Physico-mechanical and chemical properties of president plum affected by aminoethoxyvinylglycine (AVG) treatment and maturity stages

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Abstract: In the study, the effects of aminoethoxyvinylglycine (AVG) treatment and maturity stages on physicomechanical and chemical properties of the fruit of plum fruit (*Prunus domestica* cv. ‘President’) was investigated. The effect of AVG doses for each maturity stage on geometric mean diameter and surface area of plum fruit was statistically significant. The geometric mean diameter and surface area were higher on 4 August harvest date than the other harvest dates. The effect of AVG doses on the fruit volume and fruit mass of plum fruit were statistically significant for each maturity stage. While L^*, b^*, and C^* colour characteristics of plum fruit for all AVG treatments increased according to maturity stages. The effect of AVG treatments on the fruit removal force (FRF) and fruit hardness of plum fruit was statistically significant. The FRF and fruit hardness for plum fruit were higher as 19.17 N and 2.48 kg for 200 mg L^{-1} AVG dose than the other AVG doses. The laminate and rubber friction surfaces offered the minimum and maximum friction with AVG dose treatments. The effect of AVG treatments on soluble solids content (SSC) and titratable acidity of plum fruit was statistically significant ($p<0.01$). The chemical characteristics such as pH and SSC of plum fruit were higher in AVG-0 treatment and the latest harvest date than the other AVG treatment and harvest dates. For this reason, post-harvest technology applications (transporting, processing, storing and packaging systems) of the plum fruit must be designed while taking these criterias into consideration such as physicomechanical and chemical properties.
Keywords: bulk density, geometric mean diameter, colour, fruit removal force, SSC

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1 Introduction

To improve fruit quality and yield, the uses of plant growth regulators in modern agricultural treatments have become widespread. Plant growth regulators have been evaluated among factors causing changes in the physicomechanical and chemical properties of the different fruits (Shin et al., 2008).

Aminoethoxyvinylglycine (AVG) has been used heavily to decrease preharvest fruit drop, improve the quality of fruit, delay fruit harvest and protect the fruit firmness by inhibiting ethylene which causes to accelerate the maturation at a period before harvest (Yuan and Carbaugh, 2007). In addition, the use of AVG have been manipulating the control of vegetative growth and regulation of flowering, size, shape, colour development and postharvest quality (Greene, 2006).

Some important factors (colour, maturity level, size, firmness and mechanical defect) are considered for plum

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fruit marketing. In harvesting, since separating, conveying, storing, handling, processing, packaging systems and estimating the cooling and heating loads of plum fruit are used to design and improve relevant machines and facilities, there is a need to know the physicomechanical and chemical properties. The harvested agricultural products have been damaged by the mechanical harvesting methods with exert load and breaking stress (Kuna-Broniowska et al., 2012). Compression orientation and speeds affect the amount of force applied to post-harvest applications (processing of plum fruit to fruit juice and marmalade) for plum fruit (Pérez-Vicente et al., 2002). In designing of conveying, transporting and storing structures, the friction coefficients of the plum fruit against the different surfaces are necessary.

Several researchers have investigated the physicomechanical and chemical properties of some fruit such as kiwifruit (Razavi and BahramParvar, 2007), cherry tomato varieties (Kabas and Ozmerzi, 2008), fruit oil (Kılıçkan and Güner, 2008), pear cultivars (*Pyrus communis L.*) (Ozturk et al., 2009), pomegranate peel and fruit (Ekrami-Rad et al., 2011), Medlar (Altuntas et al., 2013a), cherry laurel (Altuntas et al., 2018), respectively. Technical information and data in the scientific literature with regards to the effects of AVG treatments on the physicomechanical and chemical properties of *President* plum fruit are insufficient**.** Thus, the effects of AVG treatment and maturity stages on physical, chemical and mechanical properties of President plum were examined in this study.

2 Materials and methods

Plum fruit (*Prunus domestica* cv. ‘President’) were hand-harvested on three harvest dates (28 August, 4 September, and 11 September 2012) from Tokat province, located in Mid-Black Sea Transition Climate Belt region of Turkey. 4 September was the commercial harvest date. Then, plum fruit was transferred in polyethene bags to the Biological Materials Laboratory. To determine the size of the plum fruit samples, 100 sample fruits were randomly selected as removed from foreign matters, undamaged fruit and cleaned.

