Vitamins, Flavonoids, and Phenolic Acid Levels in Early- and Late-ripening Apricot (*Prunus armeniaca* L.) Cultivars from Turkey

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Abstract. This study aimed at determination of vitamin (A, E, C, β -carotene, and lycopene), phenolic, and flavonoid contents in apricots at different stages of ripening using high-performance liquid chromatography (HPLC). The effect of ripening in terms of phytochemical contents was investigated. Early period apricots showed 2.5 to three times higher level of vitamins (A, E, C, and β -carotene, and lycopene) in all types of apricots than others ($P < 0.05$). Early-ripened cultivar, Boccia, showed the highest level of vitamins, although a higher level of vitamin C was measured in late-ripened cultivar Levent ($P < 0.05$). No lycopenes were determined in late-period apricots in contrary to early- and middle-period apricots. Levels of phenolics and flavonoids were measured in all types (3-B-Q-D, procyanidin B1, B2, B3, caffeic acid, gallic acid, p-coumaric acid, epigallocatechine, catechine, epicatechine, chlorogenic acid, ferrulic acid, and routine) and statistical deviation of all types was noted ($P < 0.05$). Among all, the cultivar Özal showed the highest level of chlorogenic acid (45,843.00 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) in all ripening periods, where middle-ripened cultivar Adilcevaz showed the lowest level of p-coumaric acid (7.93 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter content base).

Phenolic compounds are important components of many fruits, vegetables, and beverages, in which they contribute to color and sensory properties such as bitterness and astringency (Macheix et al., 1990). Consumption of foods and beverages rich in phenolic content is found to be correlated with reduced incidences of heart diseases in epidemiological studies (Crique and Ringel, 1994; Renaud and de Lorgeril, 1992).

The anticarcinogenic and antioxidant properties of vitamins A, C, E, β -carotene, and the essential element selenium are relatively recently discovered. Independently or in combination, vitamins C, E, selenium, and carotenoids may act as anticancer or cardioprotective agents by a variety of mechanisms. One such protective mechanism, attributed to vitamin C and E and the carotenoids, is antioxidant (radical-scavenging) activity (Rice-Evans et al., 1997). Vitamin C is known as the most important vitamin in fruits and vegetables for human nutrition (Lee and Kader, 2000).

Apricot fruits are regarded as a rich source of carotenoids, especially β -carotene, which represents more than 50% of total carotenoid content (Ali et al. 2011; Radi et al., 1997). Besides β -carotene, apricot fruit and its products contain smaller amounts of α -carotene, γ -carotene, zeaxanthin, and lutein (Fraser and Bramley, 2004). β -carotene level significantly varies among varieties and among different regions within the same variety (Erdoğan and Erdemoğlu, 2011; Munzuroğlu et al., 2003). Research on other plant species indicated that level of carotenoids varies significantly according to the stage of ripening. During ripening of tomato fruit, there is a remarkable accumulation of carotenoids of which lycopene represents $\approx 90\%$ of the total (Fraser et al., 1994). In acerola fruits (*Malpighia emarginata* D.C.), carotenoid content was higher in mature fruits (Lima et al., 2005).

Despite apricot widely grown in many parts of the world, the Malatya region located in eastern Turkey is particularly important for apricot production and processing as a result of its favorable climatic and geographical conditions (Altındag et al., 2006; Ercisli, 2009). The apricot varieties contain different levels of polyphenols as summarized by Macheix et al. (1990). Chlorogenic acid (5-caffeoylquinic acid) is the dominant phenolic compound in

apricots. The other phenolic compounds determined in apricots are neochlorogenic acid, caffeic acid, p-coumaric acid, ferulic acid, and their esters. (+)-Catechin and (–)-epicatechin are also determined in apricot fruits and their products (Arts and van de Putte, 2000; Dragovic-Uzelac et al., 2005a; Garcia-Viguera et al., 1997; Radi et al., 1997; Rish and Herrmann Die Gehalte, 1988). Flavonols in apricots occur mostly as glucosides and rutosides of quercetin and of kaempferol; however, quercetin 3-rutinoside (rutin) predominates (Dragovic-Uzelac et al., 2005b; Garcia-Viguera et al., 1997; Henning and Herrmann, 1980). Apricot fruits contain different levels of phytochemicals such as vitamins, carotenoids, and polyphenols, which are the determinants of taste, color, and nutritive values (Gardner et al., 2000; Rice-Evans et al., 1997; Vinson et al., 1998).

