Effect of almond genotypes on fatty acid composition, tocopherols and mineral contents and bioactive properties of sweet almond (*Prunus amygdalus* Batsch spp. *dulce*) kernel and oils

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Abstract Oil content of almond kernels ranged from 36.7% in the cultivar T12 to 79.0% in genotype T27. The major fatty acid in almond oil is oleic (62.43% in T7–76.34% in T4) followed by linoleic (13.97% in T4–29.55% in T3) and palmitic (4.97% in T2–7.51% in T3). The main tocopherol in almond oil was α -tocopherol (44.25 mg/100 g in T25–75.56 mg/100 g in T13) that was 44 folds higher than other tocopherols in the oil. Total tocopherol contents of almond oils ranged between 47.42 mg/100 g (T14) and 80.15 mg/100 g (T16). Among macro minerals, K was the highest (5238–14,683 mg/kg), followed by P (3475–11,123 mg/kg), Ca (1798–5946 mg/kg), and Mg (2192–3591 mg/kg), whereas Na was the least (334–786 mg/kg) in almond kernel. The total polyphenol was observed in T16 (98.67 mg GAE/100 g), while the least was found in T24 (23.75 mg GAE/100 g). Antioxidant activity was high in T7 (91.18%) and low in T12 (44.59%).

Keywords Almond cultivars · Almond oil · Fatty acid · Tocopherol · Mineral · Total phenol · Antioxidant activity · GC-FID · HPLC · ICP-AES

Introduction

Almonds (*Prunus amygdalus* L.) belong to the Rosaceae family and *Prunus* genus and can be found in temperate environment around the globe (Moayed et al. 2011; Izaddost et al. 2013; Čolić et al. 2019). The almonds have numerous nutritional benefits as well as industrial and medicinal importance as they contain good quality oil, protein, fiber, mineral and bioactive compounds. The consumption of nuts is greatly increased globally due to their high health benefits. Among nuts, almonds received great attention around the globe due to their wide food, medicinal, and cosmetic applications. They are frequently used as ingredients in the manufacture of snacks and other processed foods. However, the oil content and composition of food ingredients such as almond in confectionary industry are very important because high oil content reduce the water absorption and affect the product quality. Nutritionally almonds are considered as excellent sources of energy, fats, proteins, essential minerals, carbohydrates, unsaturated fatty acid (linoleic acid and γ -linoleic acids), phenolic compounds and vitamins (Welna et al. 2008). There is lot of work underway to improve the genetic, agronomic and climate adaptability features of almonds. However, the biochemical composition of newly developed almond genotypes yet needed to be explored (Moayed et al. 2011; Kodad et al. 2008). The ratio of oleic acid to linoleic acid is suggested to be used as a tool for highlighting oil stability and fatty acid profiling of the almond kernels (Kodad et al. 2008). The objective of the current

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study was to investigate effect of almond genotypes on fatty acid composition, tocopherols and mineral contents and bioactive properties of and oils of thirty-one different sweet almond (*Prunus amygdalus* Batsch spp. *dulce*) growing in the Mersin (Büyükceli-Gülнар) district of Turkey.

Materials and methods

Material

Almond fruits of thirtyone genotypes were collected during the full matured stage from the Mersin (Büyükceli-Gülнар) province in Turkey during 2018 season. Precipitation was about 702 mm per year and maximum air temperature around 28–30 °C during the summer months. In 2018, after almond genotypes were selected, almond genotypes were marked as the native population. Almond fruits from each genotype were harvested on September, and samples were collected from each genotype for analysis. About 25 kg almond were collected from each tree. The fruits were dried at 70 °C in hot air oven. The kernels were ground into fine homogeneous powder, and collected in dark colored bottles. Samples were stored at refrigerated temperature (< 5 °C) until analysis.

Methods

Oil content

The hot extraction method using Soxhlet apparatus was used to extract oil from almond seeds. Briefly, 2 g powder was extracted using petroleum ether for 6 h. After the extraction, the solvent was evaporated from the oil at 40 °C and the obtained oil was stored in vials at refrigerated temperature until used for analysis.

Fatty acid composition of almond oil

The fatty acid profile of oil samples extracted from 31 almond genotypes was determined using a gas chromatography system. The system consisted of a CP-Sil 88 capillary column (100 m long, 0.25 mm ID, and film thickness 0.2 µm) attached to a Varian 5890 gas chromatograph. The fatty acid methyl esters of the samples were injected into this system at 250 °C (Matthäus and Özcan 2006) and the individual fatty acid methyl esters were identified by comparing with the retention time of their respective ester standards.

Tocopherol contents in almond oil

Tocopherol contents in oil samples were determined using HPLC system following the method described earlier (Balz et al. 1992). The oil samples (250 mg) were mixed with 20 mL n-heptane. After that, 20 µL of this mixture was directly injected to a Diol phase HPLC column 25 cm × 4.6 mmID (Merck, Darmstadt, Germany) maintaining 1.3 mL/min flow rate.

Mineral contents in almond kernels

The dried almond powder (0.5 g) was digested by using a mixture of 65% HNO₃ (5 ml) and 35% H₂O₂ (2 ml) in a closed system (Cem-MARS Xpress). The digested mixture was then transferred to a volumetric flask and the volume was raised to 20 ml with deionized water. The diluted samples was injected to ICP AES (Varian-Vista, Australia) and the estimation of a particular mineral content in the sample was made by comparing them with the reference mineral solutions provided by the National Institute of Standard and Technology (NIST; Gaithersburg, MD, USA) (Skujins 1998). The working conditions of ICP-AES used during the experiment were: RF Power kept at 0.7–1.5 kw (1.2–1.3 kw for axial); plasma gas flow rate (Ar) was maintained at 10.5–15 L/min (radial) 15 (axial); auxiliary gas flow rate (Ar) was kept at 1.5; the viewing height was 5–12 mm; the copy and reading time was set at 1–5 s (max. 60 s) and the copy time was kept at 3 s (max. 100 s).

Total phenolic content

Total phenolic contents of obtained almond extracts were found by using the Folin-Ciocalteu (FC) reagent as applied by Yoo et al. (2004) with some modifications. 1 ml of FC was added and mixed for five minutes. Following the addition of 10 mL of 7.5% Na₂CO₃ solution tubes were mixed and the final volume was completed to 25 ml with deionised water. At the end of 1 h, total phenol content was determined as 750 nm wavelength in spectrophotometer. The results were given as mg gallic acid equivalent (GAE)/100 g of fresh weight.

Antioxidant activity

The free radical scavenging activity of almond samples was determined using DPPH(1,1-diphenyl-2-picrylhydrazyl) according to Lee et al. (1998). The extract was mixed with 2 mL methanolic solution of DPPH. The mixture was shaken vigorously and allowed to stand at room temperature for 30 min and the absorbance was recorded at 517 nm by using a spectrophotometer. All determinations were performed in triplicate.