AVG was sprayed two weeks before the commercial harvest date on the trees until run-off with a low-pressure hand sprayer. An ethylene inhibitor AVG was applied as ReTain formulation (ValentBioSciences Corp., Libertyville, IL) at three doses of 0 mg L^{-1} (AVG-0, control), 100 mg L^{-1} (AVG-100) and 200 mg L^{-1} (AVG-200), respectively. The non-spray of AVG (control) trees were treated only with water (pH = 6.48) + “Sylgard 309” surfactant.

The moisture content (initial) of plum fruit was determined using the standard hot-air oven method at 105°C ± 1°C for 24 h (Brusewitz, 1975). The three principal sizes such as length, width and thickness dimensions (geometric properties) of plum fruit were measured by using a digital vernier calliper (accuracy, 0.01 mm). With the digital electronic balance precision balance (0.01 g resolution) was used for fruit mass of plum samples. D_g (geometric mean diameter), Φ (sphericity), and S (surface area) and V (volume) of plum fruit samples were calculated using the equations explained by Mohsenin (1980). ρ_f (fruit density) was determined by the toluene (C_7H_8) displacement method, and ρ_b (bulk density) of plum fruits was determined by hectoliter standard weight method (Altuntas et al., 2018). P (porosity) was determined from fruit density and bulk density values explained by Mohsenin (1980).

*L**, *a**, *b** colour characteristics of plum fruit samples were measured by a chromometer (Minolta, model CR-3000, Tokyo, Japan) and computed as the mean of each treatment. *L**, *a** and *b** were used to define a three-dimensional colour space and interpreted [*L**, the lightness, the values ranging from 0 to 100], [*a**, redness and greenness], [b*, yellowness and blueness]. Chroma (*C**) is the purity or saturation of the colour. Hue angle (*h*°), is the color nuance, red-purple: 0; yellow: 90; bluish green: 180; blue: 270]. The hue angle and chroma were calculated using the equations explained by McGuire (1992); Jha et al.(2006). Three replications were made for each maturity stage of plum fruit as using 15 samples. Coefficients of friction of plum fruit were determined for different (chipboard, galvanized steel, plywood, laminate and rubber) surfaces (Altuntas et al., 2012).

With a hand of a digital force gauge (Tronic; HF-10, Digital Dynamometer, 100 N, Taiwan), fruit-removal-force (FRF) was determined as along the longitudinal orientation stalk of twenty plum samples for each AVG treatment and maturity stages. In the relationship, FRF and fruit mass (M) were analyzed for plum fruit samples under AVG treatments and maturity stages. With an Effigi Penetrometer with 11.1 mm (FT-327; MoCormick Fruit Tech, WA, USA), the fruit hardness of plum fruit (for skin) was measured on each fruit along three sides.

The soluble solids content (SSC), titratable acidity (TA) and pH of 'President' plum fruit samples were determined by the method of the AOAC (Association of Official Analytical Chemists, 1984) and Barrett et al. (2007). Statistical analyses of the experimental results were conducted with SPSS 13.0 software based on a randomized complete plot design. When the F test was significant, means were compared with the Duncan test.

3 Results and discussion

3.1 Physical properties

The physical properties (geometric) of '*President*' plum cultivar affected by AVG doses and maturity stage (harvest dates) are given in Table 1. The effect AVG doses for each harvest date on the geometric mean diameters and surface area of plum fruit was statistically significant ($p<0.01$), while the sphericity was not statistically significant with AVG doses for each maturity stage change. The geometric mean diameter was lower in 11 September than the other maturity stages (28 August and 4 September harvest dates), while the surface area of plum fruit was higher on 4 August than the other maturity stages (28 August and 11 September harvest dates) (Table 1).

