TÜBİTAK

Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2016) 40: 655-663

doi:10.3906/tar-1603-45

Quality traits of green plums (*Prunus cerasifera* Ehrh.) at different maturity stages

Mehmet Ali SARIDAŞ, Ebru KAFKAS, Mozhgan ZARIFIKHOSROSHAHI, Onur BOZHAYDAR, Sevgi PAYDAŞ KARGI*
Department of Horticulture, Faculty of Agriculture, Çukurova University, Adana, Turkey

Received: 11.03.2016 • **Accepted/Published Online:** 18.05.2016 • **Final Version:** 02.11.2016

Abstract: Fruits of 2 different plum cultivars (Prunus cerasifera Ehrh.) were collected in 2015 from 15-year-old trees in Hatay Province, Turkey. The 2 plum cultivars (Can and Gül) were on their own roots. Fruits were picked 5 times (both Can and Gül) at 12-day intervals (12 April [t1], 24 April [t2], 6 May [t3], 18 May [t4], and 30 May [t5]) during maturation in 2015. Higher levels of health-promoting components with the capacity to prevent several diseases, such as phenolic compounds with antioxidant activity, were found in the Can fruits, whereas the Gül fruits were characterized by lower values. The amounts of individual sugars providing taste and the soluble sugar content of the fruits differed between the 2 cultivars, with glucose and fructose being higher in the Can variety. The results show the importance of green plums in the daily diet as a good source of total phenols and antioxidants, providing health-promoting effects in humans, with good edible properties at the pre-early development stage.

Key words: Maturity stage, organic acids, phenolic compounds, *Prunus cerasifera*

1. Introduction

Plums (*Prunus spp*.) are well adapted to a broad range of ecogeographic conditions, as shown by the diversity of species worldwide. In Turkey, the identified species include *Prunus cerasifera* Ehrh., *Prunus domestica* L., *Prunus institia* L., *Prunus spinosa* L., *P. salicina* Lindl., and *P. simonii* Carr (Davis, 1972). Plums belonging to *P. cerasifera* are well adapted to various ecogeographic conditions, with cultivated and wild forms in the Anatolian region (the Asian part of Turkey) spreading from the southeast through central Anatolia, and to the Aegean and Mediterranean regions. In particular, a large diversity of plum varieties can be found in the Mediterranean coastal region, which has economically important green plum (*P. cerasifera*) genotypes that are edible in early spring (Ayanoğlu, 1995).

Plums are among the most important stone fruits growing in Turkey. Plum production is in fourth place behind peach, cherry, and apricot, respectively, with 265,490 t (15%) annually among stone fruits (TUIK, 2015). Plums have a significant place in the human diet because of their rich content of flavonoids, anthocyanins, carotenes, and polyphenolic acids, as well as their fibrous texture (Kim et al., 2003; Sommano et al., 2013). As the process of ripening progresses, some physical and biochemical changes occur, such as increases in fruit weight and size and in soluble solid content (SSC), indicating the increasing edibleness of the fruit as the acidity decreases (Valero and Valero, 2013). The biochemical changes and flesh firmness decrease during ripening. In turn, the flesh firmness affects the postharvest storage and marketing duration. Plum consumption is affected by the peel color, which is attractive to consumers (Singh and Khan, 2010).

Green plums are mainly used as rootstock due to their adaptation to various environmental conditions in Turkey. The Anatolian region has a wide range of wild and cultivated forms of *P. cerasifera* species, which include many economically important green plum genotypes. Due to the low acidity of the juicy fruits, green plums can be consumed in the early maturity stage, when other fresh fruits are not found in the market. Thus far, no previously published studies have analyzed the fruit quality parameters in Turkish green plums, which have dietary benefits. The objective of the current study was to assess the quality parameters in 2 green plum genotypes grown in Hatay Province, Turkey, at different maturation stages.

2. Materials and methods

Fruits of *Prunus cerasifera* Ehrh. cv. Can and Gül were collected in 2015 from 15-year-old trees in Hatay Province, Turkey. Trees were growing on their own roots. The planting density was 6 m × 6 m. Fruits were picked 5 times at 12-day intervals (12 April [t1], 24 April [t2], 6 May [t3], 18 May [t4], and 30 May [t5]) during maturation in 2015

* Correspondence: sevpay@cu.edu.tr

from both cultivars. One tree was used for each replication during the experiment. For each harvest and cultivar, the experiment consisted of 3 replications, which included 30 fruits for physical and phytochemical analyses.