Table 1 Oil content and fatty acid composition of different almond kernel and oils (%)

Almonds	Oil	Palmitic	Palmitoleic	Stearic	Oleic	Vaccenic	Linoleic	Linolenic	Arachidic	Eicosenoic	Total
T1	45.0 ± 1.13*1	6.17 ± 0.11 g	0.27 ± 0.01i	1.97 ± 0.17e	63.15 ± 0.71i	0.95 ± 0.05 g	27.49 ± 0.37b	—***	—	—	100.0
T2	43.1 ± 0.98n**	4.97 ± 0.07i	0.26 ± 0.03i	1.46 ± 0.21i	72.28 ± 1.16e	1.43 ± 0.11b	17.25 ± 0.61j	1.42 ± 0.11a	0.15 ± 0.03a	0.28 ± 0.09a	99.51
T3	48.6 ± 0.62j	7.51 ± 0.21a	0.39 ± 0.05e	1.56 ± 0.13 h	58.89 ± 1.11 k	1.31 ± 0.09c	29.55 ± 0.43a	0.20 ± 0.03b	0.12 ± 0.01c	0.12 ± 0.03b	99.64
T4	46.3 ± 0.76 k	5.92 ± 0.14f	0.37 ± 0.01f	2.22 ± 0.24c	76.34 ± 0.38a	1.02 ± 0.07f	13.97 ± 0.27n	0.16 ± 0.01c	—	—	100.00
T5	46.7 ± 1.23 k	5.37 ± 0.09i	0.38 ± 0.07f	2.41 ± 0.19b	74.51 ± 0.21c	1.06 ± 0.03f	15.76 ± 1.18 l	0.11 ± 0.01e	0.14 ± 0.01b	0.11 ± 0.03c	99.85
T6	55.4 ± 1.17ef	5.57 ± 0.07i	0.35 ± 0.01ef	1.62 ± 0.09 h	72.72 ± 0.56e	1.14 ± 0.01e	18.05 ± 0.98i	0.14 ± 0.03d	0.10 ± 0.01	0.11 ± 0.07c	99.80
T7	54.4 ± 1.21 g	7.34 ± 0.03c	0.46 ± 0.09d	1.98 ± 0.11e	62.43 ± 0.74j	1.21 ± 0.09e	26.36 ± 1.32c	0.10 ± 0.01e	—	—	99.89
T8	55.8 ± 1.11ef	6.64 ± 0.15f	0.52 ± 0.11c	1.58 ± 0.17 h	71.62 ± 0.89f	1.41 ± 0.07b	17.64 ± 1.35j	0.10 ± 0.03e	0.08 ± 0.01 g	0.08 ± 0.01f	99.67
T9	53.3 ± 1.09 h	5.49 ± 0.11i	0.33 ± 0.01 g	1.61 ± 0.07 h	73.48 ± 0.81d	1.12 ± 0.05e	17.33 ± 0.67j	0.10 ± 0.01e	0.11 ± 0.03d	0.10 ± 0.03d	99.68
T10	54.6 ± 2.56 g	6.92 ± 0.07d	0.35 ± 0.03 g	1.63 ± 0.05 h	66.75 ± 0.93 h	1.16 ± 0.11e	22.21 ± 0.86f	0.07 ± 0.01 g	0.10 ± 0.01e	0.10 ± 0.01d	99.29
T11	44.3 ± 1.78 m	6.64 ± 0.21f	0.63 ± 0.13a	2.01 ± 0.27d	70.78 ± 0.67 g	1.35 ± 0.17c	17.85 ± 0.71j	0.10 ± 0.03e	0.11 ± 0.05d	0.09 ± 0.01e	99.56
T12	36.7 ± 0.87ö	7.49 ± 0.18ab	0.46 ± 0.09d	1.85 ± 0.18f	62.88 ± 0.82j	1.20 ± 0.19e	25.60 ± 1.29d	0.08 ± 0.01f	0.09 ± 0.01f	0.07 ± 0.01 g	99.71
T13	55.6 ± 1.61ef	6.52 ± 0.15f	0.30 ± 0.07 g	2.32 ± 0.21b	63.93 ± 0.98i	0.91 ± 0.03 g	25.55 ± 0.89d	0.08 ± 0.01f	0.12 ± 0.03c	0.08 ± 0.01f	99.80
T14	44.5 ± 0.55 m	5.44 ± 0.21i	0.39 ± 0.03e	1.89 ± 0.11f	75.49 ± 0.54b	1.10 ± 0.07e	14.82 ± 0.75 m	—	0.09 ± 0.01f	0.09 ± 0.03e	99.31
T15	57.3 ± 0.61d	6.06 ± 0.16 g	0.34 ± 0.01 g	1.57 ± 0.13 h	72.60 ± 0.39e	1.13 ± 0.13e	18.03 ± 0.68i	—	0.10 ± 0.03e	0.10 ± 0.03d	99.92
T16	44.5 ± 0.83 m	5.85 ± 0.09hf	0.33 ± 0.05 g	1.76 ± 0.32 g	65.68 ± 0.43i	1.12 ± 0.15e	24.77 ± 1.27e	0.14 ± 0.05d	0.10 ± 0.03e	0.10 ± 0.01d	99.85
T17	53.2 ± 0.78 h	5.73 ± 0.07i	0.35 ± 0.07 g	2.26 ± 0.21c	71.78 ± 0.48f	0.95 ± 0.03 g	18.49 ± 1.13i	0.08 ± 0.03f	0.11 ± 0.07d	0.08 ± 0.01f	99.84
T18	44.4 ± 0.96 m	6.67 ± 0.14e	0.52 ± 0.09c	1.74 ± 0.27 g	69.19 ± 0.51 h	1.28 ± 0.07d	20.33 ± 1.19 h	—	0.11 ± 0.01d	0.08 ± 0.03f	99.90
T19	59.7 ± 1.33d	6.58 ± 0.21e	0.50 ± 0.05c	1.89 ± 0.18f	69.01 ± 0.37 h	1.28 ± 0.03d	20.42 ± 1.32 h	0.06 ± 0.01 g	0.09 ± 0.03f	0.08 ± 0.03f	99.91
T20	63.5 ± 1.27c	6.21 ± 0.17 g	0.52 ± 0.03c	2.09 ± 0.21d	67.42 ± 0.73 g	1.27 ± 0.05d	22.23 ± 1.56f	—	0.10 ± 0.05e	0.08 ± 0.03f	99.92
T21	56.1 ± 1.16e	5.37 ± 0.13i	0.41 ± 0.07d	2.08 ± 0.13d	74.14 ± 0.69c	1.06 ± 0.01f	16.65 ± 1.63 k	—	0.11 ± 0.01d	0.09 ± 0.01e	99.91
T22	59.6 ± 1.18d	6.90 ± 0.19d	0.52 ± 0.13c	2.02 ± 0.17d	70.11 ± 0.81 g	1.29 ± 0.07d	18.86 ± 0.58i	—	0.12 ± 0.03c	0.08 ± 0.03f	99.90
T23	52.1 ± 1.56i	5.31 ± 0.22i	0.29 ± 0.03 h	1.80 ± 0.19f	74.23 ± 0.48c	0.97 ± 0.03d	17.13 ± 0.27j	—	0.09 ± 0.01f	0.09 ± 0.01e	99.91
T24	50.2 ± 0.77i	7.37 ± 0.05c	0.63 ± 0.11a	1.09 ± 0.07i	68.07 ± 0.54f	1.57 ± 0.09a	20.90 ± 0.38 h	0.08 ± 0.01f	0.11 ± 0.03d	0.09 ± 0.03e	99.90
T25	52.6 ± 0.68i	7.12 ± 0.03 cd	0.55 ± 0.03b	2.72 ± 0.05a	62.83 ± 0.72j	1.19 ± 0.03d	25.41 ± 0.46d	—	0.11 ± 0.01d	—	99.92
T26	56.7 ± 0.94e	5.91 ± 0.17 h	0.31 ± 0.05 g	2.25 ± 0.03c	69.29 ± 0.84 h	0.93 ± 0.07 g	21.30 ± 0.75 g	—	—	—	100.00
T27	79.0 ± 2.71a	6.91 ± 0.32d	0.48 ± 0.01d	1.99 ± 0.11e	69.74 ± 0.43 h	1.24 ± 0.05d	19.53 ± 0.36i	—	0.11 ± 0.03d	—	100.00
T28	54.8 ± 1.32 g	6.93 ± 0.18d	0.60 ± 0.13ab	1.70 ± 0.09 g	63.78 ± 0.48i	1.41 ± 0.06b	25.34 ± 1.43d	—	0.07 ± 0.01 h	0.07 ± 0.01 g	99.91
T29	53.8 ± 1.19 h	7.01 ± 0.34 cd	0.46 ± 0.03d	2.50 ± 0.21b	64.58 ± 0.51i	1.09 ± 0.03f	24.07 ± 1.38e	—	0.13 ± 0.05c	0.08 ± 0.01f	99.92
T30	67.4 ± 2.58b	5.97 ± 0.13 h	0.42 ± 0.03d	1.78 ± 0.27 g	71.25 ± 0.67f	1.21 ± 0.07d	19.01 ± 0.85i	0.05 ± 0.01 h	0.11 ± 0.01d	0.10 ± 0.03d	99.91
T31	57.6 ± 1.53d	5.85 ± 0.09hf	0.37 ± 0.01 g	1.66 ± 0.18 h	73.36 ± 0.86d	1.13 ± 0.09e	17.25 ± 0.77j	0.08 ± 0.01f	0.11 ± 0.03d	0.10 ± 0.01d	99.91

*Standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$; ***nonidentified

Statistical analysis

All the treatments and measurements were replicated three times and the data was subjected to analysis of variance (ANOVA) using the MSTAT C software (Püskülcü and İkiz 1989). The results were presented as mean $\pm$ standard deviation and significance was considered at the probability level of 0.05. Principle component analysis was performed using MULTBILOT software as described previously (Vicente-Villardón 2010)

Results and discussion

The oil percentage and fatty acid composition of almond kernels collected from thirty-one genotype of naturally growing almond trees in Mersin province, Turkey are given in Table 1. The results showed high variations in oil contents and fatty acid profiles among almond genotype ($P < 0.05$). The highest oil content was noticed in the kernel of the cultivar T27 (79%) whereas the lowest value was observed in the cultivar T12 (36.7%). With exception of the genotype T1, T2, T3, T4, T5, T11, T12, T14, T16, and T18, the oil content of all other almond cultivars was higher than 50% suggesting that these almond genotypes are rich sources of vegetable oil. The commercial production of oil from *Prunus* genus is possibly due to its higher oil yields compared to other commercially used oilseeds such as rapeseed and sunflower seeds (Aşkın et al. 2007). The oil contents found in this study are comparable to those reported previously in different almond species (44.4% in *A. Scoparia* and 51.4% in *A. dulcis* (Moayedi et al. 2011). In another study, Kırbaşlar et al. (2012) reported that almond kernel contained 55.86% oil. In addition, Sathe et al. (2008) reported that almond kernels collected from 12 different locations contained 52.51–61.92% oil. Moreover, Martins et al. (2000) stated that the oil of 12 kinds of almond in Portugal ranged between 30.01 and 51%. The cultivation of almond genotypes is restricted to areas with hot and dry conditions where almond trees produce the highest yields of high-quality kernels (Rabadan et al. 2018). Rabadan et al. (2018) reported that although significant variability was reported in almond oils as a result of the crop year and the interaction between crop year and genotype. The variability in the content of oil in nuts was lower than for previous components; but, it was higher in almonds than walnuts and pistachios. The genotypes were considered for the nuts as the main source of variability for this parameter (Rabadan et al. 2019). Apparently the variation in oil contents between these studies could be attributed to the differences in almond genotype, growing conditions, and environmental factors. Zhu et al. (2015) stated that the

humid depressed almond kernel lipid synthesis regardless of the imposed deficit treatment. In addition, in average season like that 2011/2012, with generally higher lipid content, moderate water deficiency was not detrimental to almond lipid content but severe deficit irrigation was (Zhu et al. 2015).

The fatty acids profiles also differed significantly ($p < 0.05$) among the almond genotype. The major fatty acid in almond genotypes was oleic (62.43% in T8 to 76.34% in T4), followed by linoleic (13.97% in T4 to 29.55% in T3), and palmitic (4.97% in T2 to 7.51 in T3), whereas the lowest proportion was found for arachidic acid (0.07% in T28 to 0.15% in T2). The palmitic, palmitoleic, stearic, oleic, vaccenic, and linoleic acids were observed in all almond cultivars with different quantities, whereas, linolenic, arachidic and eicosenoic acids were not detected in some genotypes. These findings suggested that the fatty acid composition of almond oil depends mainly on the genotype as all these genotypes were collected from same location. Previous studies indicated that fatty acid composition of almond differed among genotype and growing environments. It was observed statistically significant differences among fatty acid compositions of almond kernel oils ($p < 0.05$). Kırbaşlar et al. (2012) studied the fatty acid compositions of the almond oil and found palmitic (0.39%), palmitoleic (0.56%), stearic (1.20%), oleic (71.98%), linoleic (20.37%) acids as the main fatty acids in almond oil. In addition, Sathe et al. (2008) reported that oleic acid content of eight almond genotype varied between 57.54% and 73.94%. The oleic acid content in almond oils in the current study was in agreement with those reported previously by Maguire et al. (2004) and Mehran and Filsoof (1974) for different types of commercially available almonds. Piscopo et al. (2010) reported the presence of higher oleic and lower linoleic acid in an almond variety in the month of August. The oleic acid content of some of the of almond species have been reported to be in between 66.7 and 69.7%, and the linoleic acid content has been detected in the range of 18.2–23.0% (Moayedi et al. 2011). Karatay et al. (2014) reported 74.46% oleic, 0.70% palmitoleic, 17.89% linoleic, 5.34% palmitic, 0.85% stearic and 0.75% linolenic acid as an average of a total of 32 different almond varieties. The presence of oleic (72.5–79.9%), linoleic (13.5–19.8%) and palmitic (5.9–6.7%) acids have been reported in different cultivars of almonds (Özcan et al. 2011). In another report about different cultivars of almond oils, oleic contents ranged between 50.41 and 81.20%, linoleic between 6.21 and 37.13%, palmitic between 5.46 and 15.78%, stearic 0.80 and 3.83% and palmitoleic between 0.36 and 2.52% (Aşkın et al. 2007). The oleic acid contents have been reported to be 60.9%, 62.9% and 61.0% in different studies carried out with domestically used almonds. Still higher oleic acid contents