Table 1 Physical (geometric) properties of '*President*' plum cultivar at maturity stages affected by AVG treatments

Geometric properties	AVG treatments (mg L^{-1})	Maturity Stages (Harvest dates)			AVG Means
		28 August	4 September	11 September	
Length, L, mm	AVG-0	55.14 (0.62)$^{\xi}$	56.15 (0.43)	56.76 (0.60)	56.02 a**
	AVG-100	53.05 (0.63)	52.79 (0.52)	50.91 (0.63)	52.25 c
	AVG-200	55.10 (0.63)	54.43 (0.42)	55.56 (0.61)	55.03 b
	Mean	54.43 ^{ns}	54.46 ^{ns}	54.41 ^{ns}	
Width, W, mm	AVG-0	45.87 (0.58)	47.18 (0.39)	46.54 (0.40)	46.53 a**
	AVG-100	45.40 (0.62)	44.74 (0.58)	42.92 (0.30)	44.35 b
	AVG-200	46.77 (0.56)	46.75 (0.51)	45.90 (0.55)	46.47 a
	Mean	46.01 a*	46.22 a	45.12 b	
Thickness, T, mm	AVG-0	42.27 (0.38)	47.03 (0.37)	46.00 (0.57)	45.10 a**
	AVG-100	44.19 (0.50)	41.90 (0.34)	42.54 (0.32)	42.88 b
	AVG-200	44.84 (0.54)	45.71 (0.45)	45.49 (0.46)	45.35 a
	Mean	43.77 ^{ns}	44.88 ^{ns}	44.68 ^{ns}	
Geometric mean diameter, Dg, mm	AVG-0	48.00 (0.45)	49.73 (0.26)	49.33 (0.46)	49.02 a**
	AVG-100	47.18 (0.46)	46.06 (0.36)	45.11 (0.32)	46.12 b
	AVG-200	48.50 (0.51)	48.60 (0.35)	48.56 (0.42)	48.55 a
	Mean	47.89 ^{ns}	48.13 ^{ns}	47.67 ^{ns}	
Sphericity, Sp	AVG-0	0.871 (0.005)	0.886 (0.006)	0.869 (0.005)	0.875 ^{ns}
	AVG-100	0.891 (0.008)	0.873 (0.006)	0.887 (0.007)	0.884 ^{ns}
	AVG-200	0.881 (0.004)	0.893 (0.006)	0.875 (0.007)	0.883 ^{ns}
	Mean	0.881 ^{ns}	0.884 ^{ns}	0.877 ^{ns}	
Surface area, Sa, mm^2	AVG-0	7250.4 (135.0)	7774.7 (80.6)	7656.9 (142.5)	7560.7 a**
	AVG-100	7007.0 (134.5)	6671.7 (104.6)	6400.3 (91.0)	6693.0 b
	AVG-200	7407.6 (157.8)	7428.7 (104.9)	7419.5 (127.2)	7418.6 a
	Mean	7221.7 ^{ns}	7291.7 ^{ns}	7158.9 ^{ns}	

Note: $^{\xi}$: SEM (standard error of the mean); ^{ns}: not significant ($p>0.05$).

*: Values in the same line followed by the same letter are not significant different ($p<0.05$); **: Values in the same line followed by the same letter are not significantly different ($p<0.01$).

Esehaghbeygi et al. (2013) reported that physical properties of the plum (Ghandi, Gatretala, and Black) cultivars were found to be statistically significant. The length, width, thickness and geometric mean diameters for plum cultivars were ranged from 28.05 to 36.52 mm, 26.78 to 35.46 mm, and 25.85 to 34.01 mm, 27.02 to 35.30 mm respectively. Altuntas et al. (2013b) reported that the geometric mean diameter and fruit mass of plum fruit were found to be 49.33 mm and 70.86 g for methyl jasmonate (MeJA-0, control) respectively, while the geometric mean diameter and fruit mass of plum fruit were ranged from 47.26 to 47.96 mm and 65.10 to 69.02 g with an increase MeJA doses from 1120 to 2240 mg L^{-1}, respectively.

Ozturk et al. (2013) reported that the length, width, thickness (size dimensions) of apple fruit was higher in 300 mg L^{-1} AVG treatment compared with the those of 0 mg L^{-1} (control) and 100 mg L^{-1} AVG treatments. The size dimensions and fruit mass linearly increased as AVG doses increased. Ozkan et al. (2012) reported that the geometric mean diameter of apple fruit (*cv. Braeburn*) was obtained as 69.68 mm for 20 mg L^{-1} 1-naphthalene acetic acid (NAA) treatment; 71.26 mm for 500 mg L^{-1} AVG treatment; 69.03 mm (control), respectively. According to these results, and also, our results related the geometric mean diameter was similar to that reported for plum fruit by Altuntas et al. (2013b), while, our results related the geometric mean diameter for plum fruit in this study were lower than that reported for Braeburn apple (Ozkan et al., 2012).