The pomological analysis included the fruit length and diameter, as measured by a digital caliper, and the fruit weight, as measured by precision scales (0.1 g). Fruit color analysis was performed using a HunterLab colorimeter. The fruit surface color was described as L, a, and b according to HunterLab values (Gould, 1977), from which the chroma and hue values were calculated. Ten fruits from each tree were used to determine flesh firmness. The firmness value, expressed in pounds (lb), was obtained by using a hand penetrometer with an 8-mm penetrating tip along the equatorial part of the fruit by cutting the coat. A sample of juice was taken from 30 fruits from each tree at different dates. The total soluble solid was determined with a digital hand refractometer. For TA, 1 mL of extract was taken from each sample, to which 49 mL of distilled water was added; the value corresponding to the consumed sodium hydroxide (NaOH) during titration with 0.1-N sodium hydroxide to increase the pH of the samples to 8.1 was expressed in g malic acid 100 mL^{-1}.

Vitamin C analysis of the fruit juice of the plums was carried out by using an HPLC system (LC-10A HPLC series; Shimadzu, Kyoto, Japan), a UV detector, and a Prevail organic acid column (150 mm × 4.6 mm, 5 µm), according to the method developed by Bozan et al. (1997). Determination of the vitamin C content of the samples was done qualitatively and quantitatively at a wavelength of 242 nm by comparison of the external standard calibration curve and the retention time of the standard. The Shimadzu HPLC system, equipped with a pump and a refractive index detector (RID-10A), was used for sugar analysis. The sugar contents were determined by using an Inertsil NH2 column (4.6 mm × 250 mm) maintained at 40 °C.

The organic acid contents were analyzed by using an HPLC system (Agilent 1100 series G1322A; Germany) according to the method of Bozan et al. (1997). An Aminex HPX-87 H column (300 mm × 7.8 mm) was used in the HPLC system, which was controlled by Agilent software run on a personal computer. The organic acid content of samples was determined qualitatively and quantitatively at a wavelength of 210 nm by comparison of the external standard calibration curve and the retention time of the standard.

The total phenolic content of the fruit juices was determined by using Folin–Ciocalteu reagent in the modified method of Spanos and Wrolstad (1990). The absorbance of all samples was measured at 760 nm with the use of a Multiskan GO microplate spectrophotometer. The results were expressed as mg gallic acid equivalent/g weight (mg GAE/g FW) (Bayır, 2007). For the ABTS assay, the procedure followed the method of Re et al. (1999), with some modifications. The results were expressed in µmol Trolox equivalent (TE)/g fresh mass.

The FRAP assay was done according to the method of Benzie and Strain (1996), with some modifications. The results were expressed in µmol TE/g fresh mass. Additional dilution was needed if the FRAP value measured was over the linear range of the standard curve.

The experiment was done as a completely randomized factorial design with 3 replications. Each replication consisted of 30 fruits subjected to physical analyses. The obtained data were analyzed with the statistical program JMP version 5.0.1 (SAS Institute Inc., Cary, NC, USA). We carried out ANOVA to determine the effects of the development stage and the 2 cultivars on certain physical and pomological parameters. A least significant difference test was done to examine the differences among groups. Comparisons that yielded $P \leq 0.05$ were considered statistically significant. In addition, correlation among all the obtained results was carried out through multivariate methods with the statistical program JMP version 5.0.1, with $P \leq 0.05$ as threshold.

3. Results and discussion

Table 1 shows some pomological properties that affect the fruit quality of the 2 green plum cultivars, such as weight, length, diameter, and firmness, at 5 maturity stages, as well as the color values; the fruit firmness at the first 2 stages is not included due to the small fruit size. Ripening (comparison from t1 to t5) resulted in statistically significant increases in fruit weight for both cultivars; however, the average fruit weights were not statistically different between the two. Our results agreed with those of Louw and Theron (2012), who determined that fruit weight increases with ripening; nevertheless, the average fruit weight that they obtained was higher than that of our cultivars at all examined stages due to genetic diversity. The fruit weights were nearly the same for Can and Gül plums at all time points; the main factor that affected the fruit weight was the stage of maturity. Kim et al. (2015) found significant differences in ripening time between Santa Rosa and Sweet Miriam Japanese plums belonging to *Prunus salicina* Lindl., which had different ripening behaviors. Due to their nonclimacteric character, Sweet Miriam plums could stay longer on the tree compared with those of the Santa Rosa variety. The fruit weights obtained in this study were lower than those reported in some research, due to genetic variability and days after full bloom (DAFB) time (Louw and Theron, 2012; Kim et al., 2015). Our results were higher than those reported by Ayanoğlu et al. (2007), who examined green plums around the Mediterranean region. The differences are due to cultural practices, such as irrigation and fertilization.

Table 1. Physical and skin color properties of two green plums at different maturation stages.

