The effect of ripening periods on physical, chemical and mechanical properties of service tree (SorbusDomestica L.) fruits

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Abstract: The effect of ripening periods on physical, chemical and mechanical properties of service tree fruits (Sorbusdomestica L.) were determined. The geometric mean diameter, fruit mass, volume, surface area and fruit density of service tree fruits decreased with the increase of ripening periods, while, bulk density increased with ripening periods. L*, a*, b*decreased with the increase of ripening periods, while hue increased with ripening periods respectively. The friction coefficients of service tree fruits with increase ripening periods were lower for laminate than the other surfaces. The soluble solid content (SSC) and total acidity of service tree fruits decreased at ripening period. Titratable acidity was higher in physiological maturity as compared to ripening periods, and pH values of service tree fruits decreased with ripening periods. For this reason, post-harvest technological applications of the service tree fruits must be designed while taking these criteria into consideration such as physical, mechanical and chemical properties properties of service tree fruits.

Keywords: ripening, density, colour, friction, firmness

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1 Introduction

The service trees (*Sorbusdomestica* L.,) are sparse wild fruit trees and their fruits are rich in vitaminA, B_2 and C and a lot of minerals. Service tree fruits contain the powerful natural antioxidants with beneficial health properties. Service tree fruits are not susceptible to parasite and pest attacks, and they are consumed fresh or processed into different food products (Termentzi et al., 2006; Bukvic et al., 2007). Service tree fruits are consumed when overriped as jams, jellies, compotes, juices or fruit wine. The service tree is used as high-value timber for furniture, tool and instrument construction. Service tree has the modest growing requirements in comparison with their fruit trees (Miletic and Paunovic, 2012).Service tree is native to western, central and southern Europe, northern Africa, the Crimea, Asia Minor, Caucasus and Transcaucasia (Orsanicet al., 2009). Service tree fruits are widely used in northern Europe, as antioxidant agents in beverages, and they are shelf-grown in the mountainous regions of Europe, northern Africa and Minor Asia (Termentzi et al., 2008). They are found scratchily in Turkey agriculture as a potential for forestation of degraded areas. Service tree is part of the natural ecosystem, and its conservation and promotion contribute to ecosystem improvement (Piagnani et al., 2012).

The consumers demand the excellent appearance, firmness and optimal texture of service tree fruits. Service tree fruit quality is a combination of visual appearance, flavor and texture of the fruit for consumer marketing in post harvest and ripening periods. To the designing of separating, storage and transporting structures, the size, shape, bulk and fruit densities, porosity and friction coefficient of service tree fruits have important effects. In service tree fruit marketing, the ripening (maturity) level, size, colours, sugar, solid content and firmness must be considered for consumer.

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No detailed study concerning the physical, mechanical and chemical properties of service tree fruit affected by the different ripening periods (physiological maturity, ripening and overripe periods)was not studied and comparatively. Thus, in this study, the physical, chemical, colour and mechanical properties were investigated by the different ripening periods of service tree fruits.

2 Materials and methods

In this research, the service tree (*Sorbusdomestica* L.) fruit was obtained in Tokat/Turkey, in 2013. The service tree fruits were harvested manually from Tokat-Niksar (38° 96’ N and 35° 24’ E) city, located in Mid-Black Sea Transition Climate Belt region, during the harvest season on 29 September 2013. Service tree fruits, non grafted, were randomly harvested from six trees, cultivated at 375 m above sea level, and they were transferred in polyethylene bags to the laboratory. To determine the service tree fruit’s size, 100 fruits were randomly selected as cleaned, removed from foreign matters and undamaged fruits. The service tree fruits were packed in a hermetic glass vessel and kept in room temperature (22 ℃), until they were used for the different ripening periods. For maturity level and ripening period dates in experiment as RP-1; physiological maturity, RP-2; ripening period and RP-3: overripe periods were 30 September, 9 October, and 23 October, respectively.

The physical (geometric) properties of service tree fruits, such as three principal length, width and thickness dimensions were measured by using a digital vernier caliper with an accuracy of 0.01 mm. For fruit mass, the digital electronic balance precision balance (0.01 g resolution) was used. The geometric mean diameter, volume, sphericity, and surface area of service tree fruits were calculated using the equations explained by Mohsenin(1970).The physical (volumetric)properties such as fruit density (ρ_f) a fruit is determined by the toluene (C_7H_8) displacement method and the bulk density (ρ_b) of service tree fruits was determined by hectoliter standard weight method (Singh and Goswami, 1996). The porosity was determined from fruits and bulk density values explained by Mohsenin (1970).The initial moisture content of service tree fruits was determined using the standard hot-air oven method at 105 ± 1 ℃ for 24 h (Brusewitz, 1975).