The physical properties (volumetric) of '*President*' plum affected by AVG doses and maturity stage (harvest dates) are given in Table 2. The effect AVG doses (AVG-0, AVG-100, AVG-200) for each maturity stage of the fruit mass and fruit volume of plum fruit were statistically significant (p<0.01). The effect of AVG treatments on the bulk density of plum fruit were statistically significant (p<0.05), while, the effect of AVG treatments on the fruit density and porosity of plum fruit were not statistically significant (p>0.05), respectively.

Table 2 Physical (volumetric) properties of '*President*' plum cultivar at maturity stages affected by AVG treatments

Volumetric properties	AVG treatments (mg L^{-1})	Maturity Stages (Harvest dates)			AVG Means
		28 August	4 September	11 September	
Fruit mass, M, g	AVG-0	66.93 (2.00)	73.34 (0.80)	70.86 (1.71)	70.38 a**
	AVG-100	59.93 (1.43)	60.65 (0.81)	60.74 (0.20)	60.44 b
	AVG-200	68.76 (1.77)	68.15 (1.27)	70.74 (1.15)	69.22 a
	Mean	65.21 ^{ns}	67.38 ^{ns}	67.45 ^{ns}	
Fruit volume, V, mm^3	AVG-0	58885.2 (1630.3)	65275.6 (1630.3)	63910.8 (1774.8)	62690.5 a**
	AVG-100	55956.6 (1665.4)	51930.7 (1230.0)	48775.6 (1028.6)	52221.0 b
	AVG-200	60859.7 (1955.5)	61004.5 (1281.5)	60935.5 (1549.1)	60933.2 a
	Mean	58567.2 ^{ns}	59403.6 ^{ns}	57874.0 ^{ns}	
Bulk density, ρ_b, kg m^{-3}	AVG-0	668.18 (8.23)	639.61 (19.65)	642.81 (15.86)	650.20 ab*
	AVG-100	646.55 (3.96)	639.95 (5.11)	623.38 (7.84)	636.63 b
	AVG-200	611.93 (6.27)	668.88 (10.35)	723.76 (23.42)	668.19 a
	Mean	642.22 ^{ns}	649.48 ^{ns}	663.32 ^{ns}	
Fruit density, ρ_f, kg m^{-3}	AVG-0	994.40 (25.89)	1037.07 (44.83)	907.77 (29.15)	979.75 ^{ns}
	AVG-100	975.00 (6.18)	1052.02 (25.45)	910.76 (6.80)	979.26 ^{ns}
	AVG-200	937.85 (19.71)	1085.57 (46.86)	913.06 (5.26)	978.83 ^{ns}
	Mean	969.08 b**	1058.22 a	910.53 b	
Porosity, P, %	AVG-0	32.71 (1.34)	37.81 (4.26)	29.08 (1.67)	33.20 ^{ns}
	AVG-100	33.67 (0.80)	39.05 (1.68)	31.55 (0.92)	34.76 ^{ns}
	AVG-200	35.23 (1.10)	38.14 (1.90)	24.56 (0.15)	32.64 ^{ns}
	Mean	33.87 b**	38.33 a	28.40 c	

Note: $^{\xi}$: SEM (standard error of the mean); ^{ns}: not significant (p>0.05);
*: Values in the same line followed by the same letter are not significant differences (p<0.05);
**: Values in the same line followed by the same letter are not significantly different (p<0.01).

3.2 Colour characteristics

The colour characteristics of '*President*' plum at different maturity stages affected by AVG treatments are presented in Table 3. The effect of AVG treatment on the L^*, a^*, b^*, $h°$, C^* colour characteristics of plum fruit were not significant (p>0.05). The effect of maturity stages on L^*, b^*, and C^* colour characteristics of plum fruit were statistically significant (p<0.01), while the effect of maturity stages on $h°$ colour characteristics of plum fruit was statistically significant (p<0.05). While L^*, b^*, and C^* colour characteristics of plum fruit for 0, 100 and 200 mg L^{-1} AVG treatments increased, according to maturity stages from 28 August to 11 September, a^* and $h°$ color characteristics of plum fruit decreased with harvest date changes in 0 mg L^{-1} AVG treatment (control).