Cultivar	Harvest date	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit firmness (lb)	L*	Hue	Chroma
Can	1t	3	18	16	-	51 bc	103.9 a	42.0 b
	2t	9	25	25	-	26 ef	103.3 a	37.7 d
	3t	12	25	28	9.83 a[(1)]	31 de	102.4 ab	39.8 c
	4t	17	28	31	7.75 b	58 ab	99.7 b	41.2 bc
	5t	25	31	35	1.30 d	61 a	90.5 c	40.2 c
Gül	1t	3	17	17	-	52 b	103.6 a	42.1 b
	2t	9	23	26	-	23 f	101.7 ab	40.2 c
	3t	13	24	29	7.59 b	35 d	99.4 b	43.9 a
	4t	16	26	32	4.69 c	43 c	50.4 d	42.8 ab
	5t	23	29	35	2.02 d	34 d	27.3 e	35.8 e
$LSD_{0.05}$		N. S.	N. S.	N. S.	0.9	7.56	3.0	1.74

([1]) Differences between means at $P \leq 0.05$ are indicated by different letters.
N.S.: not significant.

The fruit length significantly increased with progressive ripening. The greatest fruit length was found at the last maturity date, whereas the smallest was found at the first maturity date. Similar results were previously published by Ayanoğlu et al. (2007), that is, from 16.77 mm to 31.58 mm, with some selected genotypes belonging to *Prunus ceresifera* L. Can having a significantly larger fruit length (26 mm) than Gül (24 mm) at the end of the experiment. According to our results, the cultivars showed some growing regime. In contrast, Kim et al. (2015) observed different growing behaviors of Sweet Miriam and Santa Rosa with varying harvest times. They also found different reactions to ethylene for ripening. The growing behaviors of our cultivars showed similar curves, which could mean that they have the same reaction to ethylene for ripening.

While progressive ripening significantly increased ($P \leq 0.001$) fruit diameter, there were no statistical interactions between cultivar type and ripening time. The fruit diameter increased sharply between the first and second periods and continued to increase linearly over time. Such increases with progressive ripening are in agreement with the findings of other researchers (Louw and Theron, 2012; Öztürk et al., 2015; Kim et al., 2015).

Firmness is one of the most important quality parameters affected by maturity stage (Martínez-Esplá et al., 2014), genetic variability (Usenik et al., 2014), storage time and temperature (Rato et al., 2008; Davarynejad et al., 2015), and pre- and postharvest applications (Erkan and Eski, 2012; Öztürk et al., 2015). Firmness is an external quality parameter; however, it is associated with internal quality properties, such as eating quality, flesh color, and sugar content (Usenik et al., 2014). There is a negative correlation between soluble solid content and firmness during ripening and storage (Guerra and Casquero, 2008; Louw and Theron, 2012). In the present study, all measurements were expressed in lb units, which is equal to 4.45 N and 0.45 kg. The fruit firmness at the first and second measurement dates was not determined due to small fruit size; nevertheless, the firmness significantly decreased with progressive ripening. The Can plums had a higher average fruit firmness (6.29 lb) compared with the Gül variety (4.77 lb) during the experiment; with regard to firmness, Gül plums stayed firmer than the Can variety at the last observation. The firmness decreased sharply from the fourth to the fifth measurement dates for both cultivars. The relation between maturity stage and cultivars was statistically significant ($P \leq 0.001$). The highest firmness of 9.83 lb was obtained with Can plums at the first measurement date; the lowest firmness of 1.3 lb was found with the same variety at the last measurement date. Our results agree with those reported by Usenik et al. (2008), who found differences in fruit firmness among cultivars that decreased with progressive ripening. Genetics is the determining factor for fruit firmness. During fruit maturity, loss of fruit firmness takes place as a physiologic process in the tree (Abbott, 1999). The marketing of fresh plums is determined by controlling the ripening process (Valero et al., 2007); however, there are no

reference data on this for *Prunus cerasifera* L. fruits. Valero et al. (2007) created 3 categories for mature *Prunus salicina* L. fruits: plums > 26 N could be considered as "mature" or "immature", plums between > 13 N and < 26 N as "ready to buy", and plums < 13 N as "ready to eat".

Fruit appearance is another important quality parameter that determines consumer demand. Table 1 shows the differences in the L*, C, and h angle values of the skin color of the 2 green plum cultivars during progressive ripening. The L* (lightness) value was determined to be significantly different for the cultivars ($P \leq 0.001$), the ripening stages ($P \leq 0.001$), and the interaction ($P \leq 0.001$) of these 2 factors. The cultivars showed similar changes during ripening except at the last 2 measurement dates. The Can variety, which is more favored by consumers because of its good sugar/acid ratio, also had higher L* and hue angle values than the Gül plums. The L* value was significantly affected by the ripening process. Fruits with a high L* value at the onset showed a sharp decrease at the second examination date, after which the L* value increased until the fourth measurement date, and then decreased with red colorization due to ripening; this was especially noticeable in the Gül variety at the last examination date. Color change in fruits is mainly affected by red or green skin coloration. The increase of red coloration in fruits is indicated by L* and hue angle values approaching zero (Díaz-Mula et al., 2009). The hue angle value decreased with progressive ripening due to the loss of the green color of the fruit skin. The cultivars showed a significant difference in hue angle value, with Can plums having a higher hue angle value than the Gül variety during ripening, especially at the last 2 measurement dates. Kim et al. (2015) reported differences in hue value between Santa Rosa and Sweet Miriam plums; the hue values were also found to decrease during progressive ripening, which is similar to our results.

