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ORIGINAL ARTICLE

Characterization of physico-chemical and bioactive properties of oils of some important almond cultivars by cold press and soxhlet extraction

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Abstract The oleic acid composition of almonds oils expressed by cold press varied from 73.56% in Cristomorto cultivar to 76.59% in Tuono while oleic acid in oils extracted by soxhlet method ranged from 71.86% in Cristomorto and 75.63% in Tuono cultivars. Also, oil from cold press extraction contained 19.51% and 21.86% linoleic acid for Ferragnes and Tuono almond cultivars, respectively, while 18.74 and 20.51% linoleic acid was recorded in Soxhlet extracted oil from Ferragnes and Tuono almonds, respectively. In addition, α-tocopherol contents of the oil samples varied significantly ($p < 0.05$) from 14.18 to 16.86 mg/100 g in Tuono and 15.71–17.96 mg/100 g in Ferragnes for cold-press and soxhlet extracted oils, respectively. β-Sitosterol composition of the oil obtained by cold press ranged from 157.94 (Tuono) and 171.68 mg/100 g (Cristomorto) while β-sitosterol content varied from 148.91 (Tuono) and 159.68 mg/100 g (Cristomorto) for oil extracted by Soxhlet method.

Keywords Almond · Kernel oil · Genotype · Extraction systems · Fatty acid · Tocopherol · Sterol

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Introduction

Almond (*Prunus amygdalis* var. dulcis) is perennial crop and a member of Rosaceae family, which belongs to the drupe category of fruits (Gradziel 2009). Almond is cultivated in many regions of the world due to its high nutritional value. In recent years, the production of almonds has increased considerably in Turkey (Askin et al. 2007). Nutritionally, almonds is a good source of dietary lipids, proteins and dietary fiber. In addition, it is a rich source of fatty acids, phytosterols, tocopherol and many other health promoting micronutrients (Yada et al. 2011; Viorica-Mirela et al. 2013; Roncero et al. 2016). Almond growing in most locations of the world is a valuable industrial raw material apart from being a useful material for local use as a dry nut (Agunbiade and Olanlokun 2006; Piscopo et al. 2010). Various factors can affect the physico-chemical properties of almond kernel oils (George et al. 2002; Garcia-Pascual et al. 2003; Beyhan et al. 2011). Almond is a good source of tocopherol and high concentration of this essential nutrient in almond has been found to have inhibitory effect against lipid oxidation during processing and storage (Filsoof et al. 1976; Garcia-Pascual et al. 2003; Kodad et al. 2006). Also roasted almond kernels are used in sweets, cakes and sugar coated almonds and other manufactured food products. Knowledge of bioactive properties of almond kernels would help to further establish its potential health benefits (Kester and Asay 1979; Nanos et al. 2002; Piscopo et al. 2010). The potential health benefits of unsaturated fatty acids such as oleic, linoleic and linolenic from almond oil on cholesterol and cardiovascular disease in humans have been reported (Kodad et al. 2004; Ahrens et al. 2005; Beyhan et al. 2011; Karatay et al. 2014). The almond oil is commonly used in medicine, pharmaceutical and cosmetic industries (Socias et al. 2008). Vegetable seed oils extracted by cold press

method are known to be rich source of health promoting fatty acids and many bioactive compounds such as tocopherol, squalen and sterol (Koski et al. 2002; Bail et al. 2008). Solvent extraction is the most commonly used method for extracting oil from seeds at industrial level and cold press extraction which require less solvent and heating can also be employed. This present study was aimed at evaluating the effect of extraction methods (Soxhlet and cold press) on the physico-chemical properties, fatty acids composition, tocopherols and sterol contents of almond oils from Ferragnes, Tuono and Cristomorto almond cultivars.

Materials and methods

Materials

Almond fruits (Ferragnes, Tuono and Cristomorto) were collected during full maturation from almond orchard in Antalya province in Turkey in autumn. 25 trees were used for each variety. Almond varieties are completely different from each other in terms of phenotype and genotype. After collecting 25 kg almonds from each tree, the almonds were brought to the laboratory in the paper bags. The outer crusts were broken and kernels were dried in an oven at 70 °C. After drying, the samples were ground, packed inside coloured bottles and stored in the refrigerator for analysis. All solvents used were of analytical grade and procured from Merck (Darmstadt, Germany).