The carotenoids are the most widespread group of pigments in nature, and they are present in all photosynthetic organisms and are responsible for most of yellow to red colors of fruits and flowers. Ripening of the fruits involves series of complex biochemical reactions, which lead to production of phenolic compounds, carotenoids, and formation of volatile compounds (Speirs and Brady, 1991). Phenolic compounds generate a sourish taste in fruit products and blurred appearance in fruit juices (Cemeroğlu et al., 2004; Gündoğdu et al., 2011). Differences may occur in content and quantities of phytochemicals, which depend on a number of factors such as sunlight, soils, season, region of cultivation, fruit variety, and ripening stage (Harris, 1977; Spanos and Wrolstad, 1992). This study aims to analyze and describe the differences in terms of vitamin (A, E, C, carotene, and lycopene), phenolics, and flavonoid contents by HPLC. This study demonstrates once again that apricots are highly healthy food products resulting from their chemical contents. More detailed knowledge on the variability in nutrient contents of the cultivars will be of benefit in future selection of apricot genotypes with improved nutritional quality and processing characteristics.

Materials and Methods

Plant material

Cultivars (Boccia, C.D. Rona, Tyrinte, Aprikoz) and genotypes (Dortyol-4, Adilcevaz, Ordubad, Ziraat Okulu, Geç Aprikoz, Levent, Özal) were used in the study, which are grown in the Malatya Fruit Research Institute National Apricot Genetics Resources Plot. The types and cultivar (*Prunus armeniaca* L.) used in all of the experiments were fresh apricots harvested. Fruits were harvested at deep orange 1 (fully ripe) in Malatya, Turkey (Table 1). At each harvest date, we formed random lots, each with 30 fruits. Immediately after picking, fruits were cut into small pieces, frozen in liquid nitrogen, and stored at -80°C for subsequent analysis. Fruits used for polyphenol and vitamin isolation and characterization were harvested at the deep orange 1 (fully ripe) stage. The apricot types used in

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Table 1. Meteorological data for harvest dates of early-, middle-, and late-period apricot types and cultivar.

Types and cultivars	Date of harvest	Avg temp. (°C)	Total rainfall (mm)	Antinograf sun values (CAL/cm ² /min)	Avg relative humidity (%)	Avg minimum temp. (°C)	Avg maximum temp. (°C)
Boccucia	9 June	25.3	4.0	575.30	35.8	17.9	32.3
C.D. Rona	23 June	26.7	4.0	575.30	35.8	17.9	32.3
Tyrinte	24 June	25.7	4.0	575.30	35.8	17.9	32.3
Dortyol-4	30 June	26.1	4.0	575.30	35.8	17.9	32.3
Ordubat	15 July	26.8	5.8	568.88	37.6	20.3	33.6
Adilcevaz	9 July	25.7	5.8	568.88	37.6	20.3	33.6
Ziraat okulu	1 July	25.7	5.8	568.88	37.6	20.3	33.6
Aprikoz	25 July	21.7	39.0	451.83	42.8	14.8	27.1
Gec Aprikoz	19 Sept.	20.7	39.0	451.83	42.8	14.8	27.1
Ozal	1 Sept.	20.7	39.0	451.83	42.8	14.8	27.1
Levent	7 Sept.	21.03	39.0	451.83	42.8	14.8	27.1

the study were taken from Malatya Fruit Research Institute National Apricot Genetics Resources Plot and all trees have been subjected to identical agricultural procedures (irrigation, fertilization, spraying, soil). Taking also these factors into consideration, the study aimed to explore the effects of sun light on vitamin A, E, C, β -carotene, and lycopene levels in fresh fruits of apricots at different ripening stages. Sunlight, in general, is an important determinant of vitamin A, β -carotene, and lycopene levels.

