Determination of Phenolic Compounds, Antioxidant Capacity and Organic Acids Contents of *Prunus domestica* L., *Prunus cerasifera* Ehrh. and *Prunus spinosa* L. Fruits by HPLC

Ferit Celik[1], Muttalip Gundogdu[2*], Sevket Alp[3], Ferhad Muradoglu[2], Sezai Ercişli[4], Mustafa Kenan Gecer[5] and Ihsan Canan[2]

[1]*Faculty of Agriculture Department of Horticulture, Yuzuncu Yıl University, Van, Turkey*
[2]*Faculty of Agriculture and Natural Sciences, Department of Horticulture, Abant Izzet Baysal University, Bolu, Turkey*
[3]*Faculty of Agriculture, Department of Landscape Architecture, Yuzuncu Yıl University, Van, Turkey*
[4]*Faculty of Agriculture Department of Horticulture, Atatürk University, Erzurum, Turkey*
[5]*Faculty of Agriculture Department of Horticulture, Igdır University, Igdır, Turkey*

Received: 17 May 2017; accepted: 17 May 2017

The important role of fruits in human health and nutrition has been better understood with the recent studies on biochemical contents of fruits having antioxidant properties. Being one of the similar studies, in this study, total antioxidant capacity (TAC), phenolic compound, organic acid, and vitamin C contents of three plum species (*Prunus domestica* L., *Prunus cerasifera* Ehrh., and *Prunus spinosa* L.) grown in Van locality (Turkey) were identified, and the correlation between the measured values was investigated. Phenolic compound, organic acid, and vitamin C contents were determined by high-performance liquid chromatography (HPLC) method. Analysis of phenolic compound indicated that chlorogenic acid was the predominant phenolic compound, and the highest value was measured in *P. spinosa* L. as 12.985 mg kg^{-1}. Malic acid was the predominant organic acids and the highest value was measured in *P. spinosa* L. as 1.245 g 100 g^{-1}. The highest TAC and vitamin C contents were also measured in *P. spinosa* L. as 1.021 mmol TE kg^{-1} and 25.492 mg 100 g^{-1}, respectively. *P. spinosa* L. was found to be superior to the other two species with respect to antioxidant capacity and other biochemical contents. A significant ($P \leq 0.01$) and positive correlation was reported between antioxidant capacity and vitamin C content.

Keywords: Plum, antioxidant, phenolic, organic acid, vitamin C

Introduction

The history of plums dates back to ancient times. Since then, they have been one of the most popular fruits with great commercial importance. *Prunus cerasifera* Ehrh., *Prunus domestica* L., *Prunus spinosa* L., and *Prunus insititia* L. are among the plum species grown in Turkey [1]. The environs of Caucasus and the Caspian Sea including Turkey are reported to be the homeland of plum from where it spread throughout the world [2]. Plum is widely grown in various eco-geographical areas in Turkey extending from Southeastern Anatolia to Mediterranean and Aegean regions through Central Anatolia except high plateaus of Eastern Anatolia and dry and very hot areas of Southeastern Anatolia [3].

Wide distribution of plum in Turkey and worldwide is attributed to the high number of plum species originating from different climatic zones. Anatolia is of great geographical importance as it is the gene center of some plum species and serves as a bridge for distribution of some plum species worldwide. Most plum species were distributed to Greece and other European countries from Anatolia, and plum cultivation was started by early colonists in America [4–6].

Fruits with their antioxidant contents and other nutritional values have an important role in human health and nutrition. Acids in fruits are rapidly oxidized in the metabolism; hence, they do not have adverse effects on the body. Salts of fruits have an important place in diet due to their alkaline properties [7, 8]. Organic acids form complexes with heavy metal ions and inhibit their oxidation-catalyzing effects [8, 9]. Sugar–acid ratio is a criterion of fruit maturity. Organic acid profile is also used to evaluate the purity of fruit juices [8, 10]. Due to reported anticarcinogenic properties of some flavonoids, demand for fruits with anthocyanidin and anthocyanin content has been increasing [11].

Despite their low content in fruits and vegetables, phenolic compounds pose various problems in the processing of these products (particularly in fruit juice industry). On the other hand, phenolic compounds contribute to the taste and are particularly responsible for astringency. Anthocyanins belong to the group of phenolic compounds and are responsible for color in fruits and vegetables. Phenolic compounds have an important place in juice-processing industry and are highly responsible for residue formation in fruit juices and wines. Phenolic compounds are present almost in all fruits and vegetables in varying quantities [12].