Method

Oil extraction

Cold press Cold press method was used to extract oil from the almond kernel. After the extraction process, the oil was filtered to remove impurities and then kept in colored bottle under nitrogen at − 18 °C.

Soxhlet extraction

Oil was extracted from ground almond seed using petroleum ether at 50 °C in a Soxhlet apparatus and rotary evaporator was used for solvent evaporation at low pressure. The oil extracted was stored in coloured glass bottles and kept under − 18 °C until further use.

Physicochemical properties of seed oils

The method of AOAC (1993) was employed for the determination of acidity, iodine value, peroxide value, saponification value, unsaponifiable matter, specific gravity and refractive index of oil samples.

Fatty acid composition

Fatty acids were transformed to fatty acid methyl esters by direct transesterification for neutral samples. The fatty acid methyl ester was injected into gas chromatography (Varian 5890 gas chromatograph with a capillary column, CP-Sil 88 (100 m long, 0.25 mm ID, and film thickness 0.2 μm). Nitrogen was used as a carrier gas (flow rate, 24 mL/min). Fatty acids were identified by comparison of their retention times (Rt) with those of standards (Matthäus and Özcan 2011).

Tocopherol analysis

High performance liquid chromatography (HPLC) (Shimadzu series) was employed for determination of tocopherols in the oil samples. The *n*-hexane extraction was applied. 250 mg of oil was solved in 25 mL *n*-heptane, and about 20 μL of a solution for quantification of tocopherols was directly injected to a Diol phase HPLC column 25 cm × 4.6 mmID used with a flow rate of 1.3 mL/min. Standard solutions of tocopherols (α, β, γ and δ-tocopherol) were used to construct calibration curve for concentrations of 0–100 mg/L (Balz et al. 1992).

Sterol analysis

250 mg of saponified almond oil with ethanolic potassium hydroxide and unsaponifiable matter were introduced unto aluminium oxide column. Separation of sterol fraction from unsaponifiable matter was performed in a thin-layer chromatograph (TLC), followed by re-extraction of sterol components from TLC material, after which sterol composition of the fraction was determined by GLC with botulin serving as internal standard. The sterol fraction in unsaponifiable matter was determined by GLC. The carrier gas used was hydrogen and injection temperature was set to 320 °C, while oven temperature was set to run from 245 to 260 °C at 5 °C/min heating rate and maintained at 340 °C. 1 μL of sample was injected into the GC–MS by an autosampler at 1:20 split ration. The mass Spectrophotometer (MS) transfer line was 260 °C, 220 °C ion source was used, MS quadruple temperature was about 160 °C while 70 eV ionization temperature was employed (Matthäus and Özcan 2006).

Statistical analysis

Analysis of variance (ANOVA) and completely randomized split block design was employed in this present study using JMP version 9.0 (SAS Inst. Inc., Cary, N.C., U.S.A). Analyses were carried out in triplicates and results are expressed as mean ± standard deviation (MSTAT C) of

independent extraction methods and almond varieties (Püskülcü and İkiz 1989).

Results and discussion

The physico-chemical properties of almond cultivar oils extracted using cold press and Soxhlet extraction methods are shown in Table 1. Acidity values of almond oils extracted by cold press changed between 1.17 mgKOH/100 g (Ferragnes) and 2.21 mgKOH/100 g (Cristomorto) while 0.96 mgKOH/100 g (Ferragnes) and 1.11 mgKOH/100 g (Cristomorto) were obtained for oils extracted by Soxhlet method. In addition, while peroxide values of cold press almond oils are determined between 3.27 (Ferragnes) and 4.11 meqO_2/kg (Tuono), Soxhlet extracted oils had peroxide values ranging between 5.32 (Ferragnes) and 6.44 meqO_2/kg (Tuono). The density of almond oils extracted using Soxhlet method were higher, ranging from 0.9231 (Tuono) and 0.9287 g/cm^3 (Cristomorto). Also, the refractive index values of almond oils obtained by cold press method changed from 1.463 (Cristomorto) to 1.470 (Tuono), while refractive index values of Soxhlet extracted oil samples changed from 1.471 (Cristomorto) to 1.484 (Tuono). Additionally, saponification values of cold press extracted oils ranged from 98.61 (Cristomorto) and 103.60 mgKOH/100 g (Ferragnes). The highest unsaponifiable was determined in Tuono oil (1.87%) extracted by soxhlet system. Higher values reported for peroxide value in almond oils from Soxhlet method may be linked to the effect of extraction method used. In addition, higher unsaponifiable matter values obtained from Soxhlet technique may be due to transfer of more matter into the oil from the seed by the extraction solvent used. Almond oils extracted by cold press method had higher acid values. The higher acid values obtained may be linked to the action of lypolytic enzymes encountered during oil extraction since cold press does not require heat. The oil contents of the selected almond cultivars changed from 47.48 (24-Ke-29) to 56.70% (24-Ke-191) (Aslantas et al. 2001; Barbera et al. 1994; Özcan et al. 2011; Yıldırım et al. 2016). Özcan et al. (2011) reported that acidity and peroxide values of Ferragnes, Tuono and Cristomorto almond oils were 2.279, 3.559 and 2.397 mgKOH/100 g and 13.380, 10.132 and 15.590 meqO_2/kg, respectively. The results obtained in our present study differ slightly from those reported in previous studies and these variations may be attributed to genotypic differences.