Table 2 shows the contents of soluble solids and individual sugars in the 2 cultivars. Statistical analyses were done on the differences between first and fifth measurement dates (t1 to t5). Ripening (based on a comparison across all time points) resulted in a statistically significant increase in the content of soluble solids; the increase was 100% in Can (t1–t5) and 89% in Gül plums. Regarding the content of fruit soluble solids, there was no statistically significant association between time and cultivars. The average fruit soluble solid content of the 2 cultivars was not found to be significantly different. Our results are similar to those reported by Martínez-Esplá et al. (2014) and Kim et al. (2015), who found increases with progressive ripening in certain plums belonging to *Prunus salicina*. The glucose, fructose, and sucrose contents were affected by cultivars and ripening stage (time) ($P \leq 0.01$). The ANOVA for all individual sugars showed that the relation between cultivars and time was statistically significant. Our results also indicated different significant associations between cultivars and time regarding the glucose content of the fruits. In Can plums, the glucose content increased from 4400 to 6390 mg/100 g FW until t4

Table 2. Individual sugars and total soluble solids of 2 green plum cultivars grown in Hatay, Turkey, at different development stages.

Cultivar	Harvest Date	Glucose (mg/100 g FW)	Fructose (mg/100 g FW)	Sucrose (mg/100 g FW)	TSS (%)
Can	1t	4400 bc[(1)]	823 bc	0 d	6.5
	2t	4993 b	1067 b	133 d	7.5
	3t	5087 b	1047 b	63 d	9.0
	4t	6390 a	1920 a	127 d	10.8
	5t	4693 bc	1800 a	143 d	13.0
Gül	1t	4170 cd	980 b	87 d	6.5
	2t	3467 de	990 b	1160 c	6.7
	3t	3100 e	537 cd	2850 b	9.5
	4t	1184 f	110 e	8147 a	11.4
	5t	2080 f	220 de	7423 a	12.3
$LSD_{0.05}$		751	419	927	N.S.

([1]) Differences between means at $P \leq 0.05$ are indicated by different letters.
N.S.: not significant.

and then decreased to 4693 mg/100 g FW at t5. In contrast, the glucose content of Gül plums decreased from 4170 to 1184 mg/100 g FW until t4 and then increased to 2080 mg/100 g FW at t5. Can plums (5113 mg/100 g FW) had a significantly higher glucose content than the Gül variety (2931 mg/100 g FW). The results indicated significant relations between cultivars and measurement date ($P \leq 0.01$). The average fruit fructose content was higher for Can (1331 mg/kg FW) than for Gül plums (567 mg/100 g FW). During the whole measurement period, the fructose content ranged from 823 to 1920 mg/100 g FW for Can and from 110 to 990 mg/100 g FW for Gül. There were no statistically significant differences in the average values for the cultivars across the measurement period. However, between t3 and t2, a fluctuation ranging between 792 and 1028 mg/100 g FW was observed. The highest interaction value was obtained from the Can cultivar at t4 (1920 mg/100 g FW), and then at t5 (1800 mg/100 g FW), t2 (1067 mg/100 g FW), and t3 (1047 mg/100 g FW). The obtained results showed significant differences between cultivars ($P \leq 0.01$), examination dates ($P \leq 0.01$), and their relation to each other ($P \leq 0.01$). The sucrose concentration of the Gül variety was higher than that of Can plums at each examination date. A greater portion of sucrose was taken as soluble solid content with ripening in the Gül variety, whereas progressive ripening did not influence the amount of sucrose in Can plums, which ranged from 0 to 143 mg/100 g FW. Interestingly, the sucrose content of Gül plums decreased sharply at the last measurement date (t5). The reason for this could be the conversion of sucrose into other individual sugars, such as glucose and fructose, as confirmed by the sharp increase in glucose and fructose content at the last measurement date. The decrease in glucose content at the last measurement date (t5) could be explained by its conversion into unmeasured individual sugars, such as sorbitol. Generally, glucose was the predominant sugar in both cultivars, except at the last 2 measurement dates for Gül. The sweetness effect of these individual sugars is in the following order: fructose > sucrose > glucose. The high glucose and fructose content provides an edible property at the early ripening stages (t1, t2, and t3), with low total acidity ranging from 0.63% to 0.90%. These results highlight differences in the sugar accumulation mechanism between Can and Gül cultivars, which had similar total soluble solid contents but different amounts of individual sugars during ripening. In addition, differences in the activities of sugar metabolism enzymes due to controlled hormonal action can cause variations in the relative sugar concentrations (Osorio and Fernie, 2013). Our results are in agreement with those reported by Usenik et al. (2008), who found the glucose content to be highest (from 38.2 to 115 g/kg FW), followed by sucrose (21.2 to 71.9 g/kg FW), fructose (19.1 to 34.8 g/kg FW), and sorbitol (3.5 to 27.8 g/kg FW). However, the ranges obtained for individual sugars in our study were different due to longer measurement intervals and genetic variability.