Table 3 Colour characteristics of '*President*' plum cultivar at different harvest dates affected by AVG treatments

Colour characteristics	AVG treatments (mg L^{-1})	Maturity Stages (Harvest dates)			AVG Means
		28 August	4 September	11 September	
L*	AVG-0	49.59 (4.46) $^{\xi}$	55.11 (1.93)	61.39 (2.48)	55.36 ^{ns}
	AVG-100	54.98 (1.46)	56.39 (1.61)	62.13 (1.74)	57.83 ^{ns}
	AVG-200	57.12 (1.45)	55.73 (1.66)	58.93 (2.37)	57.26 ^{ns}
	Mean	53.90 b**	55.74 b	60.82 a	
a*	AVG-0	-5.26 (0.98)	-6.17 (0.55)	-6.62 (0.79)	-6.02 ^{ns}
	AVG-100	-6.78 (0.37)	-6.80 (0.46)	-5.75 (0.65)	-6.44 ^{ns}
	AVG-200	-7.66 (0.32)	-6.63 (0.60)	-6.78 (0.68)	-7.02 ^{ns}
	Mean	-6.57 ^{ns}	-6.53 ^{ns}	-6.38 ^{ns}	
b*	AVG-0	26.51 (2.81)	30.99 (1.06)	39.03 (1.56)	32.18 ^{ns}
	AVG-100	29.58 (1.10)	31.52 (0.93)	36.80 (1.48)	32.63 ^{ns}
	AVG-200	29.70 (1.79)	28.20 (1.43)	38.35 (1.26)	32.08 ^{ns}
	Mean	28.60 b**	30.24 ab	38.06 a	
Chroma, C*	AVG-0	27.14 (2.88)	31.65 (1.05)	39.66 (1.59)	32.82 ^{ns}
	AVG-100	30.37 (1.12)	32.78 (0.91)	37.32 (1.46)	33.49 ^{ns}
	AVG-200	30.74 (1.72)	29.03 (1.45)	39.00 (1.30)	32.92 ^{ns}
	Mean	29.42 b**	31.15 b	38.66 a	
Hue angle, h°	AVG-0	-65.85 (13.01)	-78.70 (1.02)	-80.54 (1.12)	-75.03 ^{ns}
	AVG-100	-77.05 (0.64)	-71.32 (6.26)	-80.95 (1.04)	-76.44 ^{ns}
	AVG-200	-74.84 (1.44)	-76.72 (1.10)	-80.05 (0.93)	-78.54 ^{ns}
	Mean	-67.68 a*	-75.58 ab	-80.51 b	

Note: $^{\xi}$: SEM (standard error of the mean); ^{ns}: not significant ($p>0.05$);
*: Values in the same line followed by the same letter are not significantly different ($p<0.05$);
**: Values in the same line followed by the same letter are not significantly different ($p<0.01$).

For 100 mg L^{-1} AVG treatment, *L**, *b** and *C** values increased with harvest date changes, whereas, *h*° colour characteristics of plum fruit decreased with harvest date changes for 100 mg L^{-1} AVG treatment. Ozturk et al. (2013) reported that the colour characteristics of apple fruit (skin) generally increased in magnitude with an increase in AVG dose treatments. *L**, *C** and *h*° values of apple for AVG-0 treatment were as 53.08, 41.66 and 57.58; for AVG-1 treatment were 54.29, 40.57 and 59.45; for AVG-2 treatment were as 53.95, 40.42 and 58.48; for AVG-3 treatment were as 54.89, 41.17 and 59.29, respectively. Ozturk et al. (2015) reported that *L** value was higher than the control treatment in 2011 for all AVG treatments, except for 100 mg L^{-1}. Hue angle colour characteristic of apple fruit significantly increased for 400 mg L^{-1} AVG and 500 mg L^{-1} AVG treatments in the second year. Ozturk et al. (2012) reported that *L** value of the plum fruit (*Prunus salicina Lindell* cv. '*Black Amber*') decreased from 28.02 to 21.84 in the control; from 30.45 to 21.49 in the 100 mg L^{-1} AVG; from 30.51 to 21.99 in the 200 mg L^{-1} AVG, respectively. According to these results, our observed results related *L** for plum fruit (*cv. President*) are higher than that reported for Black Amber (*Prunus salicina*) plum fruit (Ozturk et al., 2012).