have been reported by Nanos et al. (2002) (72–80%) and Kodad et al. (2008) (69–78%) for domestically used kernels. Karatay et al. (2014) reported that average palmitic, palmitoleic, stearic, oleic, linoleic and linolenic acid amounts of 32 almond oils were found 5.34%, 0.70%, 0.85%, 74.46%, 17.89% and 0.75%, respectively. Rabadán et al. (2017) determined 5.87–7.64% palmitic, 0.54–0.86% palmitoleic, 1.97–3.21% stearic, 48.19–56.88% oil, 65.37–72.99% oleic, 16.90–23.54% linoleic acids in almond kernels. Zhu et al. (2015) determined 48.99–54.55% and 50.64–57.32% oil, 6.76–7.04% and 6.80–7.60% palmitic, 61.85–62.80% and 57.13–64.30% oleic and 25.32–26.09% and 24.03–30.23% linoleic acids in the oils of almonds collected in 2010/2011 and 2011/2012 harvest seasons, respectively. The almond oil fatty acid compositions do not vary widely such as for the results about *A. scorparia* almond oils as reported by Farhoosh and Tavakoli (2008). Different type of reports about oils obtained from almond kernels pointed out that the oleic and linoleic acids are the predominant fatty acids in almond oils. There is a wide variation in fatty acid composition of oils obtained from different almond seeds and the presence of some characteristic fatty acids can help in differentiating different plant species and their respective families (Aitzetmuller 1993). There are various factors that can affect the fatty acid composition of oils obtained from different almond seeds and these factors include species, variety, cultivation and climatic conditions, and the harvesting time and conditions (Kritsakis and Markakis 1984). Rabadán et al. (2017) reported that almond oil yield was similar for all the selected 10 cultivars, and significant differences were observed in fatty acid profile, including essential fatty acids of main nutritional interest. Linoleic acid contents illustrate high variability (13.97–29.55%), becoming a parameter of main nutritional interest as it is the main essential fatty acid found in almond oil. On the other hand, stearic and palmitic acids are the most common saturated fatty acids in almond oil, with percentages in our samples below 2.72 and 7.11%, respectively. Rabadán et al. (2017) reported that the nutritional value of almond oil is highly influenced by the high presence of unsaturated fatty acids and although all cultivars show a health fatty acid profile. Nanos et al. (2002) reported that oleic acid levels were higher in irrigated than non-irrigated almonds (Ferragnes and Texas cv).

The results in Table 2 show the tocopherol contents in 31 almond genotypes. The results showed significant variations in tocopherol contents and composition among almond genotype. The total tocopherols content was ranged between 47.42 mg/100 g in T14 and 80.15 mg/100 g in T16. Among all detected tocopherols, α -tocopherol was the highest (44.25 mg/100 g in T5 to 75.56 mg/100 g in T13), followed by γ -tocopherol (0.63 mg/100 g in T10 to

7.51 mg/100 g in T20). With few exceptions, most of the almond kernel oils were found to have more than 50.0% of the α -tocopherol contents. α -Tocotrienol contents of almond oils varied between 0.44 mg/100 g (T22) and 1.35 mg/100 g (T28). β -tocopherol contents of almond oils were varied between 0.48 mg/100 g (T31) and 1.73 mg/100 g (T26). γ -Tocotrienol contents (0.23 and 0.46 mg/100 g) were found in only T17 and T27 almond oil, while δ -tocopherol (0.24 mg/100 g) was found only in T27 almond oil. It was observed statistically significant differences were observed among tocopherol contents of almond kernel oils ($p < 0.05$). Several researchers have also reported similar ranges of tocopherols in almond oils from different locations (Sathe et al. 2008; Moayedi et al. 2011; Gupta et al. 2012). The concentration of α -tocopherols was reported between 187 and 490 g/kg of almond oil (Kodad 2017). The range of variability for the different tocopherol homologues is of 335–657 mg/kg of almond oil for α -, 2–50 for γ -, and 0.1–22 for β -tocopherol (Kodad et al. 2018). Almond oil contained 97.3 mg/kg α -tocopherol and 2.8 mg/kg γ -tocopherol as reported by Fernandes et al. (2017). In another study by Lopez Ortiz et al. (2006), the α , γ and γ -tocopherol have been detected in the ranges of 23.5–44.9, 2.90–6.15 and 1.27–8.06 mg/100 g, respectively. Kornsteiner et al. (2006) reported that almond oil had 24.2 mg/100 g α -tocopherol content. According to Kodad et al. (2006), concentration of α -tocopherol in almond oil varied between 187 and 490 mg/kg of oil. The higher content of α - and γ -tocopherol contents in the almond oil could likely enhanced the oil resistance to oxidation because tocopherols can helps to protect the peroxidation of polyunsaturated fatty acids (Beringer and Dompert 1976; Kamal-Eldin and Andersson 1977). The oil products having higher amount of fatty acids and tocopherols are considered good from the health point of view (Oomah et al. 2000). Kodad et al. (2008) reported that environmental factors like temperature have significant effects on the concentration of tocopherols in almond. It is thought that higher concentration of tocopherols in almond oil helps its long term storage with no adverse effects on the quality of oil (Filsoof et al. 1976; Garcia-Pascual et al. 2003). One of the parameters greatly affected by genotype, crop year and the interaction of both was the energy value of nuts (Rabadan et al. 2019).

Mineral contents of 31 almond samples collected from Mersin province, Turkey are presented in Table 3. Significant variations in mineral contents and composition were observed among several almond genotype suggesting the influence of genetic makeup on the mineral composition of almond kernels. Noticeably, there are big variations in the macro and trace mineral content in almond genotypes. Among macro minerals, potassium (5238 mg/kg in T6–14,683 mg/kg in T27) represent the highest followed

Table 2 Tocopherol contents of different almond type kernel oils (mg/100 g)

