones were not found to be significant. A relative increase was observed in deformations along X-axis and decreases were observed in deformations along Y and Z-axis.

Çalışır and Aydın [2004] reported rupture force of dried cherry laurel fruits at 9.00–77.5% moisture levels as between 4.5–3.0 N and indicated decreasing rapture forces with increasing moisture levels. Present rupture force values were higher than those reported by Çalışır and Aydın [2004], since fresh fruits in present study were more elastic and required more force to rupture them.

Friction coefficient. Effects of harvest periods on friction coefficients of cherry laurel fruits over plywood and silicone surfaces were found to be significant at $p < 0.01$, the effects of harvest periods on friction coefficients over galvanized mild steel and laminate surfaces were not found to be significant (Tab. 4). The effects of harvest periods on friction coefficients of stones over galvanized mild steel and silicone surfaces were found to be significant at $p < 0.05$ and effects on friction coefficients over plywood surfaces were found to be significant at $p < 0.01$. On the other hand, effects of harvest periods on friction coefficients of stones over laminate surfaces were not found to be significant.

Table 4. Change in friction coefficients of fruit and stone of cherry laurel harvested at different maturity stages

Harvest date	Friction surface							
	fruit				stone			
	plywood	galvanized mild steel	laminate	silicone	plywood	galvanized mild steel	laminate	silicone
20 July	0.87 ±0.02 b**	0.87 ±0.01 ^{ns}	0.81 ±0.01 ^{ns}	0.82 ±0.01 c**	0.82 ±0.02 b**	0.69 ±0.01 b*	0.59 ±0.01 ^{ns}	0.72 ±0.02 c*
27 July	0.86 ±0.02 c	0.89 ±0.05 ^{ns}	0.83 ±0.02 ^{ns}	0.91 ±0.01b	0.81 ±0.02 c	0.71 ±0.01 ab	0.59 ±0.02 ^{ns}	0.77 ±0.01b
3 August	0.95 ±0.01 a	0.93 ±0.02 ^{ns}	0.87 ±0.03 ^{ns}	0.95 ±0.01 a	0.94 ±0.01a	0.74 ±0.02 a	0.59 ±0.02 ^{ns}	0.80 ±0.01 a

n = 80 for friction coefficient (20 fruits × 4 replications)
The difference between mean values shown in the same line with the same letter is not significant (*p < 0.05; **p < 0.01)
^{ns}: non-significant
Numbers following ± are standard error of the mean

Table 5. Change in biochemical properties of cherry laurel fruits harvested at different maturity stages

Biochemical Properties		Harvest dates		
		20 July	27 July	3 August
pH		4.03 ±0.09 b*	3.92 ±0.04 c	4.20 ±0.02 a
Titratable acidity (TA, g malic acid 100 g^{-1})		0.31 ±0.02 b*	0.30 ±0.01c	0.37 ±0.02 a
Soluble solids content (SSC, %)		7.57 ±0.32 c**	15.00 ±0.21b	15.53 ±0.07 a
Vitamin C (mg 100 g^{-1})		90.67 ±31.18 b**	76.00 ±11.85 c	150.00 ±7.64 a
Total phenolics (TPs, µg GAE g^{-1} f.w.)		1697.22 ±0.13 c**	1833.66 b ±40.96 b	2210.3 ±16.89 a
Total monomeric anthocyanin (TMA, mg cy-3-galactoside g f.w.)		1.75 ±0.13 c	13.43 ±2.04 b	23.45 ±3.83 a**
Total antioxidant capacity (TAC, µmol TE g^{-1} f.w.)	FRAP	2.50 ±0.06 b**	3.27 ±0.10 a	3.42 ±0.14 a
	TEAC	2.47 ±0.05 b**	3.50 ±0.12 a	3.67 ±0.19 a

n = 12 for pH, TA, SSC, vitamin C, TPs, TMA and TAC (4 replications × 3 different measurement for each replicate)
The difference between mean values shown in the same line with the same letter is not significant (*p < 0.05; **p < 0.01)
^{ns}: non-significant
Numbers following ± are standard error of the mean

Friction coefficients of cherry laurel fruits over different surfaces increased with the progress of harvest periods. Average friction coefficients of cherry laurel fruits over different frictional surfaces increased with the progress of harvest period. Friction coefficients of fruit stones over different surfaces (plywood, galvanized mild steel and silicone) also increased with the progress of harvest period, but the friction coefficients over laminate surface remained constant (0.59) in different harvest periods. The greatest friction coefficient was observed over plywood and the lowest value was observed over laminate surface. Such values indicate that cherry laurel fruits had greater adhesion over plywood surface and had lower friction coefficients over brighter and slippery laminate surfaces.