The benefits of plum species for human health and nutrition due to their total phenolic and antioxidant contents have been emphasized by many researchers [13–15]. Erturk et al. [16] identified total phenolic and antioxidant contents in wild plum species *P. spinosa* L. grown in Turkey. Different from the previous research, this study aimed to identify more specific biochemical contents in wild plum species (*P. domestica* L., *P. cerasifera* Ehrh., and *P. spinosa* L.). The study was conducted in Van locality (Turkey) which has a rich biological diversity, and total antioxidant capacity (TAC), phenolic compound, organic acid, and vitamin C contents were identified in the examined wild plum species. The study particularly focused on identification of phenolic compounds – known for their antioxidant properties – and organic acids. Based on the measurement results, the correlations between the values were analyzed statistically.

* Author for correspondence: gundogdu_m@hotmail.com

DOI: 10.1556/1326.2017.00327

First published online: 01 June 2017

Experimental

The examined plum species from Van locality (Turkey) are native wild species not exposed to a range of cultural procedures (fertilization, pruning, soil cultivation etc.). Plum fruits were harvested in June 2015 period when they reached full maturity, placed into sample containers, and transported to laboratory for analysis. The fruits samples were collected from all parts of the tree to fully represent plum species and stored at −20 °C until the analysis.

Extraction and Determination of Phenolic Compounds. The phenolic compounds were determined using the high-performance liquid chromatography (HPLC) separation method described by Rodriguez-Delgado et al. [17]. About 100 g of samples were fragmented, and 5 g from each sample was transferred to centrifuge tubes. The samples were mixed homogenously and then diluted 1:1 with distilled water and centrifuged at 15,000*g* for 15 min. The supernatant was passed through 0.45 μm membrane filter (Millipore Millex-HV Hydrophilic PVDF, Millipore, USA) and then injected into HPLC system (gradient). The chromatographic separation in Agilent 1100 series HPLC took place in diode array detector (DAD, Agilent, USA) with 250 mm × 4.6 mm, 4 μm ODS column (HiChrom, USA). The following solvents in water with a flow rate of 1 mL min^{-1} and 20 μL injection volume were used for spectral measurements at 254 and 280 nm: as mobile phase solvent A, methanol–acetic acid–water (10:2:88), and solvent B, methanol–acetic acid–water (90:2:8).

Extraction and Determination of Organic Acids. For organic acid extraction, the method by Bevilacqua and Califano [18] was modified. About 200 g of samples was fragmented, and 5 g from each sample was transferred to centrifuge tubes. The 10 mL of 0.009 N H_2SO_4 was added to the samples, and the samples were homogenized with Heidolph Silent Crusher M, Germany. Then, the samples were mixed for an hour with a shaker (Heidolph Unimax 1010, Germany) and centrifuged at 15,000*g* for 15 min. The supernatant was passed through coarse filter paper, then twice in 0.45 μm membrane filter (Millipore Millex-HV Hydrophilic PVDF, Millipore, USA), and last in the SEP-PAK C18 cartridge. The concentration of organic acids was determined by HPLC using an Aminex column (HPX-87H, 300 mm × 7.8 mm, Bio-Rad) fitted on an Agilent 1100 series HPLC G 1322 A, Germany) (Bevilacqua and Califano, 1989). Organic acids were detected at 214 and 280 nm wavelengths. As the mobile phase, 0.009 N H_2SO_4 was passed through 0.45 μm filter membrane.

Determination of Total Antioxidant Activity. For the standard TAC assay, TAC extract was prepared as follows. 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) was dissolved in acetate buffer and prepared with potassium persulfate, as described by Rice-Evans et al. [19] and Ozgen et al. [20]. The mixture was diluted in acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ± 0.01 at 734 nm for longer stability [20]. For the spectrophotometric assay, 3 mL of the ABTS+ solution and 20 μL of fruit extract were mixed and incubated for 10 min and the absorbance was determined at 734 nm determined after 6 min from mixing.