Chemicals

3-B-Q-D, procyanidin B1, B2, B3, caffeic acid, gallic acid, p-coumaric acid, epigallocatechin, catechin, epicatechin, chlorogenic acid, ferrulic acid, and quercetin-3, rutinoides (rutin). Chlorogenic and p-coumaric acid were obtained from Fluka (Neu-Ulm, Germany); (+)-catechin, (-)-epicatechin, quercetin-3, rutinoides (rutin), ferulic acid, vitamin A, E, C, β -carotene, and lycopene were obtained from Sigma (Deisenhofen, Germany); caffeic acid was obtained from Merck (Darmstadt, Germany). HPLC-grade ethanol, methanol, acetonitrile, chloroform, acetone, n-hexane, acetic acid, chemical Co 1, 2-dichloroethane, anhydrous sodium sulphate, tertbutylhydroquinone (tBHQ), and perchloric acid were from Merck.

Extraction and determination of phenolic acids and flavonoids

The polyphenols in examined samples were extracted using a procedure described by Dragovic-Uzelac et al. (2005a) based on the method of Bengoechea et al. (2007). Each apricot fruit puree (50 g) was mixed with 50 mL methanol/HCl (100:1, v/v), which contained 2% tBHQ in an inert atmosphere (N) during 14 h at 35 °C in the dark. The extract was then centrifuged at 5000 rpm/min. Supernatant were evaporated to dryness under reduced pressure (35 to 40 °C). The residue was dissolved in 25 mL of water/ethanol (80:20, v/v) and extracted four times with 25 mL of ethyl acetate. The organic fractions were combined, dried for 30 to 45 min with anhydrous sodium sulphate, filtered through the Whatman No. 40 filter (Whatman International Ltd., Kent, U.K.), and evaporated to dryness under vacuum (35 to 40 °C). The residue was dissolved in 1 mL

of methanol/water (50:50, v/v) and filtered through a 0.45- μ m filter (nylon membranes; Supelco Inc., Bellefonte, PA) before being injected (20 μ L) into the HPLC apparatus. Samples were extracted in triplicate.

Pressurized liquid extractions (PLEs) were performed on a Dionex ASE 200 (Dionex Corp., Sunnyvale, CA) system. The pre-set default conditions were as follows: pre-heating period, 5 min; solvent flush volume, 60% of the extraction cell volume; number of extraction cycles, three; purge, 90 s using pressurized nitrogen (99.995% of purity, 150 psi); and collection, in 60-mL glass vials with Teflon-coated rubber caps (I-CHEM, New Castle, DE). The solvent used was previously degassed to avoid the oxidation of the analytes under the operating conditions. Optimum extraction conditions were determined as 1500 psi pressure, 40 °C temperatures, and 1-h application time in the PLE system. Propolis ethanol extracts (1 g) was mixed in gradient conditions with methanol/water/hydrochloric acid (75:20:5), which contained 2% tBHQ in an 11- or 22-mL stainless steel extraction cell. Then, each one was filtered through a 0.45- μ m nylon membrane (Lida, Kenosha, WI) and transferred to a 50-mL volumetric flask. Solvents was evaporated to dryness in a Turbovap LV Evaporator (Zymark, Hopkinton, MA) provided with a nitrogen stream in a water bath at 40 °C. The residue was reconstituted in (2 mL) methanol–water–aqueous (50:50, v/v) and which was brought up to its volume with methanol–water filtered through a 0.45- μ m polytetrafluoroethylene filter (Waters, Milford, CA) before injection into the HPLC system.

Polyphenol analysis were performed on an Agilent Series 1100 liquid chromatography, equipped with a vacuum degasser, a quaternary pump, and a Agilent 1100, G1315B DAD detector, connected to HPChemStation software. A reversed-phase ACE 5 C18A11608 (250 $\times$ 4.6 mm, 4 μ m) column was used. The content of solvents and used gradient elution conditions were previously described by Dragovic-Uzelac et al. (2005a). For gradient elution, mobile phase A contained 3% acetic acid in water; solution B contained a mixture of 3% acetic acid, 25% acetonitrile, and 72% water. The following gradient was used: 0 to 40 min, from 100% A to 30% A, 70% B with a flow rate 1 mL·min⁻¹; 40 to 45 min, from

30% A, 70% B to 20% A, 80% B with flow rate 1 mL·min⁻¹; 45 to 55 min, from 20% A, 80% B to 15% A, 85% B with flow rate 1.2 mL·min⁻¹; 55 to 57 min, from 15% A, 85% B to 10% A, 90% B with flow rate 1.2 mL·min⁻¹; and 57 to 75 min 10% A, 90% B with flow rate 1.2 mL·min⁻¹. Operating conditions were as follows: column temperature, 30 °C, injection volume, 20 μ L, ultraviolet-VIS photo diode array detection at 280 nm. Detection was performed with an ultraviolet-VIS photodiode array detector by scanning spectra from 210 to 360 nm. Stock standard solutions at a concentration of 1 mg·mL⁻¹, G1 were prepared in methanol/water (1:1) and stored at 4 °C in darkness. Different range calibration curves for different polyphenol components in apricots samples were used.