The fatty acid compositions of almond kernel oils extracted are shown in Table 2. The fatty acid compositions of the almond oils differ significantly ($p < 0.05$). The palmitic acid contents of almond oils from cold press method varied between 6.58 (Tuono) and 6.87% (Ferragnes) while Soxhlet extracted oils had palmitic values within the range of 5.77% (Tuono) and 5.93% (Ferragnes). Also, oleic acid contents of cold press extracted oils ranged from 73.56 (Cristomorto) to 76.59% (Tuono), while oleic acid contents of oils from Soxhlet technique varied from 71.86 (Cristomorto) to 75.63% (Tuono). In addition, linoleic acids in cold press oils changed from 19.51 (Ferragnes) to 21.86% (Tuono), while Soxhlet extracted oils had their linoleic acid values between 18.74 (Ferragnes) and 20.51% (Tuono) ($p < 0.05$). Oleic, linoleic and palmitic acids were the most abundant fatty acids in almond oils extracted using Soxhlet and cold press techniques. Differences observed in fatty acids composition of the oils may be probably due to different almond seed genotype used as we extraction method employed. Significant differences ($p < 0.05$) was observed between almond cultivars and extraction methods. Generally, the fatty acid contents of almond oils extracted by cold press method were higher than those extracted using Soxhlet technique. The lower values of Soxhlet extracted oils may possibly be due to the transfer of impurities to oil during solvent extraction. The fatty acid profiles of oil samples changed depending on almond genotype and extraction systems. Pons almond oil contained 6.5% palmitic, 0.5% palmitoleic, 1.5% stearic,

Table 1 The physico-chemical properties of almond oils obtained cold press and soxhlet extraction systems

Parameters	Cold press			Solvent extraction		
	Ferragnes	Tuono	Cristomorto	Ferragnes	Tuono	Cristomorto
Acidity (mgKOH/100 g)	1.17 ± 0.13*c	1.68 ± 0.21b	2.21 ± 0.17a	0.96 ± 0.10c	1.12 ± 0.09b	1.44 ± 0.15a
Peroxide value (meqO_2/kg)	3.27 ± 0.19c**	4.11 ± 0.28a	3.87 ± 0.15b	5.32 ± 0.36c	6.44 ± 0.55a	5.81 ± 0.61b
Density (g/cm^3)	0.914 ± 0.011c	0.916 ± 0.07b	0.922 ± 0.09a	0.928 ± 0.05a	0.923 ± 0.03b	0.929 ± 0.07a
Refractive index (n_D)	1.466 ± 0.005b	1.470 ± 0.003a	1.463 ± 0.003b	1.476 ± 0.005b	1.484 ± 0.007a	1.471 ± 0.003b
Iodine value (mg/g)	13.76 ± 0.96a	12.86 ± 0.84b	11.57 ± 0.58c	11.89 ± 0.75a	11.17 ± 0.49a	10.84 ± 0.93b
Saponification value	103.6 ± 1.37a	101.87 ± 1.84b	98.61 ± 1.65c	99.83 ± 1.33a	98.67 ± 0.87b	97.81 ± 0.65c
Unsaponifiable matter (%)	1.68 ± 0.09b	1.71 ± 0.11a	1.54 ± 0.07c	1.79 ± 0.26b	1.87 ± 0.11a	1.71 ± 0.15c