It was reported in a previous study that static and dynamic friction coefficients of dry cherry laurel fruits over plywood and galvanized steel surfaces increased with increasing moisture levels (9.00–77.5%) [Çalışır and Aydın 2004]. In present study, friction coefficients of cherry laurel fruits over different surfaces increased with the progress of harvest period. Higher friction coefficients over plywood surfaces than over galvanized steel comply with the findings of Çalışır and Aydın [2004].

Bioactive compounds. Effects of harvest periods on SSC and vitamin C contents of the fruits were found to be significant at $p < 0.01$; effects on pH and TA values were found to be significant at $p < 0.05$. The effects of harvest periods on total phenolics, total monomeric anthocyanin and total antioxidant capacity values of the fruits were also found to be significant at $p < 0.01$. The SSC values increased with harvest periods. On the other hand, pH, TA and vitamin C values decreased from the 1st to 2nd harvest, but increased from the 2nd to 3rd harvest (Tab. 5).

In previous studies carried out using different cherry laurel genotypes, SSC, pH and TA values were reported respectively as between 9.64–17.10%, 4.30–4.93 and 0.27–0.70% by Celik et al. [2011]; between 16.20–25%, 4.96–5.90 and 0.21–0.32% by İslam and Deligöz [2012]. Beyhan [2010] reported SSC values between 16.0–22.0% and Sulusoglu [2011] between 13.64–24.40%. Present SSC values increased with the progress of ripening. Thusly, Var and Ayaz [2004] indicated that cherry laurel fruits had rich sugar content and thus had increased the SSC values with the progress of ripening. Present findings on SSC, pH and TA values were similar with earlier findings. Differences were mostly because of the differences in genotypes, climate parameters (temperature, light, and humidity), irrigation and fertilization as well as cultural practices [Lee and Kader 2000]. Cultivars or genotypes may have significant effects on chemical composition of the fruits.

The TPs, TMA and TAC (according to FRAP and TEAC) values of cherry laurel fruits increased with the progress of harvest period. The TPs, TMA and TAC values were quite higher at the estimated harvest date than at the first harvest date (Tab. 5). Yavru [1997] indicated that bioactive compounds (TPs, TMA and TAC) of cherry laurel fruits could significantly increase with the progress of ripening. Celik et al. [2011] investigated different cherry laurel genotype and reported TPs, TMA and TAC (according to DPPH) values respectively as between 364–503 mg GAE 100 g^{-1} f.w., 123–205 mg cy-3-gluc 100 g^{-1} f.w. and 21.2–32.2 μmol TE g^{-1} f.w. Alasalvar et al. [2005] reported TPs of cherry laurel genotypes as between 454–651 mg GAE 100 g^{-1} f.w. Present TMA values were higher, but TPs and TAC values were lower than the ones reported by Celik et al. [2011]. Alasalvar et al. [2005] and Halilova and Ercisli [2010] reported TMA values of cherry laurel fruits as between 123–206 mg cyanidin-3-glucoside 100 g^{-1} f.w. Values reported by those researchers were similar with the present ones at the first harvest date, but lower than the ones at the 2nd and 3rd harvest dates. Anthocyanins contribute significantly to the fruit phenolics content, thus to antioxidant capacity. Anthocyanin content of cherry laurel fruits increased significantly with the progress of ripening. Therefore, full-ripe fruits with abundant anthocyanin and antioxidant content are recommended to be preferred by the consumers. Anthocyanins have not only non-mutagenic and non-toxic properties but also positive therapeutic properties, such as antioxidant, anti-inflammatory, anti-carcinogenic, anti-viral, and antibacterial effects [Tall et al. 2004]. Present TPs and antioxidant capacity values were relatively lower than those reported by previous researchers. Differences in TAC values probably resulted from the differences in antioxidant tests. Such differences might have also resulted from genetic and environmental factors. In present study, TAC was positively correlated with TMA and TPs.

CONCLUSIONS

As to conclude, maturity stages (different harvest dates) had significant impact on bioactive compounds and physico-mechanical attributes of cherry laurel fruits. Therefore, it was concluded that fruit maturity stages should definitely be taken into consideration for fresh post-harvest consumption or processing technologies (cleaning, classification, transportation, drying, storage, packaging and etc.).

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