The colour characteristics (*L**, *a**, *b**)of skin and flesh service tree fruits were measured by a colourimeter (Minolta CR-3000, Japan). Colour characteristics of service tree fruit sample was measured and computed as the mean of each treatment according to the method of Jhaet al. (2005). Chroma (*C**) and hue *(h)* are the effective parameters for describing the visual colour appearance of service tree fruits. For each ripening period, five colour measurements of 10 sample fruits were done. Hue (*h*) expresses the colour nuance and values are defined as follows: red-purple: 0°; yellow: 90°; bluish-green: 180°; blue: 270°. The chroma (*C**) is a measure of chromaticity, which defines the purity or saturation of the colour (McGuire, 1992). *C** and *h* were calculated to the method of Bernalte et al.by Equation 1 and Equation 2 (2003):

$$C^* = \left[a^2 + b^2\right]^{1/2} \quad (1)$$

$$h = \left[\tan^{-1}\frac{b}{a}\right] \quad (2)$$

Friction coefficients of service tree fruit samples, tangent value of the angle of slope, were determined for different surfaces (chipboard, galvanized steel, plywood, laminate and rubber) (Altuntas et al., 2011).

For the skin and flesh service tree fruits, mechanical (puncture and compression tests) measurements of service tree fruits were measured using by 11 mm diameter cylindrical stainless steel and 73 mm diameter plate with biological materials test device (Sundoo, SH–2, 500 N, China). Force and time curves of service tree fruits were recorded and to rupture force of service tree fruits for skin and flesh firmnesses along three axial forces (F_x, F_y *and* F_z) were measured (Figure 1). Three replications were made for each ripening period of service tree fruit as using 15 samples (Braga et al., 1999).

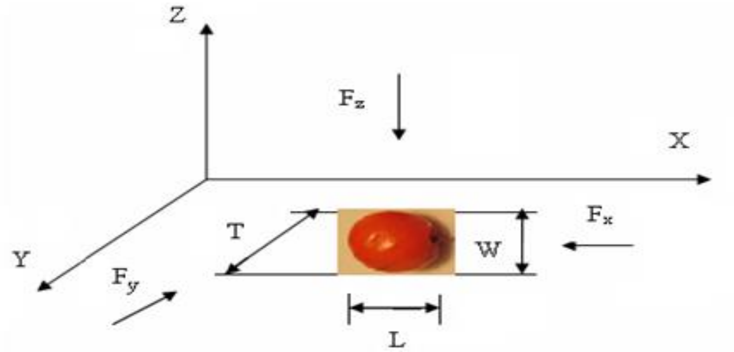

Figure 1Presentation of the three perpendicular dimensions of service tree fruit the and three axial forces ($F_{x,}$ F_y and F_z)

For each ripening period, SSC (Soluble solid content), TA (titratable acidity) and pH of service tree fruits were determined by the method of the AOAC (Association of Official Analytical Chemists, 1984; Barrett et al., 2007).Statistical analyses for the experiment results were conducted with SPSS 13.0 software based on a randomized complete plot design.

3 Results and discussion

3.1 Physical properties

The physical properties of service tree fruits affected by ripening periods (RP-1 physiological maturity, RP-2 ripening period and RP-3 overripe period) are given in Table 1. The effect ripening periods on the geometric mean diameters of service tree fruits was statistically significant (p<0.01), while the sphericity was not statistically significant with ripening period changes. The sphericity was lower in RP-2 than RP-3 maturity levels, and also the geometric mean diameter were lower in RP-3 than the other RP-1 and RP-2 ripening changes. The surface area and volume of service tree fruits was higher in RP-1 than the other ripening periods. The fruit volume of service tree fruits ranged between 10.82 to 8.39 cm^3 from RP-1 physiological maturity to RP-3 overripe period, respectively (Table 1).