*Mean ± standard deviation; **values within each row followed by different letters are significantly different ($p < 0.05$)

Table 2 Fatty acid composition of almond oils obtained cold press and soxhlet extraction systems (%)

Fatty acids	Cold press			Solvent extraction		
	Ferragnes	Tuono	Cristomorto	Ferragnes	Tuono	Cristomorto
Palmitic	6.87 ± 0.17*a	6.58 ± 0.21b	6.71 ± 0.13a	5.93 ± 0.09a	5.77 ± 0.15c	5.85 ± 0.09b
Palmitoleic	0.37 ± 0.01b**	0.48 ± 0.05a	0.32 ± 0.03c	0.33 ± 0.01b	0.41 ± 0.01a	0.28 ± 0.03c
Stearic	1.31 ± 0.07c	1.64 ± 0.09a	1.52 ± 0.11b	1.21 ± 0.09b	0.40 ± 0.05c	1.46 ± 0.07a
Oleic	74.63 ± 0.67b	76.59 ± 0.89a	73.56 ± 0.75c	73.58 ± 0.53b	75.63 ± 0.36a	71.86 ± 0.65c
Linoleic	19.51 ± 0.13c	21.86 ± 0.11a	20.13 ± 0.17b	18.74 ± 0.09c	20.51 ± 0.07a	19.68 ± 0.15b
Linolenic	0.91 ± 0.03a	0.73 ± 0.01b	0.58 ± 0.07c	0.64 ± 0.09b	0.69 ± 0.05a	0.49 ± 0.03c
Arachidic	0.15 ± 0.01a	0.13 ± 0.01b	0.11 ± 0.03c	0.13 ± 0.01a	0.09 ± 0.01b	0.07 ± 0.01c
Gondoic	0.12 ± 0.01a	0.10 ± 0.01b	0.09 ± 0.01c	0.09 ± 0.01a	0.07 ± 0.01b	0.06 ± 0.01c

*Mean ± standard deviation; **values within each row followed by different letters are significantly different ($p < 0.05$)

62.5% oleic and 29.0% linoleic acids (Soler et al. 1988). In another study, Aşkın et al. (2007) reported that several almond oils contained palmitic (5.46–15.78%), palmitoleic (0.36–2.52%), stearic (0.80–3.83%), oleic (50.41–81.20%) and linoleic (6.21–37.13%) acids. Sathe et al. (2008) reported values ranging from 57.54 to 73.94% for oleic acid in eight almond oil cultivars. Moayedi et al. (2011) reported that four almond oils contained 7.1–9.5% palmitic, 0.3–0.6% palmitoleic, 1.0–2.6% stearic, 66.7–69.7% oleic, 18.2–23.0% linoleic acids. Piscopo et al. (2010) reported that Ferragnes and Tuono almond oils contained 5.79 and 6.50% palmitic, 78.89 and 74.96% oleic, 1.35 and 1.79% stearic, 12.59 and 15.09% linoleic and 0.03 and 0.04% linolenic and 0.08 and 0.12% C20:0 acids, respectively. In addition, Özcan et al. (2011) reported values ranging from 72.5 to 79.9% for oleic, 13.5–19.8% for linoleic and 5.9–6.7% for palmitic acids in several almond kernel oils. Additionally, Kırbaşlar et al. (2012) reported 71.98% for oleic acid in an almond genotype in Turkey, while Izaddost et al. (2013) reported 46.16–61.02% oil, 71.27–77.39% oleic acid, 31.41–19.85% linoleic and 6.30–6.52% palmitic acids in several almond kernel oils (Fragnessi Mamaee, Saba, Fragiulio and Shokoofe cv.). Palmitic (5.34%), palmitoleic (0.70%), stearic (0.85%), oleic (74.46%), linoleic (17.89%) and linolenic (0.75%) acids were reported in 32 almond oil samples by Karatay et al. (2014). Myristic values ranging from 0.01 to 0.10%, palmitic (4.68–6.48%), palmitoleic (0.24–0.56%), stearic (1.45–2.56%) and linoleic (15.57–27.72%) acid values were reported for almond oils from Serbian almond seeds (Colic et al. 2017). These results showed similarity with the fatty acid composition of many *Prunus* kernels previously studied (Femenia et al. 1995; Hassanein 1999). In addition, the results obtained are comparable with those reported in literatures. However, quantitative differences between fatty acid values were observed and these may be due to effects originating from variations in genotype of almond cultivars used, harvesting time, growing conditions and methods of oil extractions.