3.3 Mechanical properties

The mechanical characteristics such as fruit removal force (N), fruit hardness, and *M/FRF* of plum fruit as affected by AVG treatment and maturity stages are given in Table 4. The effect of AVG treatments on the *FRF* and fruit hardness of plum fruit was statistically significant ($p<0.01$), whereas, the effect of AVG treatments on *M/FRF* ratio of plum fruit was not significant ($p>0.05$). The effect of the maturity stages on the fruit-removal-force was statistically significant ($p<0.05$), whereas, the effect of maturity stages on the fruit hardness and *M/FRF* ratio of plum fruit was not significant ($p>0.05$).

The FRF for plum fruit ranged 19.11 N, 17.33 N and 19.17 N for AVG dose treatments from 0 to 200 mg L^{-1}. The *FRF* and fruit hardness for plum fruit were higher in AVG 200 mg L^{-1} than the other AVG treatments. Gezer et al. (2000) reported that the *M/FRF* ratio and fruit-removal-force values were of 7.90 and 16.57 N for Golden Delicious apple cultivar, respectively. Sahin (2007) reported that M/FRF and the fruit-removal-force of apple cultivars were of 18.99 and 9.86 N for Starking

Delicious; 10.07 and 14.57 N for Golden Delicious, respectively. Altuntas et al. (2012) reported that the *FRF* of Fuji apple fruit decreased from 21.74 to 17.67 N, and also *M/FRF* ratio decreased from 9.18 to 11.19 as MeJA doses increased from 1120 to 4480 mg L^{-1}. According to these results, our observed results related to *FRF* for plum fruit (*cv. President*) are higher than reported in the literature by Gezer et al. (2000), and Sahin (2007), whereas, our results related to *FRF* for plum fruit (*cv. President*) are similar to that reported in the literature by Altuntas et al. (2012).

Table 4 Mechanical properties of '*President*' plum cultivar at different harvest dates affected by AVG treatments

Mechanical properties	AVG treatments (mg L^{-1})	Maturity Stages (Harvest dates)			AVG Means
		28 August	4 September	11 September	
FRF (N)	AVG-0	16.577 (2.33)$^{\xi}$	18.568 (1.62)	22.192 (2.42)	19.112 a**
	AVG-100	16.670 (1.86)	18.843 (1.55)	16.482 (1.08)	17.332 b
	AVG-200	19.094 (1.66)	20.367 (1.51)	18.056 (1.20)	19.172 a
	Mean	17.447 b*	19.259 a	18.910 a	
Fruit hardness (kg)	AVG-0	2.575 (0.21)	2.110 (0.12)	2.280 (0.22)	2.322 b**
	AVG-100	2.000 (0.09)	1.995 (0.18)	1.930 (0.15)	1.975 c
	AVG-200	2.120 (0.13)	2.755 (0.19)	2.550 (0.14)	2.475 a
	Mean	2.232 ^{ns}	2.287 ^{ns}	2.253 ^{ns}	
M/FRF	AVG-0	4.358 (0.70)	4.106 (0.49)	3.327 (0.37)	3.930 a*
	AVG-100	3.732 (0.38)	3.286 (0.23)	3.749 (0.26)	3.589 b
	AVG-200	3.679 (0.31)	3.422 (0.33)	3.997 (0.35)	3.699 ab
	Mean	3.923 ^{ns}	3.605 ^{ns}	3.691 ^{ns}	

Note: $^{\xi}$: SEM (standard error of the mean); ^{ns}: not significant (p>0.05);
*: Values in the same line followed by the same letter are not significantly different (p<0.05);
**: Values in the same line followed by the same letter are not significantly different (p<0.01).

The effects of AVG treatment and maturity stages on the static friction coefficient of the different friction surfaces such as rubber, plywood, laminate, galvanized steel, and chipboard were given in Table 5.