Table 1Physical properties of service tree fruits at the different ripening periods

	Ripening periods (RP)		
Physical properties	RP-1	RP-2	RP3
Length (L; mm)	29.46 a‡(0.20)*	27.29 b (1.52)	27.11 c (1.17)
Width (W; mm)	28.54 a‡ (0.19)	25.86 b (1.40)	25.77 c (1.52)
Thickness (T; mm)	24.46 a‡ (0.16)	23.26 b (1.19)	23.18 c 1.29)
Geometric mean diameter (GMD;	27.30 a‡ (0.17)	25.76 b (0.99)	25.09 c (1.00)
Sphericity (S_p; %)	92.72 ^{ns} (0.21)	92.13 ^{ns} (2.20)	93.03 ^{ns} (2.57)
Fruit mass (M_f ; g)	12.78 a‡ (0.20)	11.00 b (0.20)	10.09 c (0.16)
Bulk density (ρ_b; kg/m^3)	228.44 a‡ (1.88)	233.77 b (6.17)	370.36 b (2.42)
Fruit density (ρ_f ; kg/m^3)	1015.23 a† (81.43)	940.52 ab (45.82)	782.94 b (56.89)
Porosity, p (%)	77.32 a‡ (4.99)	74.17 a (3.01)	51.50 b (8.14)
Surface area (S_a ; cm^2)	23.46 a‡ (0.29)	20.87 b (1.63)	19.80 c (1.56)
Fruit volume (F_v; cm^3)	10.82 a‡ (0.20)	9.07 b (1.07)	8.39 c (0.98)

Note: RP-1: Physiological maturity; RP-2: ripening period; RP-3: Overripe period; *: SEM (standard error of the mean)

† : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different (p<0.05);

‡ : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different (p<0.01); ns: not significant

The effect ripening periods on the fruit mass, surface area and fruit volume of service tree fruits were statistically significant ($p<0.01$). Altuntas et al. (2013)reported that the fruit mass, sphericity, volume and geometric mean diameter values were reported as 15.48 g, 95.0%, 10.28 cm^3 and 26.82 mm at 66.3% dry basis moisture content for ripening period of medlar fruit.

Owolarafe et al. (2007)reported that, fruit length, width and thickness of fresh palm (for Dura cultivar) were found as 30.25 mm and 19.94 mm and 15.66 mm, respectively.While, bulk density increases of 62.13% observed from RP-1 physiological maturity to RP-3 overripe period of service tree fruits, the fruit density decreases of 22.88% occurred from RP-1 to RP3 increase, respectively (Table 1).The effects ripening periods on the bulk density and porosity of service tree fruits were statistically significant ($p<0.01$), while, the fruit density was affected by statistically $p<0.05$ significant with ripening period changes.

Haciseferogullari et al. (2005) reported the fruit density of medlar fruits as 1031.1 kg/m^3, bulk density of 379.9 kg/m^3 and porosity of 63.1% at ripening period. In this study, the porosity, bulk density and fruit density values of service tree fruits were found lower than that of for medlar fruit reported by Haciseferogulları et al. (2005). Jahromi et al. (2008)reported that fruit volume, fruit mass, fruit density, bulk density and porosity of date fruit (cv. Dairi) were as 5.49 cm^3 and 5.30 g, 970 kg/m^3, 490 kg m^{-3} and 49.14%, respectively, while, the sphericity, surface area and the geometric mean diameter were found as 0.63, 15.78 mm^2 and 22.38 mm, respectively.

3.2 Colour characteristics

In Table 2, service tree skin and flesh colour characteristics were presented. The effect ripening periods on the *L**, *a*,b**, *C** and *h* colour characteristics of service tree fruits were statistically significant ($P<0.01$). While, a* and *h* values of service tree fruits varied from -8.92 to 3.54 and -1.29 to 1.30 with the increase from RP-1 to RP-3 for skin service tree fruits, *a** and *h* changed from -6.66 to 9.13 and -1.32 to 1.00 with the increase ripening periods of for flesh service tree fruits, respectively. *a** and *h* values of service tree fruits ripening periods increased with the increase from physiological maturity to overripe period for skin and flesh service tree fruits.

Table 2 Colour characteristics of service tree fruits at the different ripening periods

Colour characteristics	Ripening periods (RP)		
	RP-1	RP-2	RP3
Skin fruit			
*L**	61.31 a‡ (0.75)*	53.55 b (1.05)	27.48 c (0.31)
*a**	-8.92 c‡ (1.40)	0.29 b (1.14)	3.54 a (0.37)
*b**	30.64 b‡ (0.66)	42.66 a (1.12)	12.74 c (0.54)
*Chroma, C**	32.02 b‡ (0.94)	42.73 a (1.14)	13.23 c (0.59)
Hue, h	-1.29 b‡ (0.039)	0.93 a (0.549)	1.30 a (0.022)
Flesh fruits			
*L**	61.08 a‡ (1.73)*	60.66 a (1.37)	22.45 b (0.52)
*a**	-6.66 b‡ (0.31)	5.29 b (0.90)	9.13 a (0.51)
*b**	24.46 b‡ (0.49)	38.22 a (1.90)	14.23 c (0.63)
*Chroma, C**	27.30 b‡ (0.48)	38.64 a (1.86)	16.91 c (0.81)
Hue, h	-1.32 b‡ (0.012)	-1.43 c (0.025)	1.00 a (0.007)