Analytical quality control

Recoveries were measured by comparing retention times and spectral data with those of authentic standards. Quantitative determinations were carried out using calibration curves of the standards.

Extraction and determination of vitamins

Apricot samples (50 g) were mashed in a homogenizer and 4 g homogenate paste per sample were taken for extraction of vitamins A, E, β -carotene, and lycopene, and 1 g per sample was taken for extraction of vitamin C. To these homogenates, 4 mL of ethanol was added, vortexed, and the mixture centrifuged (Mistral #2000) at 2000 rpm for 3 min at 4 h. The supernatant was also filtered through Whatman No. 1 paper and to the filtrate 0.15 mL n-hexane was added and mixed. Vitamins A, E, and β -carotene were extracted twice in the hexane phase and the collected extract was dried under a stream of liquid nitrogen. Dried extract was solubilized in 0.2 mL methanol for HPLC. Injections were made in duplicate for each sample. The quantification (Catignani, 1983; Miller et al., 1984) used absorption spectra of 326, 296, and 436 nm for vitamins A, E, and β -carotene, respectively.

HPLC separations were accomplished at room temperature consisting of a sample injection valve (Cotati 7125) with a 20-mL sample loop, an ultraviolet spectrophotometric detector [and a Techsphere ODS-2 packed (5-mm particle and 80 Å pore size) column (250_4.6 i.d.) with a methanol:acetonitrile:chloroform (47:42:11, v/v) mobile phase at 1 mL·min⁻¹ flow rate]. The extraction of vitamin C was according to the method of Cerhata et al. (1994). To 1 g homogenized apricot paste, 1 mL of 0.5 M perchloric acid was added, vortexed, and the volume adjusted to 5 mL by adding ddH₂O. The mixture was centrifuged at 5000 rpm for 8 min at 4 °C. The supernatant was filtered, as earlier, and the vitamin C level was determined using the method of Tavazzi et al. (1992) by HPLC using a column (250_3.9 i.d.) packed with Tecopak C18 reversed-phase material (10 mm particle size) with mobile phase (3.7 mM phosphate buffer, pH 4.0) at 1 mL·min⁻¹ flow rate.

Statistical analysis

Experimental data were evaluated using analysis of variance and significant differences among the means ($P < 0.05$) were determined by Duncan's multiple range test using the SPSS 10.0 for Windows (SPSS Inc., Chicago, IL).

Results and Discussion

Vitamin levels (A, E, C, β -carotene, and lycopene) in fresh apricots at different stages of ripening are depicted in Table 2. Average vitamin levels per gram were measured in fresh apricots of all types. It has been determined that vitamin A level ranged between 25.5 and 2.04 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter; vitamin E level ranged between 65.33 and 25.33 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter; vitamin C level ranged between 18,553.51 and 3,923.21 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter; β -carotene level ranged between 2100.00 and 171.42 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter; and lycopene level ranged between 70.0 and 8.32 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter.

With respect to ripening stages, in general, highest vitamin levels (A, E, β -carotene, and lycopene) were determined in early period apricots, whereas the highest vitamin C level was determined in late-period 'Levent' apricots. No lycopene content was determined in none of the late-period apricots. As seen from Table 2, vitamin levels (A, E, β -carotene, and lycopene) in early-period apricots are significantly higher (2.5 to three times) than those of middle- and late-period apricots ($P < 0.05$). Vitamin A, E, β -carotene, and lycopene levels in all early-period apricots were higher compared with those of middle- and late-period apricots and lowest vitamin levels were recorded in late-period apricots.