Extraction and Determination of Ascorbic Acid (Vitamin C). Ascorbic acid content was determined following the modified HPLC (isocratic program) (Agilent 1100 series HPLC G 1322 A, Germany) analytical procedure outlined by Cemeroglu [21]. The 5 g of sample was transferred to a 50 mL volumetric flask including 10 mL 6% (w/v) metaphosphoric acid (Sigma, M6285, 33.5%). The sample was then homogenized at 24,000 rpm for 15 s and centrifuged at 14,000 rpm for 10 min at 1 °C. Five milliliters of the supernatant was filtered through 0.45 μm PTFE syringe filters (Phenomenex, UK) and placed in an amber colored vial (AIM, Screw vial, SV-15A). Quantification of ascorbic acid was made by an external standard method using an L-ascorbic acid standard (Sigma A5960). Samples were separated on a Luna C18 column (250 mm × 4.60 mm, 5 μm from Phenomenex) at 25 °C by an HPLC. The mobile phase was 25 mM KH_2PO_4 (adjusted to pH 2.2 with phosphoric acid) with a flow rate of 1 mL min^{-1}. L-Ascorbic acid was detected at 254 nm.

Statistical Analysis. Descriptive statistics were expressed as average and standard error. 2-Factor Factorial Analysis of Variance was used for comparing cultivar averages in terms of examined parameters. Subsequent to variance analysis, Duncan's Multiple Range Test was used to determine the different cultivars. Statistical Significance Level of 5% was applied in the calculations which were executed with SPSS (ver: 13) statistical package.

Results and Discussion

Technological developments and increasing population are accompanied by growing interest and demand to the innovations in the field of health. In this context, there has been a remarkable increase in the studies on fruits which are crucial for human health and nutrition. This study particularly focused on identification of phenolic compounds known for their antioxidant properties, organic acids, and TAC. The analysis of phenolic compounds in plum species indicated that chlorogenic acid was the predominant phenolic compound, and the highest value was measured in *P. spinosa* L. as 12.985 mg kg^{-1} (Table 1). The second predominant phenolic compound was caffeic acid, and the highest value was measured in *P. spinosa* L. as 10.753 mg kg^{-1}. *o*-Coumaric acid was only measured in *P. domestica* L. (0.174 mg kg^{-1}) and could not be identified in the other species. Contents of vanillic acid (0.032–0.359 mg kg^{-1}), rutin (0.091–0.467 mg kg^{-1}), gallic acid (0.145–0.376 mg kg^{-1}), and phloridzin (0.269–0.719 mg kg^{-1})

Table 1. Contents of phenolic compounds in plum species

	P. cerasifera Ehrh.	*P. domestica* L.	*P. spinosa* L.
Protocatechuic acid (mg kg^{-1} fw)	1.329 ± 0.002 b[a]	1.872 ± 0.009 a	0.257 ± 0.002 c
Vanillic acid (mg kg^{-1} fw)	0.072 ± 0.002 b	0.359 ± 0.002 a	0.032 ± 0.001 c
Rutin (mg kg^{-1} fw)	0.091 ± 0.001 c	0.192 ± 0.001 b	0.467 ± 0.002 a
Gallic acid (mg kg^{-1} fw)	0.145 ± 0.006 c	0.216 ± 0.002 b	0.376 ± 0.004 a
Catechin (mg kg^{-1} fw)	1.722 ± 0.03 c	5.171 ± 0.108 a	2.12 ± 0.003 b
Chlorogenic acid (mg kg^{-1} fw)	11.95 ± 0.042 c	11.565 ± 0.064 b	12.985 ± 0.064 a
Caffeic acid (mg kg^{-1} fw)	3.334 ± 0.019 c	9.729 ± 0.023 b	10.753 ± 0.166 a
Syringic acid (mg kg^{-1} fw)	3.288 ± 0.004 a	1.737 ± 0.032 b	2.673 ± 0.023 c
p-Coumaric acid (mg kg^{-1} fw)	1.919 ± 0.019 b	1.863 ± 0.051 b	2.363 ± 0.036 a
Ferulic acid (mg kg^{-1} fw)	0.965 ± 0.011 b	1.523 ± 0.032 a	0.972 ± 0.008 b
o-Coumaric acid (mg kg^{-1} fw)	N.D.	0.174 ± 0.002	N.D.
Phloridzin (mg kg^{-1} fw)	0.379 ± 0.004 b	0.269 ± 0.005 c	0.719 ± 0.005 a

[a]There were significant ($P < 0.05$) differences among the different letters in the same lines.
N.D. indicates not determined.