Note: RP-1: Physiological maturity; RP-2: ripening period; RP-3: Overripe period; *: SEM (standard error of the mean)

† : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different ($p<0.05$);

‡ : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different ($p<0.01$);

Altuntas et al. (2013) reported that L*, *a**and b*colour values were between 37.3 to 47.6; 5.0 to 11.7 and 19.5 to 26.0 at physiological maturity for skin medlar fruits, while, *L**, *a** and *b**colour values were between 66.3 to 75.2; 2.5 to 4.2 and 20.5 to 24.2 at ripening period for flesh medlar fruits, respectively. While, Costa et al. (2006) reported that the flesh colour for kiwifruits as *L** of 56.41, *a** of -17.47 and *b** of 32.35, respectively, *L**, *a** and *b** values for skin kiwifruit colours were found as 43.94, 5.51 and 24.04 by Celik et al. (2007), respectively.

3.3 Mechanical properties

The mechanical characteristics of service tree fruits during physiological maturity, ripening period and overripe period are given in Table 3. Skin firmness of service tree fruits along X- axis and Y-axis punctured using with cylindirical probe varied from 2.804 to 0.089 N (96.83% decrease) and from 4.455 to 0.138 N(96.90% decrease) with increase from physiological maturity (RP-1) to overripe period (RP-3), respectively. Flesh firmness of service tree fruits along X- axis and Y- axis punctured using with cylindirical probe decreased from 2.046 and 0.191 N; from 2.746 to 0.196 N with the increase from physiological maturity (RP-1) to ripening period (RP-2), respectively. In overripe period, flesh firmness value's measuring failed for the service tree fruits. In overripe period for skin and flesh firmnesses value's measuring failed for the service tree fruits because of the sample fruits were too soft already to measure. Skin and flesh firmnesses of service tree fruits decreased by maturity periods along X- axis and Y- axis for puncture and compression tests.

Altuntas et al. (2013)reported that rupture force punctured using with cylindrical and needle probe along X- axis for medlar fruits decreased (with 90.2% and 93.1% decreases) from physiological maturity to ripening period, respectively.

Table 3 Mechanical behaviour of service tree fruits at the different ripening periods

Mechanical behaviours	Ripening period (RP)		
Puncture test (by 11 mm cylinder probe)	RP-1	RP-2	RP3
Skin firmness (X axis, N)	2.804±0.608	0.197±0.020	0.089±0.038
Skin firmness (Y axis, N)	4.455±0.956	0.201±0.010	0.138±0.010
Flesh firmness (X axis, N)	2.046±0.178	0.191±0.022	Measuring failed
Flesh firmness (Y axis, N)	2.746±0.565	0.196±0.010	Measuring failed
Compression test (by 73 mm circular plate)			
Skin firmness (X axis, N)	46.85±15.69	3.604±0.221	Measuring failed
Skin firmness (Y axis, N)	35.45±12.29	3.556±0.831	Measuring failed
Flesh firmness (X axis, N)	36.15±5.38	2.304±0.488	Measuring failed
Flesh firmness (Y axis, N)	26.31±4.85	2.223±0.232	Measuring failed

Note: RP-1: Physiological maturity; RP-2: ripening period; RP-3: Overripe period; *: SEM (standard error of the mean)

† : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different (p<0.05);

‡ : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different (p<0.01);

The effect of ripening periods from RP-1 to RP-3 on the friction coefficient for friction surfaces was given in Table 4. Effect maturity levels of service tree fruits on the friction coefficients of against for all friction tests were statistically significant. In general, the friction coefficients for galvanized steel, laminate, plywood and chipboard friction surfaces increased with maturity levels of service tree fruits. This is a result of the increasing adhesion between the friction surface and softened service tree fruits at overripe maturity according to physiological maturity of fruits (Altuntas et al., 2013).