Almonds	α -tocopherol	α -tocotrienol	β -tocopherol	γ -tocopherol	β -tocotrienol	P8	γ -tocotrienol	δ -tocopherol	Total
T1	56.94 $\pm$ 0.67 ^{*i}	0.52 $\pm$ 0.09 ⁱ	0.74 $\pm$ 0.03 h	3.33 $\pm$ 0.37c	0.61 $\pm$ 0.03 g	–	–	–	62.15
T2	49.79 $\pm$ 0.81 ^{**}	0.65 $\pm$ 0.05g	0.82 $\pm$ 0.09g	1.08 $\pm$ 0.19f	2.94 $\pm$ 0.11a	–	–	–	55.28
T3	62.54 $\pm$ 0.47fg	1.10 $\pm$ 0.13d	0.87 $\pm$ 0.01g	5.00 $\pm$ 0.21b	2.68 $\pm$ 0.18b	1.27 $\pm$ 0.13a	–	–	73.46
T4	47.18 $\pm$ 0.24m	0.75 $\pm$ 0.09g	0.90 $\pm$ 0.13f	1.37 $\pm$ 0.15ef	0.15 $\pm$ 0.03i	0.38 $\pm$ 0.05 h	–	–	50.74
T5	44.25 $\pm$ 0.32n	1.01 $\pm$ 0.07d	1.12 $\pm$ 0.09e	1.07 $\pm$ 0.09f	0.32 $\pm$ 0.07i	0.50 $\pm$ 0.09f	–	–	48.26
T6	44.95 $\pm$ 0.51n	0.45 $\pm$ 0.01i	0.80 $\pm$ 0.07 g	0.96 $\pm$ 0.13 g	0.58 $\pm$ 0.09 h	–	–	–	47.74
T7	59.93 $\pm$ 0.63h	0.66 $\pm$ 0.03g	1.27 $\pm$ 0.03cd	2.48 $\pm$ 0.32d	2.28 $\pm$ 0.17c	–	–	–	66.61
T8	48.94 $\pm$ 0.88lm	0.83 $\pm$ 0.11f	1.26 $\pm$ 0.09 cd	1.21 $\pm$ 0.19ef	1.51 $\pm$ 0.21e	0.31 $\pm$ 0.03i	–	–	54.06
T9	50.68 $\pm$ 0.76kl	0.53 $\pm$ 0.07 h	0.91 $\pm$ 0.07f	2.09 $\pm$ 0.27de	1.82 $\pm$ 0.23d	–	–	–	56.03
T10	51.11 $\pm$ 0.62k	0.69 $\pm$ 0.03g	1.01 $\pm$ 0.03e	0.63 $\pm$ 0.03h	1.12 $\pm$ 0.18f	–	–	–	54.56
T11	60.58 $\pm$ 0.54g	0.72 $\pm$ 0.09g	1.33 $\pm$ 0.17c	2.49 $\pm$ 0.11d	– ^{***}	–	–	–	65.12
T12	68.63 $\pm$ 0.29e	0.90 $\pm$ 0.12e	1.23 $\pm$ 0.19cd	2.55 $\pm$ 0.33d	–	–	–	–	73.32
T13	75.56 $\pm$ 0.31a	0.68 $\pm$ 0.11g	1.10 $\pm$ 0.03e	2.31 $\pm$ 0.28d	–	0.28 $\pm$ 0.01j	–	–	79.92
T14	44.72 $\pm$ 0.47n	0.83 $\pm$ 0.17f	0.84 $\pm$ 0.15g	0.67 $\pm$ 0.09 h	–	0.36 $\pm$ 0.03h	–	–	47.42
T15	69.84 $\pm$ 0.98dg	0.80 $\pm$ 0.15f	1.02 $\pm$ 0.09e	3.02 $\pm$ 0.42c	–	–	–	–	74.67
T16	74.38 $\pm$ 0.77b	1.15 $\pm$ 0.09c	1.62 $\pm$ 0.21b	2.31 $\pm$ 0.19d	–	0.68 $\pm$ 0.05d	–	–	80.15
T17	60.19 $\pm$ 0.69g	0.88 $\pm$ 0.13f	1.20 $\pm$ 0.18 cd	1.36 $\pm$ 0.21ef	–	0.27 $\pm$ 0.09k	0.23 $\pm$ 0.07b	–	64.13
T18	58.61 $\pm$ 0.81n	0.58 $\pm$ 0.07 h	1.28 $\pm$ 0.13cd	1.62 $\pm$ 0.27e	–	–	–	–	62.09
T19	54.64 $\pm$ 0.95j	0.95 $\pm$ 0.19e	0.52 $\pm$ 0.09i	1.07 $\pm$ 0.09f	–	–	–	–	57.19
T20	56.34 $\pm$ 0.47i	1.16 $\pm$ 0.07c	1.23 $\pm$ 0.07cd	7.51 $\pm$ 0.39a	–	0.28 $\pm$ 0.03j	–	–	66.81
T21	54.19 $\pm$ 0.27j	0.64 $\pm$ 0.03 g	1.20 $\pm$ 0.03cd	1.79 $\pm$ 0.25e	–	0.22 $\pm$ 0.07l	–	–	58.05
T22	53.24 $\pm$ 0.13jk	0.44 $\pm$ 0.03i	1.50 $\pm$ 0.11b	2.23 $\pm$ 0.17d	–	–	–	–	57.40
T23	61.34 $\pm$ 0.38g	0.76 $\pm$ 0.09 g	1.37 $\pm$ 0.09c	1.00 $\pm$ 0.09f	–	0.81 $\pm$ 0.09b	–	–	65.28
T24	57.08 $\pm$ 0.17i	0.47 $\pm$ 0.01i	0.96 $\pm$ 0.03f	2.78 $\pm$ 0.18d	–	0.73 $\pm$ 0.07c	–	–	62.01
T25	63.55 $\pm$ 0.21f	0.67 $\pm$ 0.03 g	0.64 $\pm$ 0.15i	5.23 $\pm$ 0.46b	–	0.26 $\pm$ 0.03f	–	–	70.34
T26	70.69 $\pm$ 0.28c	0.94 $\pm$ 0.15e	1.73 $\pm$ 0.27a	2.17 $\pm$ 0.38d	–	0.50 $\pm$ 0.03f	–	–	76.03
T27	69.30 $\pm$ 0.43d	1.18 $\pm$ 0.13b	1.20 $\pm$ 0.18cd	3.15 $\pm$ 0.23c	–	0.45 $\pm$ 0.01g	0.46 $\pm$ 0.03a	0.24 $\pm$ 0.03	75.97
T28	64.92 $\pm$ 0.86f	1.35 $\pm$ 0.17a	0.59 $\pm$ 0.07i	5.14 $\pm$ 0.38b	–	0.62 $\pm$ 0.09e	–	–	72.62
T29	62.24 $\pm$ 0.84fg	0.70 $\pm$ 0.09 g	0.79 $\pm$ 0.11h	0.83 $\pm$ 0.03g	–	0.60 $\pm$ 0.07e	–	–	65.16
T30	45.62 $\pm$ 0.57mn	0.54 $\pm$ 0.03 h	0.68 $\pm$ 0.09i	1.55 $\pm$ 0.11e	–	0.31 $\pm$ 0.01i	–	–	48.70
T31	45.59 $\pm$ 0.65mn	0.58 $\pm$ 0.07 h	0.48 $\pm$ 0.03i	1.11 $\pm$ 0.07f	–	0.50 $\pm$ 0.09f	–	–	48.26

*Standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$; ***nonidentified

Table 3 Mineral contents of different almond type kernels (mg/kg)