Early-period 'Boccucia' apricot demonstrated significantly higher levels of vitamin A (25.51 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter), β -carotene (2100.00 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter), and lycopene (70.08 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) than all other apricots. On the other hand, the lowest levels of vitamin A (2.04 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) and β -carotene (171.42 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) were determined in late-period 'Levent' apricot and the lowest level of vitamin E (253,324.00 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was recorded in pre-late-period 'Özal' apricot. The highest vitamin E level (65.33 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in early-period 'Tyrinte' apricot and the highest vitamin C level (18,553.51 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in late-period 'Levent' apricot.

Differentials in percent values of the compounds in early-, middle-, and late-period apricots are compared in Table 2 as $\mu\text{g}\cdot\text{g}^{-1}$ dry matter. Generally, vitamin A, E, β -carotene, and lycopene levels in early-period apricots were higher compared with middle- and late-period apricot types and vitamin C level was higher in late-period 'Levent' apricot. No statistically significant differences were identified between vitamin C levels of other apricot types ($P < 0.05$). Munzuroglu et al. (2003) have also formerly conducted a study on the determination of vitamin A, E, C, and β -carotene levels in different apricot types.

Vitamin A, β -carotene, and lycopene levels in early-period 'Boccucia' and 'Dörtöl-4' apricots were found to be significantly higher ($P < 0.05$) compared with those of early-period 'Tyrinte' and 'Ce De Rona' apricots as well as all middle- and late-period apricots. No statistically significant differences were determined between vitamin E levels of early-period 'Tyrinte' and 'Dörtöl-4' apricots. However, vitamin E levels in these apricots were significantly higher ($P < 0.005$) compared with those of other early-period apricot types 'Boccucia' and 'Ce De Rona' as well as middle- and late-period apricots. The significantly highest vitamin C level was measured in late-period 'Levent' apricot, whereas the lowest level was measured in 'Ce De rona', 'Geç apriköz', 'Tyrinte', 'Özal', and 'Ziraat Okulu' apricots with no statistically significant differences in between ($P < 0.005$). As indicated by the findings, harvest date, average temperature ($^{\circ}\text{C}$), total precipitation (mm), antinographic insolation values ($\text{CAL}/\text{cm}^2/\text{min}$), average relative humidity (%), average minimum-maximum temperature, and cultivar type are considered to be the determinants of vitamin A, E, β -carotene, and lycopene contents.

Dragovic-Uzelac et al. (2007) conducted a study on 'Keckemetska ruža', 'Madjarska najbolja', and 'Velika rana' apricots grown in Neretva valley and they determined β -carotene contents of these apricots in the ripeness stage, respectively, as 795.5 $\mu\text{g}/100\text{ g}$, 1374.95 $\mu\text{g}/100\text{ g}$, and 948.33 $\mu\text{g}/100\text{ g}$. The findings of this study are partially in accord with the findings of other researchers and

comparatively higher and lower findings are also observed in this study. Although all vitamin C analysis procedures were conducted by using ice, degradation was observed as a result of oxidation. Therefore, the differences in vitamin contents of examined cultivars are attributed to cultivar and genotype characteristics, applied crop procedures, and environmental factors (Yilmaz et al., 2009).

Phenolic acids and their derivatives (3-B-Q-D, procyanidin B1, B2, B3, caffeic acid, gallic acid, p-coumaric acid, epigallocatechin, catechin, epicatechin, chlorogenic acid, ferulic acid, and quercetin-3-rutinoside) were determined in all ripe apricots (Tables 3, 4, and 5). Kan and Bostan (2013) also formerly determined some of these polyphenols (caffeic acid, gallic acid, p-coumaric acid, epigallocatechin, catechin, epicatechin, chlorogenic acid, ferulic acid, and rutin) in a sample of organically and conventionally grown cultivars and rutin was identified to be the dominant flavonol in all apricot types.

Statistically significant differences ($P < 0.005$) were identified between quercetin-3-rutinoside (rutin) contents. Dry matter quercetin-3-rutinoside (rutin) contents $\mu\text{g}\cdot\text{g}^{-1}$ in early-period 'Boccucia' and 'Tyrinte' apricots were equal and ranged between 12,338.11 and 13,262.42 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter. Furthermore, no statistically significant differences ($P < 0.005$) were recorded between rutin contents of early-period 'Dörtöl-4' apricot, middle-period 'Ordubat' apricot, and late-period 'Levent' apricot. The lowest level of p-coumaric acid (7.929 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured

Table 2. Vitamin A, E, C, lycopene, and β -carotene contents in apricot types and cultivars ($\mu\text{g}\cdot\text{g}^{-1}$ dry matter).