Table 2. Organic acids and vitamin C contents and TAC of plum species

	P. cerasifera Ehrh.	*P. domestica* L.	*P. spinosa* L.
Citric acid (mg 100 g^{-1} fw)	13.898 ± 0.072 b[a]	5.45 ± 0.018 c	27.613 ± 0.588 a
Malic acid (g 100 g^{-1} fw)	0.896 ± 0.008 b	0.601 ± 0.013 c	1.245 ± 0.018 a
Succinic acid (mg 100 g^{-1} fw)	1.435 ± 0.035 c	3.065 ± 0.009 a	2.817 ± 0.011 b
Fumaric acid (mg 100 g^{-1} fw)	3.952 ± 0.006 b	4.786 ± 0.014 a	1.98 ± 0.011 c
Vitamin C (mg 100 g^{-1} fw)	18.985 ± 0.04 b	18.753 ± 0.23 b	25.492 ± 0.239 a
TAC (mmol TE kg^{-1} fw)	0.355 ± 0.006 c	0.470 ± 0.004 b	1.021 ± 0.013 a

[a]There were significant ($P < 0.05$) differences among the different letters in the same lines.
fw indicates fresh weight; TAC, total antioxidant capacity.

Table 3. Correlations between phenolic compounds, organic acids, vitamin C, and TAC contents of plum species

	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}
Protocatechuic (V_1)	0.826*	−0.827*	−0.80	0.68	−0.99**	−0.31	−0.44	−0.96**	0.75	0.76	−0.99**	−0.99**	−0.99**	−0.05	0.99**	−0.95**	−0.87*
Vanillic (V_2)		−0.37	−0.32	0.97**	−0.78	0.28	−0.86*	−0.67	0.99**	0.99**	−0.77	−0.85*	−0.89*	0.52	0.80	−0.62	−0.46
Rutin (V_3)			0.99**	−0.16	0.86*	0.79	−0.14	0.92**	−0.25	−0.26	0.87*	0.80	0.74	0.60	−0.85*	0.95**	0.99**
Gallic (V_4)				−0.11	0.84*	0.81*	−0.18	0.91*	−0.21	−0.22	0.85*	0.77	0.71	0.63	−0.82*	0.94**	0.98**
Catechin (V_5)					−0.63	0.48	−0.95**	−0.49	0.99**	0.99**	−0.61	−0.72	−0.78	0.70	0.65	−0.43	−0.25
Chlorogenic (V_6)						0.38	0.37	0.97**	−0.70	−0.71	0.99**	0.99**	0.97**	0.12	−0.99**	0.97**	0.90*
Caffeic (V_7)							−0.72	0.52	0.40	0.39	0.40	0.26	0.18	0.96**	−0.35	0.58	0.73
Syringic (V_8)								0.22	−0.92**	−0.91**	0.35	0.48	0.56	−0.87*	−0.40	0.15	−0.04
p-Coumaric (V_9)									−0.57	−0.58	0.98**	0.95**	0.92**	0.27	−0.97**	0.99**	0.95**
Ferulic (V_{10})										0.99**	−0.68	−0.78	−0.83*	0.63	0.72	−0.51	−0.34
o-Coumaric (V_{11})											−0.69	−0.79	−0.84*	0.62	0.73	−0.53	−0.35
Phloridzin (V_{12})												0.98**	0.97**	0.14	−0.99**	0.97**	0.92**
Citric (V_{13})													0.99**	0.00	−0.99**	0.93**	0.85*
Malic (V_{14})														−0.09	−0.98**	0.90*	0.80
Succinic (V_{15})															−0.09	0.34	0.52
Fumaric (V_{16})																−0.96**	−0.89*
Vitamin C (V_{17})																	0.98**
TAC (V_{18})																	1

*$P \leq 0.05$.
**$P \leq 0.01$.