Almonds	Al	Ca	B	Cr	Cu	Fe	K
T1	8.6 ± 0.3*k	2485 ± 261	13.0 ± 0.2h	0.34 ± 0.02f	13.0 ± 1.3f	41.0 ± 1.2 m	7798 ± 169de
T2	12.7 ± 0.1g**	2292 ± 140	13.9 ± 1.1h	0.34 ± 0.05f	13.2 ± 1.1f	39.7 ± 1.6ö	7574 ± 74ef
T3	12.5 ± 0.0g	3940 ± 29	14.6 ± 0.5g	0.33 ± 0.01f	11.0 ± 0.0h	45.7 ± 0.3j	7692 ± 52e
T4	10.9 ± 0.9i	2216 ± 134	19.1 ± 0.3c	0.39 ± 0.02f	11.2 ± 1.1h	39.3 ± 2.8ö	7402 ± 5f
T5	9.3 ± 0.9j	3286 ± 150	17.1 ± 1.1d	0.29 ± 0.01g	13.0 ± 0.6f	34.7 ± 2.2 s	9324 ± 57b
T6	8.4 ± 1.0k	2866 ± 186	12.4 ± 0.9i	0.36 ± 0.02f	12.2 ± 1.4g	40.3 ± 3.7n	5238 ± 132 m
T7	8.8 ± 0.3k	2585 ± 175	11.8 ± 0.0i	0.47 ± 0.08c	14.8 ± 0.8e	41.5 ± 1.8 m	7082 ± 43g
T8	8.8 ± 0.7k	2148 ± 122	14.4 ± 0.3g	0.32 ± 0.04f	14.4 ± 0.6e	37.4 ± 0.9p	6777 ± 81g
T9	14.4 ± 0.4e	2637 ± 22	16.9 ± 0.1e	0.49 ± 0.11c	17.0 ± 0.0b	46.4 ± 1.4i	6200 ± 1i
T10	16.7 ± 0.0c	2612 ± 150	11.1 ± 0.4i	0.51 ± 0.08b	16.7 ± 0.1c	64.8 ± 5.6d	6336 ± 42i
T11	28.0 ± 1.6a	3092 ± 80	15.1 ± 1.0f	0.46 ± 0.05d	13.9 ± 0.5f	42.7 ± 2.3i	7124 ± 347 fg
T12	13.1 ± 0.8f	2695 ± 236	20.3 ± 1.2b	0.41 ± 0.07e	11.8 ± 0.8h	44.2 ± 1.7k	5704 ± 350l
T13	13.2 ± 0.7f	3307 ± 191	21.9 ± 0.9a	0.41 ± 0.04e	11.6 ± 0.7h	39.0 ± 1.5ö	6743 ± 307g
T14	9.3 ± 0.7j	4252 ± 95	16.1 ± 0.8e	0.37 ± 0.01f	9.8 ± 0.4j	39.2 ± 0.4ö	7987 ± 282 cd
T15	12.4 ± 0.2g	2021 ± 36	10.6 ± 0.4j	0.34 ± 0.02f	14.0 ± 0.2e	45.6 ± 1.2j	7167 ± 130 fg
T16	12.0 ± 1.2g	3118 ± 206	6.8 ± 0.1l	0.27 ± 0.02g	12.9 ± 0.4g	42.1 ± 1.2l	6763 ± 74g
T17	14.2 ± 1.0e	3490 ± 38	16.6 ± 0.1e	0.40 ± 0.0e7	15.1 ± 0.3d	48.1 ± 3.0g	7613 ± 303e
T18	8.0 ± 1.1k	3770 ± 120	12.8 ± 0.7i	0.21 ± 0.02i	10.4 ± 0.3i	52.8 ± 5.3f	8072 ± 194d
T19	12.6 ± 0.2g	3739 ± 200	14.4 ± 0.7g	0.45 ± 0.04c	12.5 ± 1.1g	47.2 ± 1.1h	7929 ± 404 cd
T20	8.9 ± 0.1k	2590 ± 3	11.0 ± 1.2i	0.41 ± 0.02e	15.2 ± 0.1d	42.8 ± 1.8l	6404 ± 91h
T21	15.1 ± 0.5d	2946 ± 53	12.9 ± 0.0i	0.43 ± 0.04c	9.4 ± 0.1j	56.9 ± 2.0e	6691 ± 104gh
T22	12.8 ± 1.1g	2037 ± 144	4.6 ± 0.1n	0.41 ± 0.01e	10.5 ± 0.5i	36.9 ± 4.0r	7536 ± 34ef
T23	12.8 ± 0.2g	2754 ± 37	6.1 ± 0.5l	0.19 ± 0.01h	13.7 ± 0.1f	95.0 ± 1.2a	6083 ± 71k
T24	10.7 ± 0.3i	1798 ± 133	12.4 ± 1.0i	0.32 ± 0.03f	15.9 ± 0.9d	40.8 ± 0.1n	6243 ± 14j
T25	17.8 ± 4.0b	2504 ± 128	5.7 ± 0.7 m	0.41 ± 0.07e	13.7 ± 0.2f	47.4 ± 2.3h	9154 ± 130b
T26	17.3 ± 5.6b	3493 ± 229	4.6 ± 0.6n	0.40 ± 0.04e	13.2 ± 0.1	47.9 ± 1.8h	6744 ± 622g
T27	15.7 ± 0.1d	5946 ± 21	15.0 ± 0.3f	0.58 ± 0.02a	26.6 ± 0.2a	70.9 ± 0.2c	14,683 ± 69a
T28	8.3 ± 1.0k	2538 ± 33	10.2 ± 0.8	0.31 ± 0.04f	17.5 ± 1.6b	37.8 ± 4.1p	7626 ± 487e
T29	11.6 ± 0.4h	1906 ± 93	8.8 ± 0.5j	0.38 ± 0.02f	9.2 ± 0.8j	44.0 ± 4.4k	7539 ± 425ef
T30	7.0 ± 0.6l	1970 ± 62	7.8 ± 0.4k	0.27 ± 0.03g	8.6 ± 0.0k	37.4 ± 2.8p	6254 ± 327j
T31	9.3 ± 0.1j	2040 ± 17	7.0 ± 0.6k	0.45 ± 0.04c	6.6 ± 0.2l	83.5 ± 4.1b	8494 ± 562c
Almonds	Mg	Mn	Na	P	S	Zn	
T1	2514 ± 40	11.4 ± 0.2f	563 ± 7d	4507 ± 42l	1232 ± 23d	51.1 ± 0.9b	
T2	2502 ± 29b	15.4 ± 1.0b	632 ± 41c	5621 ± 465c	1338 ± 32c	47.6 ± 0.8d	
T3	2631 ± 15b	14.9 ± 0.2c	710 ± 5b	5848 ± 77b	1332 ± 1c	48.3 ± 0.1 cd	
T4	2572 ± 33b	15.9 ± 0.1b	530 ± 40d	5185 ± 30h	1378 ± 11c	39.3 ± 2.1j	
T5	2442 ± 8c	15.3 ± 0.1b	527 ± 17d	5163 ± 437h	1345 ± 11c	37.1 ± 1.2k	
T6	2338 ± 68d	8.0 ± 0.5i	555 ± 53d	4458 ± 170 m	975 ± 27g	32.9 ± 2.9n	
T7	2395 ± 59d	6.9 ± 0.3k	630 ± 42c	5506 ± 101d	871 ± 6j	36.6 ± 0.1lm	
T8	2473 ± 34c	9.7 ± 0.2h	489 ± 47e	5975 ± 109a	908 ± 21i	37.8 ± 1.9k	
T9	2424 ± 10c	7.0 ± 0.1j	527 ± 5d	5118 ± 20h	1210 ± 19	39.5 ± 0.2j	
T10	2384 ± 3d	10.1 ± 0.3g	540 ± 23d	4596 ± 229l	1256 ± 46d	37.7 ± 0.1k	
T11	2279 ± 81e	10.5 ± 0.2g	556 ± 52d	5517 ± 464d	1113 ± 79e	38.0 ± 1.4jk	
T12	2546 ± 91b	9.0 ± 0.0h	535 ± 29d	5098 ± 357i	1221 ± 52d	42.1 ± 1.7g	
T13	2462 ± 70c	10.9 ± 0.5g	539 ± 22d	5968 ± 179a	1178 ± 60e	38.0 ± 1.9l	
T14	2234 ± 61e	12.3 ± 0.0e	525 ± 5d	5981 ± 191a	1469 ± 48b	46.5 ± 0.2e	
T15	2510 ± 34b	6.2 ± 0.1k	484 ± 9f	5103 ± 139h	936 ± 17h	35.1 ± 0.4lm	
T16	2293 ± 9e	11.9 ± 1.4f	678 ± 14c	4642 ± 16k	1114 ± 0e	42.2 ± 2.5g	