Table 3 shows the tocopherol contents of almond seed oil extracted using cold press and Soxhlet extraction methods. As presented in Table 3, α-tocopherol content of oil extracted from almond seed by cold press technique ranged from 14.18 (Tuono) and 16.86% mg/100 g (Ferragnes) while Soxhlet extracted oil had α-tocopherol within the range of 15.71 mg/100 g (Tuono) and 17.96 mg/100 g (Cristomorto). In addition, β-tocopherol contents of almond oils expressed using both extraction systems (cold press and Soxhlet) varied from 1.79 (Ferragnes) to 2.15 mg/100 g (Tuono) and 1.88–2.47 mg/100 g (Tuono), respectively. γ-Tocopherol and α-tocotrienol contents of the oil samples generally low. The tocopherol contents of almond oils expressed using cold press method were generally low when compared to Soxhlet oil samples. This is may be partly due to the fact that the amount of non-saponified material in the kernel is taken up more by solvent. Significant differences ($p < 0.05$) were observed in the tocopherol contents of almond oils extracted using Soxhlet and cold press techniques. In previous studies where oils were extracted from several almond cultivars, values of 0.012–0.019 mg/g and 0.101–0.158 mg/g were reported for β-tocopherol and α-tocopherols contents, respectively (Izaddost et al. 2013). Kodad et al. (2006) reported 187–490 g/kg for α-tocopherol for oils extracted from almond while Martins et al. (2000) reported values ranging from 30.01 to 51.0% for oils from 12 different almond varieties obtained in Portugal. Also, Fernandes et al. (2017) reported values of 97.3 mg/kg for α-tocopherol and 2.8 mg/kg for γ-tocopherol in almond oil. Extraction techniques employed in this present study had great impact on the tocopherol contents of oils from almond seeds. In addition to extraction techniques, climatic factors, variety and analytical conditions also affected tocopherol content of the oils.

Table 3 Tocopherol contents of almond oils obtained cold press and soxhlet extraction systems (mg/100 g)

Tocopherols	Cold press			Solvent extraction		
	Ferragnes	Tuono	Cristomorto	Ferragnes	Tuono	Cristomorto
α-Tocopherol	16.86 ± 0.45*a	14.18 ± 0.67b	16.71 ± 0.38a	17.64 ± 0.56a	15.71 ± 0.81b	17.96 ± 0.27a
β-Tocopherol	1.79 ± 0.13c**	2.15 ± 0.09a	1.98 ± 0.21b	1.88 ± 0.10c	2.47 ± 0.17a	2.19 ± 0.15b
γ-Tocopherol	0.50 ± 0.03b	0.40 ± 0.01c	0.60 ± 0.07a	0.60 ± 0.03b	0.60 ± 0.09b	0.80 ± 0.07a
α-Tocotrienol	0.06 ± 0.01a	0.05 ± 0.01b	0.06 ± 0.01a	0.08 ± 0.03b	0.07 ± 0.01c	0.09 ± 0.03a

*Mean ± standard deviation; **values within each row followed by different letters are significantly different ($p < 0.05$)