Table 3 shows the contents of total and individual acids in the plum cultivars. On average, the total acid concentration decreased during the experiment period. Interaction of cultivar with time was not statistically significant. The decrease in total acid content was higher

Table 3. Individual acids and total acidity of 2 green plum cultivars at different development stages.

Cultivar	Harvest Date	Malic acid (mg/100 g FW)	L-ascorbic acid (mg/100 g FW)	Succinic acid (mg/100 g FW)	Total acidity (%)
Can	1t	247 bc[(1)]	53 cd	517 d	0.73
	2t	303 ab	97 ab	830 bc	0.68
	3t	153 cd	103 ab	1123 ab	0.63
	4t	103 d	113 ab	1293 a	0.58
	5t	47 d	43 d	487 d	0.42
Gül	1t	413 a	103 ab	650 cd	0.90
	2t	150 cd	93 ab	540 cd	0.73
	3t	77 d	123 a	827 bc	0.72
	4t	57 d	87 abc	573 cd	0.75
	5t	77 d	83 bc	517 d	0.68
$LSD_{0.05}$		115	39	299	N.S.

([1]) Differences between means at $P \leq 0.05$ are indicated by different letters.
N.S.: not significant.

for Can plums than for Gül plums during the ripening progress. The total acidity ranged from 0.42 to 0.90 during the study period. In particular, the acidity decreased sharply in Can plums at the last examination date (t5). Ayanoğlu et al. (2007) reported a wide range of 0.72% to 1.81% in the total acid content of plums (*Prunus cerasifera* L.) adapted to the Mediterranean region. The results could be explained by differences in the harvest maturity of the plums in the studies and by cultural practices, such as irrigation and fertilization. Researchers have found that the total acidity content of plums belonging to *Prunus salicina* L. and *Prunus domestica* L., even at the tree-ripened stage, was higher than 0.9% (Guerra and Casquero, 2008; Louw and Theron, 2012; Martínez-Esplá et al., 2014). Our results show that green plums are edible, thanks to their low acidity at the pre-early maturity stage. Succinic, L-ascorbic, and malic acids were detected in the plum cultivars (Table 3). Generally, succinic acid was the predominant acid. The malic acid content of the plums decreased continuously in both cultivars during ripening. Malic acid has been shown to decrease with fruit development (Kim et al., 2015) and during cold and room storage periods (Erkan and Eski, 2012) due to respiration in the fruit. Such respiration causes consumption of organic acids, which decreases the titratable acidity, as reported by Zokaee-Khosroshahi et al. (2007) and Ishaq et al. (2009). Our results differed from those reported by Usenik et al. (2008), who detected malic, shikimic, and fumaric acids (except for malic acid) due to genetic variability. The highest individual acid found was succinic acid, which ranged in content from 487 to 1293 mg/100 g FW; this was followed by malic acid (4 to 413 mg/100 g FW) and L-ascorbic acid (43 to 123 mg/100 g FW). The succinic acid content, averaged across all measurement dates, was higher for Can plums (85 mg/100 g FW) than for Gül plums (621 mg/100 g FW).

Previous researchers (Kim et al., 2003; Sharma et al., 2012; Gündüz and Saraçoğlu, 2012; Campbell et al., 2013; Mihalache Arion et al., 2014; Martínez-Esplá et al., 2014; Öztürk et al., 2015) have indicated that phenolic phytochemicals and antioxidant activity would be influenced by maturity, cultivars, environment conditions, growing season, storage condition, and pre- and postharvest practices (use of plant growth regulators). There are no previously published studies on the effects of different ripening times on the fruit quality properties, which greatly influence human nutrition. The richness in phenols and antioxidants of green plum cultivars make them edible at all maturity stages in Turkey. Gündüz and Saraçoğlu (2012) found total phenolics of between 10.2 and 58.3 mg GAE/100 g FW in 5 cultivars (Can 2, Cin, Havran, Ozark Premier, and Papaz) of green plums selected by Ayanoğlu et al. (2007) from the Mediterranean region. Table 4 shows the total phenol content measured in the plum fruits studied. The results indicate significant differences ($P \leq 0.05$) in total phenol content (averaged across all measurement dates) between cultivars, with

Table 4. Total phenolic content and total antioxidant activity of 2 green plum cultivars at different development stages, as determined by FRAP and ABTS.

Cultivar	Harvest date	Total phenols (mg GAE/g)	Antioxidant activity (FRAP) (µmol TE/g)	Antioxidant activity (ABTS) (µmol TE/g)
Can	1t	165	67	28
	2t	90	43	38
	3t	133	44	60
	4t	122	77	93
	5t	152	88	79
Gül	1t	152	82	29
	2t	65	32	29
	3t	109	37	43
	4t	112	61	92
	5t	103	61	89
$LSD_{0.05}$		N. S.	N. S.	N. S.