Table 3 continued

Almonds	Mg	Mn	Na	P	S	Zn
T17	2356 ± 33d	8.8 ± 1.2i	709 ± 14b	5824 ± 318b	1531 ± 12ab	48.2 ± 2.0 cd
T18	2383 ± 52d	12.7 ± 0.4e	334 ± 10f	5213 ± 185g	1046 ± 36f	42.0 ± 0.7g
T19	2319 ± 46d	15.0 ± 0.2b	572 ± 17d	5101 ± 431h	1060 ± 40f	41.5 ± 0.1h
T20	2435 ± 56c	6.5 ± 0.5k	527 ± 41d	5353 ± 79f	1066 ± 23f	42.3 ± 0.4g
T21	2564 ± 39b	13.8 ± 0.3d	562 ± 9d	5843 ± 129b	1137 ± 11e	47.9 ± 0.6d
T22	2192 ± 9f	6.5 ± 0.4k	542 ± 14d	5894 ± 11b	1152 ± 0e	39.1 ± 4.8j
T23	2508 ± 34b	10.7 ± 0.2g	349 ± 4f	4755 ± 105j	1346 ± 28c	40.7 ± 0.4i
T24	2474 ± 22c	12.9 ± 0.8e	522 ± 42d	5511 ± 116d	1562 ± 24a	42.0 ± 0.2g
T25	2437 ± 11c	15.7 ± 1.9b	520 ± 20d	5483 ± 39e	1238 ± 39d	49.5 ± 0.9c
T26	2324 ± 36d	10.2 ± 1.0g	643 ± 17c	5397 ± 420f	1274 ± 80d	40.3 ± 2.9i
T27	3591 ± 29a	24.7 ± 0.0a	786 ± 5a	11,123 ± 127	2594 ± 23a	87.4 ± 0.4a
T28	2332 ± 74d	12.6 ± 1.9e	532 ± 12d	5357 ± 145f	1423 ± 18b	47.2 ± 3.7d
T29	2448 ± 65c	10.6 ± 0.7g	526 ± 11d	5910 ± 463a	1441 ± 23b	47.2 ± 4.5d
T30	2440 ± 17c	8.6 ± 0.6i	561 ± 37d	5419 ± 244e	1265 ± 22d	43.3 ± 3.6f
T31	2585 ± 80b	12.1 ± 1.3e	636 ± 92c	3475 ± 314n	1275 ± 40d	41.2 ± 0.9h

*Standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$

by phosphorous (3475 mg/kg in T31–11,123 mg/kg in T27), calcium (1798 mg/kg in T24–5946 mg/kg in T27) and magnesium (2192 mg/kg in T22–3591 mg/kg in T27), whereas sodium showed the lowest content (334 mg/kg in T18–786 mg/kg in T27). Among the trace minerals, zinc (32.9 mg/kg in T6–87.4 mg/kg in T27) was the major mineral in almond kernel, followed by iron (34.7 mg/kg in T5–83.5 mg/kg in T31), aluminum (7.0 mg/kg in T30–28.0 mg/kg in T11), copper (6.6 mg/kg in T31–26.6 mg/kg in T27), and manganese (6.2 mg/kg in T15–24.7 mg/kg in T27), while, chromium (0.19 mg/kg in T23–0.58 mg/kg in T27) was found as the least trace mineral in almond kernel. Interestingly, with view exceptions, the cultivar T27 outscores all other genotypes in quantity of most minerals indicating that the kernel of this cultivar is of great importance from nutritional stand point. It was observed statistically significant differences were observed among mineral contents of almond kernels ($p < 0.05$). Özcan et al. (2011) reported that some almond kernels contained 2.98–4.04 mg/g Mg, 0.29–0.38 mg/g Na, 7.93–9.38 mg/gP, 13.14–15.10 mg/g K, 1.83–2.94 mg/g Ca, 0.20–0.27 mg/g Fe and 0.04–0.06 mg/g Zn. In a previous study, almond kernels contained 1546–1685 mg/100 g K, 253–259 mg/100 g P, 640–678 mg/100 g Ca, 447–496 mg/100 g Mg, 24.30–25.80 mg/100 g Cu, 76.33–80.50 mg/100 g Zn, 54.83–65.33 mg/100 g Fe and 37.67–37.83 mg/100 g Mn (Barbara et al. 1994). Aslantas et al. (2001) reported values of 98.5–187.00 mg/100 g Ca, 360.8–513.4 mg/100 g Mg, 403.9–800 mg/100 g P,

1677.3–2051.1 mg/100 g K, 39.77–146.35 mg/100gFe, 77.86–88.44 mg/100 g Zn, 29.0–33.95 mg/100gMn, 16.0–23.0 mg/100 g Cu and 56.66–103.88 mg/100 g Na in selected almond cultivars naturally grown in Kemaliye district of Erzincan in Turkey. Schirra et al. (1994) determined 1050 mg/100 g K, 300 mg/100 g P, 467 mg/100 g Ca, 30 mg/100 g Mg, 5 ppm Cu 34 ppm Zn and 70 ppm Fe in Texas almonds during fruit growth and ripening. Significant differences were observed in the mineral composition of almonds by several researchers (Saura Calixto et al. 1981; Özcan et al. 2011). The difference in mineral contents and composition between the almond fruits may be due to the kind and genetic structure of the fruit, variety, genetic factors, ecological conditions and different ripening stages. In addition, harvesting time is generally affects the chemical contents of almond kernel. The current investigations showed that the almond kernels were found to be rich in most of the essential elements. The mineral elements present in the dry nuts have a pivotal role in human nutrition. The high levels of macro (Ca, K, P, Mg, and Na) and micro (Zn, Fe, Cu, and Mn) elements demonstrated that almond kernels in the current study could serve as excellent sources of these essential minerals in the human diet.