Table 5 The static friction coefficient of '*President*' plum cultivar at different harvest dates affected by AVG treatments

Friction surfaces	AVG treatments (mg L^{-1})	Maturity Stages (Harvest dates)			AVG Means
		28 August	4 September	11 September	
Rubber	AVG-0	0.426 (0.062)$^{\xi}$	0.491 (0.602)	0.325 (0.064)	0.414 ^{ns}
	AVG-100	0.338 (0.013)	0.496 (0.038)	0.439 (0.007)	0.424 ^{ns}
	AVG-200	0.384 (0.001)	0.518 (0.032)	0.437 (0.007)	0.446 ^{ns}
	Mean	0.382 b**	0.502 a	0.400 b	
Plywood	AVG-0	0.326 (0.038)	0.326 (0.070)	0.385 (0.032)	0.345 ^{ns}
	AVG-100	0.384 (0.001)	0.371 (0.029)	0.449 (0.061)	0.401 ^{ns}
	AVG-200	0.424 (0.001)	0.344 (0.011)	0.405 (0.023)	0.391 ^{ns}
	Mean	0.378 ^{ns}	0.347 ^{ns}	0.413 ^{ns}	
Laminate	AVG-0	0.332 (0.024)	0.332 (0.024)	0.306 (0.036)	0.323 ^{ns}
	AVG-100	0.319 (0.017)	0.344 (0.011)	0.346 (0.012)	0.336 ^{ns}
	AVG-200	0.338 (0.017)	0.326 (0.022)	0.349 (0.028)	0.338 ^{ns}
	Mean	0.329 ^{ns}	0.334 ^{ns}	0.334 ^{ns}	
Galvanized metal	AVG-0	0.344 (0.012)	0.345 (0.012)	0.364 (0.018)	0.351 ^{ns}
	AVG-100	0.351 (0.001)	0.365 (0.001)	0.371 (0.027)	0.362 ^{ns}
	AVG-200	0.319 (0.025)	0.344 (0.001)	0.384 (0.031)	0.349 ^{ns}
	Mean	0.338 b*	0.351 ab	0.373 a	
Chipboard	AVG-0	0.424 (0.025)	0.425 (0.025)	0.344 (0.006)	0.398 ^{ns}
	AVG-100	0.307 (0.047)	0.435 (0.006)	0.377 (0.007)	0.373 ^{ns}
	AVG-200	0.325 (0.019)	0.426 (0.036)	0.378 (0.040)	0.377 ^{ns}
	Mean	0.352 b**	0.428 a	0.367 ab	

Note: $^{\xi}$: SEM (standard error of the mean); ^{ns}: not significant (p>0.05);
*: Values in the same line and column followed by the same letter are not significantly different (p<0.05);
**: Values in the same line and column followed by the same letter are not significantly different (p<0.01).

The effect of AVG treatment on the friction coefficients of against for plywood, laminate, galvanized steel, rubber, and chipboard friction surfaces was not statistically significant (p>0.05). The effect of maturity stages on the friction coefficients against for rubber and chipboard was statistically significant (p<0.01), whereas the effect of maturity stages on the friction coefficients against for galvanized steel was statistically significant (p<0.05). Generally, the friction coefficients for rubber and laminate friction surfaces increased with the AVG dose and maturity stages changes of plum fruit. The laminate and rubber friction surfaces offered the minimum and maximum friction with AVG dose treatments. This is a result of the increased adhesion of rubber and also decreasing adhesion for laminate between the friction surface and softened plum fruit, respectively. Esehaghbeygi et al. (2013) reported that the friction coefficients of plum fruit cultivars (Ghandi, Gatretala, and Black) ranged from 0.090 to 0.137 (fiberglass), from 0.105 to 0.169 (galvanized metal), from 0.155 to 0.181 (plywood), and from 0.131 to 0.194 (rubber), respectively. Altuntas et al. (2013a) reported that the friction coefficients of the medlar fruit were higher for rubber than the other surfaces during physiological maturity and ripening period. According to these results, our observed results related the friction coefficients for plum fruit 'President' were higher than that reported for Ghandi, Gatretala and Black plum cultivars (Esehaghbeygi et al., 2013).

3.4 Chemical properties

The effects of AVG treatment and maturity stages on chemical properties such as SSC, TA and pH were presented in Table 6. The effect of AVG dose treatment on SSC and TA of plum fruit was statistically significant (p<0.01), whereas, the effect of AVG dose treatment on pH was statistically significant (p<0.05). The effect of maturity stages on SSC, TA and pH of plum fruit were statistically significant (p>0.01), respectively. pH and SSC of plum fruit were higher in AVG-0 treatment and 11 September harvest date than other AVG treatment and harvest dates. Generally, SSC and pH increased with the maturity stages changes of plum fruit. Ozturk et al. (2013) reported that the effect of the AVG treatment on SSC, starch index, pH, and TA of apple fruit were statistically significant (p<0.05). The highest and lowest pH and SSC values were obtained from AVG-0 dose as 2.87%-15.44%, and AVG-3 as 2.69%-13.6%, respectively. SSC, pH, TA of apple increased with AVG dose treatments.