([1]) Differences between means at $P \leq 0.05$ are indicated by different letters.
N.S.: not significant.

Can plums having a higher content (132 mg GAE/100 g FW) than Gül plums (108 mg GAE/100 g FW). The reasons for the higher total phenolic contents obtained in this study, compared with Gündüz and Saraçoğlu (2012), may be cultural practices and the maturity stage of the green plums. Mihalache Arion et al. (2014) reported that the total phenolic content ranged from 60 to 364 mg GAE/100 g among 12 plum cultivars that had different maturity behaviors as summer and autumn varieties. A significant difference ($P \leq 0.01$) in total phenolic content, which ranged from 125 to 373 mg GAE/100 g fresh weight, was also found in 11 plum cultivars, apart from Empress, NY 101, and Stanley (Kim et al., 2003). The total phenol content was significantly higher at t1 in plums of the Can cultivar (165 mg GAE/100 g) than those of Gül (152 mg GAE/100 g) at the same time. The lowest total phenol content was obtained at t2 (77 mg GAE/100 g), at which a sharp decrease was found in both cultivars at the same time after the first observation (t1). The other values that belong to different times were taken in the same statistical group with values ranging from 117 to 128 mg GAE/100 g. Usenik et al. (2008) reported that ripening had no influence on the phenol content of plum fruits. Sharma et al. (2012) found significantly higher phenolic contents in Santa Rosa plums harvested at the climacteric stage (12.1 mg/100 g pulp) than those harvested at a preclimacteric stage of maturity (11.1 mg/100 g pulp). The possible reasons for the differences in total phenols may be the cultivars, maturity stage, climatic conditions in the growing season, agricultural practices (pruning, irrigation, and fertilization), geographic origin, and differences in analytical methods. The antioxidant capacity of plant tissues is mainly determined by anthocyanins and other polyphenols, several vitamins (A, C, and E), and carotenoids (Mihalache Arion et al., 2014). The total antioxidant activity was determined by ABTS+ radical scavenging activity and Fe^{+3} reducing antioxidant power assays (FRAP), as presented in Table 4. There was no statistically significant difference between the green plum cultivars or the interaction of cultivar with time in either method. However, higher antioxidant activity was obtained in Can plums in both methods. Although the FRAP method showed statistical similarity between the plum cultivars at t1 (74 µmol TE/g FW), t4 (69 µmol TE/g FW), and t5 (75 µmol TE/g FW), there was no such similarity at t2 (38 µmol TE/g FW) or t3 (41 µmol TE/g FW). The antioxidant activity was affected by the measurement method. However, a similar reaction was found during ripening except at t1, when a higher value was obtained with FRAP (74 µmol TE/g FW) compared with $ABTS^+$ (28 µmol TE/g FW), and at t5, when a higher value was obtained with $ABTS^+$ (84 µmol TE/g FW) compared with FRAP (75 µmol TE/g FW). In the $ABTS^+$ method, the antioxidant activity in both cultivars showed a linear increase until t4, but decreased at t5. Additionally, in the $ABTS^+$ method, the highest average value was obtained at t4 (92 µmol TE/g FW), whereas the lowest average value was determined at t1 (28 µmol TE/g FW). Our results with FRAP indicated that consumption of Gül plums at the pre-early maturity stage (t1) provided the highest benefit (82 µmol TE/g FW) in antioxidant activity; for the Can variety, the highest antioxidant activity (88 µmol TE/g FW) was obtained at the last measurement date (t5). Gündüz and Saraçoğlu (2012) reported antioxidant capacities ranging from 0.123 to 0.835 mmol TE/kg, lower than those in our study. Similarly to Gündüz and Saraçoğlu (2012), we were unable to detect anthocyanins in our sample (data not shown).

The correlation results showed that only a few variables were significantly correlated with each other (Table 5). There were good positive correlations between fructose and glucose; however, sucrose showed a negative correlation with these 2 individual sugars. Additionally, the size variables (fruit width, length, and weight) were all correlated with each other, as found by Gündüz and Saraçoğlu (2012) (data not shown). Consumer preferences are mainly determined by the organic acid and sugar concentrations of plum fruits. Research has found a negative correlation between sugar and acidity with progressive ripening; as the sugar content increases, the acidity decreases (Usenik et al., 2008; Kim et al., 2015). Our results also support previous reports of a negative correlation between the soluble solid content and total acidity of plum fruits.