Total phenol and antioxidant activity values of almond kernels collected from naturally growing almond trees in Mersin province are given in Table 4. Significant differences among total phenol and antioxidant activity values were observed among almond kernels ($P < 0.05$). The total

Table 4 Total phenol and antioxidant activity values of almond kernels

Almonds	Total phenol mgGAE/100 g)	Antioxidant activity (%)	Almonds	Total phenol mgGAE/100 g)	Antioxidant activity (%)
T1	54.18 ± 1.17* ^{hi}	49.15 ± 0.87 ^{no}	T17	37.93 ± 0.53 ⁿ	79.83 ± 3.56 ^g
T2	38.29 ± 2.37 ^{m**}	64.82 ± 3.28 ^{jk}	T18	51.28 ± 1.32 ⁱ	81.29 ± 2.87 ^f
T3	41.57 ± 1.76 ^{kl}	59.33 ± 1.76 ^k	T19	57.61 ± 1.17 ⁱ	83.47 ± 1.61 ^{de}
T4	64.98 ± 2.51 ^f	47.19 ± 2.13 ^o	T20	49.63 ± 0.76 ^j	85.46 ± 1.19 ^c
T5	44.71 ± 3.64 ^{jk}	51.28 ± 1.18 ⁿ	T21	59.38 ± 0.33 ^{fg}	78.32 ± 2.65 ^g
T6	39.11 ± 0.89 ^m	73.42 ± 1.78 ⁱ	T22	47.19 ± 0.45 ^j	65.38 ± 1.43 ^j
T7	56.83 ± 0.63 ^h	65.37 ± 2.65 ^j	T23	28.34 ± 0.51 ^p	91.18 ± 3.76 ^a
T8	71.19 ± 1.34 ^d	54.28 ± 2.88 ^{lm}	T24	23.75 ± 1.15 ^r	87.35 ± 2.98 ^b
T9	47.61 ± 1.71 ^j	76.29 ± 1.89 ^{gh}	T25	42.89 ± 1.13 ^k	48.53 ± 1.17 ^ö
T10	67.82 ± 1.57 ^e	82.38 ± 1.63 ^e	T26	37.21 ± 2.38 ⁿ	55.38 ± 0.98 ^{lm}
T11	88.49 ± 3.87 ^b	67.17 ± 2.54 ⁱ	T27	56.81 ± 1.68 ^h	49.21 ± 0.86 ^{no}
T12	65.51 ± 1.64 ^f	44.59 ± 1.35 ^p	T28	74.17 ± 3.27 ^c	56.71 ± 1.67 ^{lm}
T13	43.26 ± 1.29 ^k	71.37 ± 1.08 ⁱ	T29	43.82 ± 1.56 ^k	66.98 ± 2.31 ⁱ
T14	53.28 ± 0.81 ⁱⁱ	46.83 ± 2.27 ^o	T30	59.48 ± 1.87 ^g	75.25 ± 3.48 ^h
T15	41.19 ± 0.45 ^{kl}	71.87 ± 3.18 ⁱ	T31	34.63 ± 0.98 ^ö	59.77 ± 1.83 ^k
T16	98.67 ± 1.09 ^a	65.23 ± 3.76 ^j			

*Standard deviation; **values within each column followed by different letters are significantly different at $p < 0.05$

phenol and antioxidant activity values of almond kernels different depending on almond genotype. The highest value of total phenolic was found in T16 (98.67 mg GAE/100 g), whereas the lowest value was observed in T24 (23.75 mg GAE/100 g). The antioxidant activity of almond cultivars ranged from 44.59% (T12) to 91.18 (T23). Statistically significant differences were observed between total phenolic contents and antioxidant activity values of almond

kernel ($p < 0.05$). In previous study, Yıldız et al. (2014) reported that total phenolic contents of almond kernels changed between 45.58 (cv. Primorski) and 93.64 mg GAE/g (cv. Garrigues), respectively. Esfahlan and Jamei (2012) reported total phenolic content of 10 wild almond species kernel extracts between 184 mg GAE/g (*A. urumiensis*) and 482 mg GAE per g extract for (*A. pabotti*). T23 genotype in general showed the highest antioxidant

Fig. 1 The HJ-biplot based on principal component analysis for biochemical properties of 31 almond genotypes collected from Mersin district of Turkey

activity values in all almonds. In other study, almond extract scavenged 89.50% of the ABTS radical, 66.77% of the hydroxyl radical, and 87.30% of the DPPH radical (Keser et al. 2014). Ten different almond kernels were collected from Spanish almond varieties in the same plot to remove the environmental and agricultural management effects on almond chemical traits (Rabadán et al. 2017). A wide differences of antioxidant activity of almond kernel types were found.

Principle component analysis results clearly indicated the interrelationship between the genotype and their influence on the biochemical composition of almond kernel and oils (Fig. 1). In the HJ-biplot, the short distance between the genotypes indicated their similarity based on the biochemical composition, while long distance indicated dissimilarity. In this sense, the genotype were group into three groups, in which, T27 formed separate group and other genotype formed two groups with some interaction between them. Regarding the traits, the cosine of the angle between the vectors specifies correlations, where, acute angle indicate positive correlation, obtuse and strait angles shows negative correlations, and right angle show no correlations (Yan and Fregeau-Reid, 2008). In this regard, strong positive correlations were observed among minerals, tocopherols, and fatty acids. The first group (upper left, circle symbol) composed of the cultivar T27 which is characterized by high levels of minerals (mainly Mn, S, Mg, K, Ca, Zn, P, Na, Cu, Cr, and Al), oil, γ -tocotrienol, δ -tocopherol, P8, and α -tocotrienol. The second group (upper right, square symbols) is consisted of the cultivars T2, T4, T5, T6, T8, T9, T10, T14, T15, T17, T18, T19, T21, T22, T23, T30 and T31. This group is characterized by high levels of antioxidant, Fe, oleic, linolenic, arachidic, eicosenoic, and β -tocotrienol. Within this group, the cultivars T2 and T6 contributed more to these parameters than other cultivars. The third group (lower of the graph, triangle symbol) consisted of the cultivars T1, T3, T7, T11, T12, T13, T16, T20, T24, T25, T26, T28, and T29. This group is characterized by great contents of total polyphenols (TPC), tocopherols (α -, β -, and γ - tocopherols), stearic, palmitic, linoleic, palmitoleic, and vaccenic acids. Among this group, the cultivars T3, T7, T12, T25, and T28 contributed more to these biochemical properties than other cultivars. Overall, PCA suggested that the genotypes T2, T3, T6, T7, T12, T25, T27 and T28 contains considerable amounts of nutritional compounds and they could thus be recommended for human consumption. Within these cultivars, T27 has a higher nutritional quality than the other genotypes.

Conclusion

In the present study, the biochemical composition and antioxidant activity of 31 almond genotypes wildy grown in Turkey was investigated. The results of the present study indicate that the almond kernels constitute a viable source of certain health-beneficial phytochemical compounds. The results showed wide variations in oil contents, fatty acid composition, tocopherols, minerals, phenolics and antioxidant activity among the kernels and oils of almond genotype. Obtained results from analyzing fatty acid profile revealed that, almond oils contained high amounts of polyunsaturated fatty acids. The oil products having higher amount of good fatty acids and higher tocopherols contents are considered good from the health point of view. The high levels of macro (Ca, K, P, and Mg,) and micro (Zn, Fe, and Cu) minerals in the kernels of almond genotype indicated that they could serve as excellent sources of these elements in the human diet. The current investigations showed that the almond kernels were found to be rich in most of the essential elements. Almond kernels had high total phenolic contents. The total phenol and antioxidant activity values of almond kernels differed depending on almond genotype.

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Compliance with ethical standard

Conflict of interest The authors declare that there are no conflicts of interest.

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