Table 6 Chemical properties of 'President' plums at different harvest dates affected by AVG treatments

Chemical properties	AVG treatments (mg L^{-1})	Maturity Stages (Harvest dates)			AVG Means
		28 August	4 September	11 September	
pH	AVG-0	3.517 (0.026)	3.673 (0.011)	3.770 (0.012)	3.653 a*
	AVG-100	3.413 (0.064)	3.627 (0.015)	3.697 (0.009)	3.579 c
	AVG-200	3.427 (0.062)	3.657 (0.003)	3.660 (0.010)	3.581 b
	Mean	3.452 c**	3.652 b	3.709 a	
SSC, %	AVG-0	16.633 (0.067)	15.100 (0.600)	18.433 (0.033)	16.722 a**
	AVG-100	13.067 (0.033)	14.267 (0.120)	15.433 (0.067)	14.256 c
	AVG-200	14.433 (0.120)	14.800 (0.067)	16.233 (0.145)	15.155 b
	Mean	14.711 b**	14.722 b	16.700 a	
TA, g/100 g	AVG-0	1.287 (0.019)	1.122 (0.025)	1.151 (0.021)	1.187 b**
	AVG-100	1.491 (0.077)	1.276 (0.031)	1.176 (0.011)	1.314 a
	AVG-200	1.520 (0.052)	1.142 (0.024)	1.260 (0.041)	1.307 a
	Mean	1.433 a**	1.180 b	1.196 b	

Note: $^{\xi}$: SEM (standard error of the mean); ^{ns}: not significant (p>0.05);
*: Values in the same line and column followed by the same letter are not significant differences (p<0.05);
**: Values in the same line and column followed by the same letter are not significantly different (p<0.01).

Karaman et al. (2013) reported that the highest and lowest pH values for '*Fortune*' plum cultivar were obtained from 200 mg L^{-1} AVG treatments (3.27) and control (3.21) at the end of the storage, respectively. Ozkan et al. (2016) reported that SSC of apple fruit, treated AVG, was found to be lower than those of control and NAA-treated fruit, whereas TA of apple fruit, treated AVG, was found to be higher at all harvest dates of 2010 and 2011. Yildiz et al. (2018) reported that SSC values of '*Sweetheart*' cherries significantly decreased with AVG 200 mg L^{-1} treatment in all analysis dates, but decreased with AVG 100 mg L^{-1} treatment on 21 and 28th of June. Altuntas et al. (2013a) reported that SSC and pH of medlar fruits changed from 17.8 to 15.5%, from 4.01 to 4.70 at physiological maturity and overripe period, respectively. According to these results, our results related SSC and pH for plum fruit were lower than that reported for medlar fruit (Altuntas et al., 2013a).

4 Conclusion

The physico-mechanical and chemical properties of plum fruit (*cv. President*) are highly dependent on AVG doses treatments and maturity stages. The geometric mean diameter was lower on latest maturity stage than the other maturity stages, while the surface area of plum fruit was higher on the second maturity stage than the other maturity stages. The effect of AVG treatments on the bulk density of plum fruit were statistically significant, while, the effect of AVG maturity stages on the fruit density and porosity of plum fruit was statistically significant. *L**, *b**, and *C** color characteristics of plum fruit for AVG treatments increased, according to the maturity stages, whereas, *a** and *h°* values of plum fruits decreased with harvesting date changes in control. The *FRF* and fruit hardness for plum fruit were higher in AVG 200 mg L^{-1} than the other AVG treatments. The friction coefficients for rubber and laminate friction surfaces increased with AVG dose and maturity stages changes of plum fruit. The laminate friction surface offered the minimum friction with AVG dose treatments. For chemical properties, pH and SSC of plum fruit were higher in the control treatment than 100 mg L^{-1} and 200 mg L^{-1} AVG treatments. The pH and SSC chemical characteristics increased with the maturity stages of plum fruit changes. For this reason, the plum transporting, processing, storing and packaging systems in postharvest treatments must be designed while taking these criteria into consideration such as physico-mechanical and chemical properties of plum fruit.

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