4. Conclusion

Can plums were found to be richer in health-promoting components and to have higher disease-prevention capacity related to the presence of phenolic compounds and antioxidant activity compared with the Gül variety. The 2 cultivars differed in their contents of individual sugars, which provide different tastes, and soluble sugar. The glucose and fructose contents were higher in the Can variety. With ripening, a higher amount of sucrose accumulated in Gül plums, whereas, at all measurement dates, the Can fruits had higher levels of glucose and fructose, which provide more sweetness than sucrose. Although the 2 cultivars had similar physical characteristics (fruit weight, length, and diameter), the firmness of Can plums decreased sharply over time, especially at the last measurement date (t5); however, the average firmness during ripening was still higher in this variety. Thus, consumers can eat these green plums at the pre-early stage due to their high total phenols and good antioxidant activity (as measured by the FRAP method). These cultivars also had lower acidity compared with other plums (*P. domestica* and *P. salicina*), which improved their edibility at very early stages (about 3 g). The results also

Table 5. Correlation coefficients of several fruit quality properties at different development stages for 2 plum cultivars (*P. cerasifera*) grown in Hatay, Turkey (P = 0.05).

Trait	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12	v13	v14
Fructose (v1)	**0.85***	**–0.74***	0.01	–0.03	**0.40***	0.09	**0.47***	0.35	0.12	0.17	**–0.53***	–0.01	**0.58***
Glucose (v2)		**–0.83***	–0.19	0.10	**0.61***	0.28	0.31	0.24	–0.04	0.25	–0.35	–0.03	**0.71***
Sucrose (v3)			**0.51***	0.04	–0.31	**–0.45***	–0.17	–0.11	**0.44***	–0.29	0.18	–0.11	**–0.91***
Soluble solid (v4)				–0.16	–0.01	**–0.71***	0.31	0.32	**0.73***	0.09	**–0.53***	–0.21	**–0.63***
L-ascorbic (v5)					**0.72***	0.23	–0.29	**–0.39***	–0.02	–0.34	0.29	0.20	0.13
Succinic acid (v6)						0.12	–0.02	–0.15	0.19	–0.05	–0.19	0.11	0.33
Malic acid (v7)							–0.05	0.02	–0.51*	0.17	**0.52***	–0.01	**0.44***
L (v8)								**0.72***	0.35	**0.56***	–0.26	0.34	0.07
TAA (FRAP) (V9)									0.23	**0.66***	–0.15	0.04	–0.09
TAA ABTS (V10)										–0.07	**–0.49***	–0.22	**–0.57***
Total phenolic content (v11)											–0.06	0.24	0.16
Total acidity (v12)												0.16	0.00
C (v13)													**0.37***
h° (v14)													1.00

*Significant coefficients, at 0.05, are shown in bold.

show the importance of green plums in the daily diet as a good source of total phenols and antioxidants, providing health-promoting effects in humans, with good edible properties at the pre-early development stage.

Acknowledgments

The authors thank Dr Ben Faber (bafaber@ucanr.edu) who works at the Division of Agriculture and Natural Resources, University of California Cooperative Extension.

References

Abbott JA (1999). Quality measurement of fruits and vegetables. Postharvest Biol Tec 15: 207-225.

Ayanoğlu H (1995). Doğu Akdeniz Bölgesinde Sofralık Erik Seleksiyonu. Doktora Tezi, Çukurova Üniversitesi, Adana, Turkey.

Ayanoğlu H, Bayazit S, İnan G, Bakır M, Akpınar AE, Kazan K, Ergül A (2007). AFLP analysis of genetic diversity in Turkish green plum accessions (*Prunus cerasifera* L.) adapted to the Mediterranean region. Sci Hortic 114: 263-267.

Bayır A (2007). Bazı Şaraplık Üzüm Çeşitlerine Ait Çekirdeklerin Toplam Fenolik Madde İçerikleri ve Antiradikal Aktivitelerinin Belirlenmesi. Yüksek Lisans Tezi, Akdeniz Üniversitesi, Antalya, Turkey.

Benzie IFF, Strain JJ (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. Anal Biochem 239:70-76.

Bozan B, Tunalıer Z, Koşar M, Altıntaş A, Başer KHC (1997). Comparison of ascorbic and citric acid contents in 'Emphasis Type.' Proc. 11. Symp Plant Origin Crude Drugs, Ankara.

Campbell OE, Merwin IA, Padilla-Zakour OI (2013). Characterization and the effect of maturity at harvest on the phenolic and carotenoid content of northeast USA apricot (*Prunus armeniaca*) varieties. J Agr Food Chem 61: 12700-12710.

Davarynejad GH, Zarei M, Nasrabadi ME, Ardakani E (2015). Effects of salicylic acid and putrescine on storability, quality attributes and antioxidant activity of plum cv. 'Santa Rosa.' J Food Sci Technol 52: 2053-2062.

Davis PH (1972). Flora of Turkey and the East Aegean Islands, vol. IV. Edinburgh, UK: Edinburgh University Press.

Díaz-Mula HM, Zapata PJ, Guillén F, Martínez-Romero D, Castillo S, Serrano M, Valero D (2009). Changes in hydrophilic and lipophilic antioxidant activity and related bioactive compounds during postharvest storage of yellow and purple plum cultivars. Postharvest Biol Tec 51: 354-363.