Table 4 Friction coefficients of service tree fruits at the different ripening periods

Friction coefficients	Ripening period (RP)		
	RP-1	RP-2	RP3
Chipboard	0.487 b† (0.024)*	0.528 ab (0.022)	0.563 a (0.017)
Galvanized steel	0.439 b† (0.023)	0.517 ab (0.028)	0.535 a (0.029)
Plywood	0.498 b‡ (0.025)	0.570 a (0.010)	0.576 a (0.012)
Laminate	0.435 b‡ (0.023)	0.473 ab (0.016)	0.505 a (0.006)
Rubber	0.535 b† (0.036)	0.622 ab (0.044)	0.672 a (0.027)

Note: RP-1: Physiological maturity; RP-2: ripening period; RP-3: Overripe period; *: SEM (standard error of the mean)

† : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different (p<0.05);

‡ : Values in the same column (within nut or kernel sections) followed by the same letter are not significant different (p<0.01);

The friction coefficient was lower in laminate than the rubber, galvanized steel, chipboard and plywood surfaces. Owolarafe et al. (2007) reported that the friction coefficient (static) were 0.56, 0.58, 0.56 and 0.53 for mild steel, plywood, galvanized steel and aluminum for fresh palm fruit, respectively variety. The friction coefficients for service tree fruits were similar to reported by reported literatures.

3.4 Chemical properties

The effect of maturity levels on chemical properties (TA, SSC, and pH) were presented in Table 5. The effect of the ripening periods on SSC, pH, TA of plum fruit was not statistically significant (P>0.05). SSC of service tree fruits was 13.07%, 12.22% and 11.75% for ripening periods from RP-1 to RP-3, respectively. pH and TA values of service tree fruits were 4.637 and 0.241 g 100 g^{-1} (RP-1), 4.683 and 0.229 g 100 g^{-1} (RP-2), 4.647 and 0.215 g 100 g^{-1} (RP-3), respectively.

Table 5Chemical characteristics (TA, SSC and pH) and moisture content of service tree fruitsat the different ripening periods

	Ripening period (RP)		
Chemical characteristics	RP-1	RP-2	RP3
TA; g/100 g	0.241^{ns} (0.015)*	0.229^{ns} (0.020)	0.215^{ns} (0.008)
SSC; %	13.07^{ns} (0.68)	12.22^{ns} (0.39)	11.75^{ns} (0.36)
pH	4.637^{ns} (0.003)	4.683^{ns} (0.022)	4.647^{ns} (0.012)
Moisture content (M_c; %)	73.18^{ns} (0.82)	72.61^{ns} (0.25)	71.84^{ns} (0.89)

Note: RP-1: Physiological maturity; RP-2: ripening period; RP-3: Overripe period; *: SEM (standard error of the mean) ns: not significant

With increasing maturity levels, SSC and TA values decreased. The highest TA and SSC were obtained from RP-1 physiological maturity, while, pH of service tree fruits were found at RP-1 physiological maturity. For physiological maturity (RP-1), ripening period (RP-2) and overripe period (RP-3), the moisture content (M_c) of service tree fruits were found to be 73.18%, 72.61% and 71.84% (dry basis), respectively. The effect of the ripening periods on M_c of service tree fruit was not statistically significant (P>0.05).

Celik and Ercisli (2008)reported that TA, SSC and pH of persimmon (cv. Hachiya) fruits were 2.06%, 17.1 and 5.40, respectively. Altuntas et al. (2013)reported that, pH and SSC of medlar fruit varied from 4.01 to 4.70 and 17.8 to 15.5% at physiological maturity and overripe period, respectively.

The titratableacidity of medlar fruit ranged from 0.68 to 0.39 g 100 g^{-1}during physiological maturity and ripening period, respectively. TA and pH of medlar fruits were as 0.3 g 100 g^{-1} and 4.3 at ripening period reported byHaciseferogullari et al. (2005). In this study, the chemical results are generally in consistent with the results of previous studies.

4 Conclusion

The engineering (physical, mechanical and chemical) properties are highly dependent on maturity periods from physiological maturity (RP-1), ripening period (RP-2) and overripe period (RP-3).

1. The sphericity and the geometric mean diameter were lower in RP-1 than the other RP-2 and RP-3maturtiy levels. The surface area and volume of service tree fruits were higher in RP-1 than the other ripening period. At overripe period, the fruit density and porosity of service tree fruits are lower than the other maturity levels.
2. With increase ripening periods (from RP-1 to RP-3), *L**values of service tree fruits decreased for skin fruits and flesh fruits respectively. With the increase from physiological maturity to overripe period, *a** and *h* values of service tree fruits ripening periods increased. For puncture and compression tests, skin and flesh firmnesses of service tree fruits decreased by maturity periods along X-axis and Y-axis.
3. The friction coefficients for galvanized steel, laminate, plywood and chipboard friction surfaces increased with maturity levels of service tree fruits. SSC and TA values decreased with increasing maturity levels.
4. The highest TA and SSC were obtained from RP-1 physiological maturity, while, the lowest pH of service tree fruits were found at RP-1 physiological maturity.

The engineering properties of service tree fruits should be considered to design the postharvest treatments, systems and processing.

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