The sterol contents of almond oils expressed using Soxhlet and cold press techniques are presented in Table 4. The most abundant sterol in almond oil was β-sistosterol followed by δ5-avenasterol, campesterol, stigmasterol and stigmastanol. β-Sitosterol contents of almond oil sample obtained by cold press varied between 157.94 (Tuono) and 171.68 mg/100 g (Cristomorto) while β-sitosterol composition of the oils expressed using Soxhlet system ranged from 148.91 (Tuono) to 159.68 mg/100 g (Cristomorto). In addition, δ5-avenasterol contents of cold pressed almond oils changed between 19.47 (Tuono) and 21.36 mg/100 g (Ferragnes). Also, δ5-avenasterol contents of almond oils obtained by Soxhlet method changed from 18.54 (Tuono) to 20.18 mg/100 g (Ferragnes). While campesterol contents of cold press extracted almond oils varied from 16.54 (Tuono) to 22.61 mg/100 g (Cristomorto) and campesterol contents of almond oils obtained by Soxhlet technique ranged from 14.61 (Tuono) to 21.54 mg/100 g (Cristomorto). The highest stigmasterol content of 19.67 mg/100 g was reported in oil extracted from Cristomorto variety by cold press method. Also, the highest stigmasterol and 7-stigmasterol were obtained in cold press oil from Tuono (6.38 mg/100 g) and Cristomorto (5.61 mg/100 g) almond varieties. Fernandes et al. (2017) reported values of 2.5 mg/kg for campesterol, 2.5 mg/kg for δ7-campesterol, 55.9–95.1 mg/kg for β-sistosterol and 8.5–28.2 mg/kg for δ5-avenasterol. Generally, sterol contents of almond oils obtained by cold press were higher than those extracted using Soxhlet technique.

Conclusion

Extraction techniques had varying effects on the physicochemical and bioactive properties of almond seed oils. The acid value, density, peroxide value and unsaponifiable matter values of almond oils extracted by cold press was higher than values reported for Soxhlet extracted oils. The major fatty acid present in almond oils extracted by both methods was oleic acid. Also, the values obtained for fatty acids from cold press almond oils was higher than the values obtained from Soxhlet extracted oils. In addition,

Table 4 Sterol profiles of almond oils obtained cold press and soxhlet extraction systems (mg/100)

Sterols	Cold press			Solvent extraction		
	Ferragnes	Tuono	Cristomorto	Ferragnes	Tuono	Cristomorto
24-Ethylencholesterol	1.07 ± 0.03*b	1.27 ± 0.09a	0.98 ± 0.05c	0.86 ± 0.03b	1.03 ± 0.07a	0.71 ± 0.05c
Campesterol	18.26 ± 0.13b**	16.54 ± 0.17c	22.61 ± 0.21a	17.12 ± 0.09b	14.61 ± 0.18c	21.54 ± 0.23a
δ7-campesterol	4.13 ± 0.09a	3.97 ± 0.03b	4.38 ± 0.07a	3.21 ± 0.13b	2.63 ± 0.21c	3.57 ± 0.11a
Stigmasterol	14.46 ± 0.11c	16.58 ± 0.23b	19.67 ± 0.17a	12.89 ± 0.09c	15.43 ± 0.07b	18.51 ± 0.15a
Clerosterol	1.33 ± 0.07c	1.58 ± 0.11a	1.47 ± 0.09b	0.97 ± 0.03b	1.04 ± 0.03a	1.06 ± 0.07a
Stigmastanol	5.71 ± 0.05c	6.38 ± 0.09a	5.93 ± 0.11b	4.23 ± 0.17b	5.17 ± 0.09a	4.38 ± 0.13b
β-Sitosterol	165.42 ± 0.98b	157.94 ± 0.76c	171.68 ± 0.81a	152.86 ± 0.88b	148.91 ± 0.65c	159.68 ± 0.57a
δ7-avenasterol	2.17 ± 0.09a	1.81 ± 0.11b	1.63 ± 0.07c	1.54 ± 0.05a	1.11 ± 0.03b	1.09 ± 0.05b
δ5-avenasterol	21.36 ± 0.21a	19.47 ± 0.13c	20.58 ± 0.26b	20.18 ± 0.19a	18.54 ± 0.32c	19.26 ± 0.18b
δ5,25-stigmastadienol	3.47 ± 0.05a	2.84 ± 0.09b	1.69 ± 0.11c	2.71 ± 0.13a	1.96 ± 0.07b	0.89 ± 0.03c
Stadienol	2.23 ± 0.11a	1.17 ± 0.09c	1.89 ± 0.13b	1.84 ± 0.07a	0.93 ± 0.05c	1.03 ± 0.01b
7-Stigmasterol	4.28 ± 0.17b	3.97 ± 0.13c	5.61 ± 0.09a	3.67 ± 0.05b	2.86 ± 0.19c	4.49 ± 0.21a

*Mean ± standard deviation; **values within each row followed by different letters are significantly different ($p < 0.05$)

cold press oils was chemically free from organic solvents. The α- and β-tocopherols contents of almond oils from both extraction methods was generally high and sterol content of oils obtained by cold press extraction was higher than that of Soxhlet extracted oils. This study has further revealed the potential health benefits of almond oils due to the presence of health promoting bioactive compounds.