Erkan M, Eski H (2012). Combined treatment of modified atmosphere packaging and 1- methylcyclopropene improves postharvest quality of Japanese plums. Turk J Agric For 36: 563-575.

Guerra M, Casquero PA (2008). Effect of harvest date on cold storage and postharvest quality of plum cv. Green Gage. Postharvest Biol Tec 47: 325-332.

Gündüz K, Saraçoğlu O (2012). Variation in total phenolic content and antioxidant activity of *Prunus cerasifera* Ehrh. selections from Mediterranean region of Turkey. Sci Hortic 134: 88-92.

Gould WA (1977). Food Quality Assurance. Westport, CT, USA: the AVI Publishing Company, Inc.

Ishaq S, Rathore HA, Majeed S, Awan S, Zulfiqar-Ali-Shah S (2009). The studies on the physico-chemical and organoleptic characteristics of apricot (*Prunus armeniaca* L.) produced in Rawalakot, Azad Jammu and Kashmir during storage. Pakistan J Nutr 8:856-860.

Kim DO, Chun OK, Kim YJ, Moon HY, Lee CY, 2003. Quantification of polyphenolics and their antioxidant capacity in fresh plums. J Agri Food Chem 51: 6509-6515.

Kim HY, Farcuh M, Cohen Y, Crisosto C, Sadka A, Blumwald E (2015). Non-climacteric ripening and sorbitol homeostasis in plum fruits. Plant Sci 231: 30-39.

Louw ED, Theron IK (2012). Volatile dynamics during maturation, ripening and cold storage of three Japanese plum cultivars (*Prunus salicina* Lindl.). Postharvest Biol Tec 70: 13-24.

Martínez-Esplá A, Zapata PJ, Castillo S, Guillén F, Martínez-Romero D, Valero D, Serrano M (2014). Preharvest application of methyl jasmonate (MeJA) in two plum cultivars. 1. Improvement of fruit growth and quality attributes at harvest. Postharvest Biol Tec 98: 98-105.

Mihalache Arion C, Tabart J, Kevers C, Niculaua M, Filimon R, Beceanu D, Dommes J (2014). Antioxidant potential of different plum cultivars during storage. Food Chem 146: 485-491.

Osorio S, Fernie AR (2013). Biochemistry of fruit ripening. In: Seymour GB, Poole M, Giovannoni JJ, Tucker G, editors. Molecular Biology of Fruit Maturation and Ripening. Ames, IA, USA: Wiley-Blackwell, pp. 1-19.

Öztürk B, Küçüker E, Yıldız K, Çelik SM (2015). Changes of bioactive compounds and ethylene production of Japanese plums treated with pre-harvest aminoethoxyvinylglycine. Int J Food Prop 18: 2165-2186.

Rato AE, Agulheiro AC, Barroso JM, Riquelme F (2008). Soil and rootstock influence on fruit quality of plums (*Prunus domestica* L.). Sci Hortic 118: 218-222.

Re R, Pellegrini N, Protrggente A, Panala A, Yang M, Rice Evance C (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Bio Med 26:1231-1237.

Sharma S, Sharma RR, Pal RK, Paul V, Dahuja A (2012). 1-Methylcyclopropene influences biochemical attributes and fruit softening enzymes of 'Santa Rosa' Japanese plum (*Prunus salicina* Lindl.). J Plant Biochem Biotechnol 21:295-299.

Singh Z, Khan AS (2010). Physiology of plum fruit ripening. Stewart Postharvest Review 2: 3.

Sommano S, Caffin N, Kerven G (2013). Screening for antioxidant activity, phenolic content, and flavonoids from Australian native food plants. Int J Food Prop 16: 1394-1406.

Spanos GA, Wrolstad RE (1990). Influence of processing and storage on the phenolic composition of Thompson seedless grape juice. J Agric Food Chem, 38:1565-1571.

TUIK, (2015). Turkish Statistical Institute. Agricultural Production Statistics Database. URL: http://www.tuik.gov.tr.

Usenik V, Stampar F, Kastelec D (2014). Indicators of plum maturity: when do plums become tasty? Sci Hortic 167: 127-134.

Usenik V, Kastelec D, Veberič R, Štampar F (2008). Quality changes during ripening of plums (*Prunus domestica* L.). Food Chem 111: 830-836.

Valero C, Crisosto CH, Slaughter D (2007). Relationship between nondestructive firmness measurements and commercially important ripening fruit stages for peaches, nectarines and plums. Postharvest Biol Tec 44: 248-253.

Valero D, Valero M (2013). Growth and ripening stage at harvest modulates postharvest quality and bioactive compounds with antioxidant activity. Stewart Postharvest Review 3: 5.

Zokaee-Khosroshahi MR, Esna-Ashari M, Ershadi A (2007). Effect of exogenous putrescine on post-harvest life of strawberry (*Fragaria ananassa* Duch.) fruit, cultivar 'Selva.' Sci Hortic 114:27-32.