Ripening time	Types and cultivars	A	E	C	β -carotene	Lycopene
Early ripening	Boccucia	25.51 a ^z	41.73 e	9,122.32 ab	2,100.00 a	70.08 a
	Dörtöl-4	16.00 b	64.67 a	10,329.97 ab	1,567.50 b	52.28 ab
	C.D. Rona	9.90 c	52.93 bc	7,799.62 b	1,144.50 c	38.17 cd
	Tyrinte	11.25 cb	65.33 a	6,855.43 b	950.00 d	31.48 cde
Medium ripening	Adilcevaz	10.73 c	46.00 de	8,960.48 ab	650.69 ef	21.69 def
	Ordubat	2.97 de	54.00 bc	9,740.84 ab	249.55 g	8.32 ef
	Ziraat okulu	10.06 c	50.67 dc	3,923.21 b	733.48 e	24.45 def
	Apriköz	8.00 dc	60.00 ab	7,284.11 ab	750.97 e	ND
Late ripening	Geç Apriköz	7.40 dc	28.00 f	10,812.53 b	621.53 ef	ND
	Levent	2.04 e	26.00 f	18,553.51 a	171.42 g	ND
	Özal	6.24 cde	25.33 f	5,853.31 b	523.58 f	ND

^zDifferent letters in columns indicate significantly different values at $P \leq 0.05$.

ND = not determined.

Table 3. Polyphenol contents in early-, middle-, and late-period apricots ($\mu\text{g}\cdot\text{g}^{-1}$ dry matter).

Ripening time	Types and cultivars	Rutin	Ferulic acid	Catechin	Chlorogenic acid	Epicatechin
Early ripening	Boccucia	12,338.11 a ^z	577.77 e	812.55 de	2,245.53 cd	514.65 cd
	Dörtöl-4	5,362.92 c	859.18 c	931.89 d	1,364.93 cd	340.49 de
	C.D. Rona	3,805.68 ed	771.27 d	1523.53 c	525.77 d	340.49 de
	Tyrinte	13,262.42 a	246.55 e	1498.14 c	1,240.61 cd	964.55 b
Medium ripening	Adilcevaz	3,823.48 ed	1339.83 b	2417.33 b	782.18 cd	1279.37 a
	Ordubat	5,142.76 c	433.33 f	837.94 ed	5,692.82 c	1234.72 a
	Ziraat okulu	3,145.23 e	191.01 e	372.24 f	2,545.97 cd	292.49 f
	Apriköz	9,812.86 b	1576.41 a	3250.19 a	2,434.60 cd	358.36 de
Late ripening	Geç Apriköz	5,528.03 c	393.43 f	1371.18 c	31,598.00 b	432.04 de
	Levent	4,890.24 dc	405.43 f	571.32 fed	1,427.09 cd	85.96 g
	Özal	3,501.35 e	786.96 dc	479.91 fe	45,843.00 a	624.06 c

^zDifferent letters in columns indicate significantly different values at $P \leq 0.05$.

Table 4. Polyphenol contents in early-, middle- and late-period apricots ($\mu\text{g}\cdot\text{g}^{-1}$ dry matter).

Ripening time	Types and cultivars	Epigallocatechin	3-BQ-D	P-qumaric acid	Gallic acid
Early ripening	Boccucia	205.41 cd ^a	380.88 c	12.30 e	880.50 d
	Dörtöl-4	220.86 c	205.67 e	52.62 c	548.00 e
	C.D. Rona	426.90 a	421.82 b	12.01 e	1268.02 b
Medium ripening	Tyrinte	361.71 b	445.54 a	81.93 b	1052.00 c
	Adilcevaz	85.52 e	61.23 h	7.93 e	1875.00 a
	Ordubat	91.81 e	110.46 g	129.3 a	614.50 e
	Ziraat okulu	81.00 e	165.65 f	14.49 e	635.00 e
Late ripening	Aprikoz	225.96 c	265.67 d	79.45 b	868.25 d
	Geç Aprikoz	74.48 ef	199.01 e	19.39 e	485.25 f
	Levent	45.91 f	188.73 e	33.40 d	512.60 f
	Özal	181.32 d	52.28 h	19.44 e	365.00 g

^aDifferent letters in columns indicate significantly different values at $P \leq 0.05$.