were lower compared to those of other phenolics (Table 1). There were statistically significant differences ($P < 0.05$) between the examined plum species in phenolic contents. Lombardı-Boccıa et al. [22] identified phenolic contents of organically grown plum (*P. domestica* L.) fruits. In their study, the content of protocatechuic acid was reported as 0.6 mg kg^{-1}, caffeic acid as 22.6 mg kg^{-1}, ferulic acid as 9.3 mg kg^{-1}, and chlorogenic acid as 37.5 mg kg^{-1}. Treutter et al. [23] measured the content of rutin as 66.1 mg 100 g^{-1}, chlorogenic acid as 17.4 mg 100 g^{-1}, *p*-coumaric acid as 3.8 mg 100 g^{-1}, and catechin as 0.2 mg 100 g^{-1} in peels of Jojo plum fruits. Gündüz and Saraçoğlu [24] reported a total phenolic content of 294.2 mg kg^{-1} fw in Pastor plum variety of the species *P. cerasifera* Ehrh. It has been suggested in another study that plum fruits have rich phenolic content and are important for human health [25]. The findings of this study are mostly in agreement with those of other researchers. The minor differences are possibly attributed to environmental conditions and genetical factors of the studied species and varieties. The phenolics flavonol glycosides are light yellow in color and present in almost all plants. Since light is required for synthesis of flavonol glycosides in the plants, they occur more intensely in the peels of fruits. These phenolics are responsible for color formation, and hence, climatic factors such as temperature and light are particularly important [12].

Analysis of organic acid contents in the examined plum species from Van locality (Turkey) indicated that malic acid was the predominant organic acid, and the highest value was measured in *P. spinosa* L. as 1.245 g 100 g^{-1}. The highest content of citric acid was measured in *P. spinosa* L. (27.613 mg 100 g^{-1}), and the highest contents of succinic acid and fumaric acid were measured in *P. domestica* L. (3.065 mg 100 g^{-1} and 4.786 mg 100 g^{-1}, respectively). The highest vitamin C content (25.492 mg 100 g^{-1}) and TAC (1.021 mmol TE kg^{-1}) were measured in *P. domestica* L. (Table 2). There were statistically significant differences ($P < 0.05$) between the examined plum species in contents of organic acids, vitamin C, and total antioxidants. In a study on the varieties of species *P. cerasifera* Ehrh, total antioxidant capacities of Auran and Pastor plum varieties were measured respectively as 0.267 mg Gallic acid equivalent (GAE) kg^{-1} and 0.128 mg GAE kg^{-1} with TAC method [24]. Similar results were obtained by Kim et al. [13] (348–495 GAE 100 g^{-1}), Rupasinghe et al. [15] (214–468 GAE 100 g^{-1}), and Rop et al. [15] (86–413 GAE 100 g^{-1}) in their studies on antioxidant contents of plum species (*P. domestica*, *P. salicina*, and *P. spinosa*). Usenik et al. [26] monitored the changes throughout the maturity period. They reported the content of malic acid as 9.0–21.8 g kg^{-1}, shikimic acid as 55.1–64.0 mg kg^{-1}, and fumaric acid as 1.2–6.7 mg kg in Jojo plum fruits [26]. Nergiz and Yıldız [27] measured the contents of ascorbic acid in Victoria and Stanley plum varieties as 192.6 mg kg^{-1} and 234.3 mg kg^{-1}, respectively. Lombardi-Boccia et al. [22] identified organic acid contents of organically grown plum (*P. domestica* L.) fruits. They measured citric acid as 25.7 mg 100 mg^{-1}, malic acid as 1.98 g 100 g^{-1}, and ascorbic acid as 1.60 mg 100 g^{-1}. The findings of the present study seem to be mostly consistent with this research although different from some published studies. It should be kept in mind that while loss of organic acids can be minimized during the stages of harvest, storage, and analysis, it cannot be totally prevented. Hence, changes and reactions in the physiology of fruits have an effect on their organic acid content. Additionally, species characteristics and environmental factors are also determinants of organic acid content [28, 29].

In this study, the correlations between the measured values of phenolic compounds, organic acids, antioxidant capacity, and vitamin C in the examined plum species were analyzed statistically (Table 2). The findings indicated that vitamin C had a positive correlation ($P < 0.01$) with TAC, rutin, gallic

acid, chlorogenic acid, *p*-coumaric acid, phloridzin, and citric acid while it had a negative correlation with *o*-coumaric acid, ferulic acid, catechin, and especially with protocatechuic acid (Table 3). TAC was positively correlated ($P < 0.01$) with gallic acid, *p*-coumaric acid, phloridzin, and citric acid, whereas it was negatively correlated ($P < 0.05$) with protocatechuic acid and fumaric acid.

References

1. Davis, P. H. *Flora of Turkey and East Aegean Islands* vol. IV. Edinburgh University Press, 1972.
2. Eremin, V. G. *Acta Hortic.* **1978**, *74*, 61–65.
3. Özbek, S. Özel meyvecilik (kışın yaprağını döken meyve türleri). *Çukurova üniversitesi ziraat fakültesi yayınları*, 1978, *11*, 221–253.
4. Gönülşen, N.; Özvardar, S. *E. Baldıran Bahçe Dergisi* **1985**, *14*, 69–75.
5. Güleryüz, M. *Mutedil iklim meyve türleri ders notları*. Ata, Ünv. Z. F Bahçe Bitkileri Bölümü, Erzurum, 1985.
6. Beyhan, Ö. *Bahçe* **2005**, *34*, 47–56.
7. Schobinger, U. *Meyve ve Sebze Üretim Teknolojisi*. Ceviren: J. Acar. H. Ü. Basımevi, Ankara, 1988, pp. 63–64.
8. Savran, H. S. *Nar Suyunda Organik Ait Dağılımı (Yüksek Lisans Tezi)* AÜ, Fen Bilimleri Enstitüsü, Ankara, 1999.
9. Balcı, N. *Meyve Sularında Organik Asit Dağılımı, yüksek lisans semineri (basilmamiş)*. Ankara Üniversitesi, Ankara, 1996.
10. Özkaya, H. Analitik Gıda Kalite Kontrolü, vol. 1086. Ankara Üniversitesi Ziraat Fakültesi Yayını. **1988**, pp. 43–46.
11. Tosun, İ.; Artık, N. *Gıda* **1998**, *23*, 403–413.
12. Cemeroğlu, B.; Yemenicioğlu, A.; Özkan, M. Meyve ve Sebzelerin Bileşimi, 1. In: B. Cemeroğlu (Ed.), *Meyve ve Sebze İşleme Teknolojisi, 2,* Başkent Klişe Matbaacılık, 1, Ankara, 2004.
13. Kim, D. O.; Jeong, S. W.; Lee, C. Y. *Food Chem.* **2003**, *81*, 321–326.
14. Rupasinghe, H. P. V.; Jayasankar, S.; Lay, W. *Sci. Hortic.* **2006**, *108*, 243–246.
15. Rop, O.; Jurikova, T.; Mlcek, J.; Kramarova, D.; Sengee, Z. *Sci. Hortic.* **2009**, *122*, 545–549.
16. Erturk, Y.; Ercisli, S.; Tosun, M. *Int. J. Plant Prod.* **2009**, *3*, 89–92.
17. Rodriguez-Delgado, M. A.; Malovana, S.; Perez, J. P.; Borges, T.; Garcia-Montelongo, F. J. *J. Chromatogr.* **2001**, *912*, 249–257.
18. Bevilacqua, A. E.; Califano, A. N. *J. Food Sci.* **1989**, *54*, 1076–1079.
19. Rice-Evans, C. A.; Miller, N. J.; Bolweel, P. G.; Bramley, P. M.; Pridham, J. B. *Free Radic. Res.* **1995**, *22*, 375–383.
20. Ozgen, M.; Reese, R. N.; Tulio, A. Z.; Scheerens, J. C.; Miller, A. R. *J. Agric. Food Chem.* **2006**, *54*, 1151–1157.
21. Cemeroglu, B. *Ankara* **2007**, *34*, 168–171.
22. Lombardı-Boccıa, G.; Lucarını, M.; Lanzı, S.; Aguzzı, A.; Cappellonı, M. *J. Agric. Food Chem.* **2004**, *52*, 90–94.
23. Treutter, D.; Wang, D.; Farag, A. M.; Argueta Baires, D. G.; Rühmann, S.; Neumüller, M. *J. Agric. Food Chem.* **2012**, *60*, 12011−12019.
24. Gündüz, K.; Saraçoğlu, O. *Sci. Hortic.* **2012**, *134*, 88–92.
25. Donovan, J. L.; Meyer, A. S.; Waterhouse, A. L. *J. Agric. Food Chem.* **1998**, *46*, 1247–1252.
26. Usenik, V.; Kastelec, D.; Veberic, R.; Štampar, F. *Food Chem.* **2008**, *111*, 830–836.
27. Nergiz, C.; Yıldız, H. *J. Agric. Food Chem.* **1997**, *45*, 2820–2823.
28. Poyrazoglu, E.; Gokmen, V.; Artik, N. *J. Food Compos. Anal.* **2002**, *15*, 567–575.
29. Çam, M.; Hışıl, Y.; Durmaz, G. *Food Chem.* **2009**, *112*, 721–726.