Table 5. Polyphenol contents in early-, middle-, and late-period apricots ($\mu\text{g}\cdot\text{g}^{-1}$ dry matter).

Ripening time	Types and cultivars	Caffeic acid	Procyanidin B1	Procyanidin B2	Procyanidin B3
Early ripening	Boccucia	979.05 a ^a	485.39 b	416.65 d	422.86 ef
	Dörtöl-4	394.76 cd	375.04 c	445.37 d	642.21 b
	C.D. Rona	413.24 c	521.41 b	914.01 b	875.14 a
	Tyrinte	656.23 b	1069.37 a	639.99 c	568.21 c
Medium ripening	Adilcevaz	317.20 cde	125.90 e	402.58 de	475.71 ef
	Ordubat	213.89 ef	381.11 c	227.09 f	406.21 ef
	Ziraat okulu	212.15 ef	86.46 e	304.04 ef	179.45 h
	Aprikoz	270.64 de	1071.27 a	446.68 d	562.93 c
Late ripening	Geç Aprikoz	283.74 de	182.21 d	1039.75 a	298.64 g
	Levent	100.98 f	483.11 b	728.20 c	388.50 f
	Özal	667.87 b	111.11 e	433.54 d	528.57 dc

^aDifferent letters in columns indicate significantly different values at $P \leq 0.05$.

in 'Adilcevaz', 'C.D. Rona', 'Boccucia', and 'Ordubat', respectively.

Ferulic acid and catechin levels in early-, middle-, and late-period apricots varied significantly ($P < 0.05$). The highest ferulic acid and catechin levels were determined in middle-period 'Aprikoz' and 'Adilcevaz' apricots, whereas the lowest ferulic acid and catechin levels were measured in middle-period 'Ziraat okulu' apricot.

Levels of chlorogenic acid were also found to vary significantly ($P < 0.05$). The highest level of chlorogenic acid (31,598.0 to 45,843.00 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was determined in late-period 'Levent' and 'Özal' apricots, whereas the lowest chlorogenic acid content (525.77 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in early-period 'Ce De Rona' apricot. Levels of epicatechin were also found to vary significantly ($P < 0.05$). Although the highest epicatechin levels (1279.37 to 1234.72 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) were measured in middle-period 'Adil cevaz' and 'Ordubat' apricots, the lowest epicatechin level (433.327 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was recorded in late-period 'Geç aprikoz' apricot.

The highest epigallocatechin levels (426.903 to 361.71 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) were determined in early-period 'Ce De Rona' and 'Tyrinte' apricots, whereas the lowest epigallocatechin level (45.91 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in late-period 'Geç aprikoz' apricot. Epigallocatechin and 3-B-Q-D levels were found to vary significantly ($P < 0.05$).

Levels of gallic acid were also found to vary significantly ($P < 0.05$). The highest (1875.00 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) and the lowest (365.00 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) gallic acid levels

were measured in middle-period 'Adil cevaz' apricot and late-period 'Özal' apricot, respectively.

The highest procyanidin B1 levels (1071.27 to 1069.37 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) were measured in middle-period 'Aprikoz' apricot and early-period 'Tyrinte' apricot. The lowest procyanidin B1 levels (125.90 to 86.46 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) were measured in late-period 'Özal' apricot and middle-period 'Adilcevaz' and 'Ziraat okulu' apricots. Provitamin B1 levels were found to vary significantly ($P < 0.05$). Procyanidin B2 levels were also found to vary significantly ($P < 0.05$). The highest procyanidin B2 level (1039.75 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was determined in late-period 'Levent' apricot, whereas the lowest procyanidin B2 level (227.09 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in middle-period 'Ordubat' apricot. Procyanidin B3 levels were also found to vary significantly ($P < 0.05$). The highest procyanidin B3 level (875.14 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in early-period 'Ce De Rona' apricot and the lowest procyanidin B3 level (179.45 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) was measured in middle-period 'Ziraat okulu' apricot.

Levels of caffeic acid were also found to vary significantly ($P < 0.05$). The highest (979.05 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) and the lowest (100.98 $\mu\text{g}\cdot\text{g}^{-1}$ dry matter) levels of caffeic acid were measured in early-period 'Boccucia' apricot and late-period 'Levent' apricot, respectively. The highest levels of quercetin-3-rutinoside (rutin) were measured in early-period 'Tyrinte' and 'Boccucia' apricots; the highest levels of ferulic acid and catechin were measured in middle-period 'Aprikoz' apricot; the highest levels of epicatechin were

measured in middle-period 'Adilcevaz' and 'Ordubat' apricots; the highest level of chlorogenic acid was measured in late-period 'Özal' apricot; the highest level of epigallocatechin was measured in early-period 'Ce De Rona' apricot; the highest level of 3-B-Q-D was measured in early-period 'Tyrinte' apricot; the highest level of p-coumaric acid was measured in middle-period 'Ordubat' apricot; the highest level of gallic acid was measured in middle-period 'Adil cevaz' apricot; the highest levels of provitamin B1 were measured in middle-period 'Aprikoz' apricot and early-period 'Tyrinte' apricot; the highest level of caffeic acid was measured in early-period 'Boccucia' apricot; the highest level of provitamin B2 was measured in late-period 'Levent' apricot; and the highest level of procyanidin B3 was measured in early-period 'Ce De Rona' apricot.

Cultivar type was observed to be the predominant determinant of the polyphenol levels depicted previously and ripening stage (early, middle, and late period) was not identified to be effective on polyphenol levels. Cultivar type, ripening stage, and exposure to sunlight were observed to be the determinants of vitamin A, E, C, β -carotene, and lycopene levels. Biochemical changes associated with different ripening stages in apricots are examined in a very limited number of studies. (Sharaf et al., 1989). There is not any reliable and precise data on carotenoids during the ripening period of apricots. The findings indicate that carotene and vitamin production is insufficient in late-period apricots as a result of incomplete ripening and inadequate exposure to sunlight. No lycopene content was determined in late-period apricots in our study. The studies on different plant species report significant changes in carotenoid levels throughout the ripening period. Apricots are rich in carotenoids. Particularly β -carotene represents more than 50% of the total carotenoid content in apricots (Radi et al., 1997).

Conclusion

During ripening, carotenoid concentration increases, chlorophyll concentration decreases, and organoleptical quality of the fruit undergoes changes (Burns et al., 2003). In early periods, the tomato fruits are green and contain the same elements of carotenoids (p-carotene, lutein, violaxanthin) as in green leaves. Other factors like smoke, dust, clouds, and rain might interfere with the sunlight effect and, hence, may indirectly affect red color formation (Andris and Crisosto, 1996).

Significantly higher levels of vitamin A, E, β -carotene, and lycopene were determined in early-period apricots compared with those of middle- and late-period apricots and sunlight was identified to be an important determinant of the level of these nutrients. Fruit pomology was also found to be effective on the level of these nutrients. Early-period 'Boccucia' apricot was richer in phytochemicals compared with other apricot types and the lowest phytochemical content was

identified in late-period 'Levent' apricot. A significant remark was the lack of lycopene production in all late-period apricots. On the other hand, late-period apricots contained significantly higher levels of vitamin C compared with those of early- and middle-period apricots. As known, the most important factors contributing to degradation of vitamin C are oxygen (O₂), exposure of the plant to sunlight, degradations in hormone concentration, and temperature. Additionally, cooler temperatures in fall as a result of shorter days and reduced exposure to sunlight lead to a decrease in respiration rate of the fruit and, hence, in amount of O₂ concentration. These factors result a delay in degradation of vitamin C (Çelik et al., 2006) As seen from the findings on phenolic acids and flavonoids, apricot type is the predominant determinant of polyphenol levels.

In this study, chemical compounds of the apricot cultivars were examined throughout the ripening period and nutritional values and importance of these cultivars for human health were determined. In literature, there is a gap on studies examining the changes in carotenoid, vitamin, and polyphenol levels in apricots at different ripening stages (early, middle, and late periods). In this respect, this study is deemed valuable as a result of its contribution to the literature and guidance for forthcoming studies.

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