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References

Agunbiade SO, Olanlokun JO (2006) Evaluation of some nutritional characteristics of Indian almond (*Prunus amygdalus*) nut. Pakistan J Nutr. 5(4):316–318

Ahrens S, Venkatachalam M, Mistry AM, Lapsley K, Sathe SK (2005) Almond (*Prunus dulcis* L.) protein quality. Plant Foods Hum Nutr 60(3):123–128

AOCS (1993) Official methods and recommended practices of the American Oil Chemists Society, 4th edn. AOCS, Champaign

Aşkın MA, Balta MF, Tekintaş FE, Kazankaya A, Balta F (2007) Fatty acid composition affected by kernel weight in almond (*Prunus dulcis* (Mill.) D.A. Webb.) genetic resources. J Food Compos Anal 20:7–12

Aslantas R, Guleryuz M, Turan M (2001) Some chemical contents of selected almond (*Prunus amygdalus* Batsch) types. CIHEAM Opt Méditer 56:347–350

Bail S, Stuebiger G, Krist S, Unterweger H, Buchbauer G (2008) Characterization of various grape seed oils by volatile compounds, triacylglycerol composition, total phenols and antioxidant capacity. Food Chem 108:1122–1132

Balz M, Schulte E, Their HP (1992) Trennung von Tocopherolen und Tocotrienolen durch HPLC. Fat Sci Technol 94:209–213

Barbera G, Martını L, Monastra F (1994) Response of Ferragnes and Tuono almond cultivars to different environmental conditions in Southern Italy. Acta Hortic 373:99–103

Beyhan O, Aktaş M, Yılmaz N, Şimşek N, Gerçekçioğlu R (2011) Determination of fatty acid compositions of some important almond (*Prunus amygdalus* L.) varieties selected from Tokat province and Aegean region of Turkey. J Med Plants Res 5(19):4907–4911

Colic SD, Aksic MMF, Lazarevic KB, Zec GN, Gasic UM, Zagorac DCDZ, Natic MM (2017) Fatty acid and phenolic profiles of almond grown in Serbia. Food Chem 234:455–463

Femenia A, Chen YC, Mulet A, Canellas J (1995) Chemical composition of bitter and sweet apricot kernels. J Agric Food Chem 43:356–361

Fernandes GD, Gómez-Coca RB, Pérez-Camino MC, Moreda W, Barrera-Arellano D (2017) Chemical characterization of major and minor compounds of nut oils: Almond, Hazelnut, and Pecan nut. J Chem. https://doi.org/10.1155/2017/2609549

Filsoof M, Mehran M, Farrohi F (1976) Determination and composition oil characteristics in Iranian almond, apricot and peach nuts. Fette Seifen Anstrich 78(4):150–151

Garcia-Pascual P, Mateos M, Carbonell V, Salazar DM (2003) Influence of storage conditions on the quality of shelled and roasted almonds. Biosyst Eng 84:201–209

George D, Ioannis K, Kefalas P, Petrakis C, George G (2002) Irrigation and harvest time affect almond kernel quality and composition. Sci Hortic 96:249–256

Gradziel TM (2009) Almond (*Prunus dulcis*) breeding. In: Breeding plantation tree crops: temperate species, pp 1–31. Springer, New York

Hassanein MMM (1999) Studies on non-traditional oils. I. Detailed studies on different lipid profiles of some Rosaceae kernel oils. Grasas Aceites 50:379–384

Izaddost M, Imani A, Piri S, Bagiri AM (2013) Oil content, major fatty acids composition, α-tocopherol and nut characteristics of almond at time of harvest. J Basic Appl Sci Res 3:201–205

Karatay H, Şahin A, Yılmaz Ö, Aslan A (2014) Major fatty acids composition of 32 almond (*Prunus dulcis* (Mill.) D.A. Webb.) genotypes distributed in east southeast of Anatolia. Turk J Biochem 39:307–316

Kester DE, Asay R (1979) Almonds. In: Janick J, Moore JN (eds) Advances in fruit breeding. Purdue University Press, Westlafayette, pp 387–418

Kırbaşlar FG, Türker G, Özsoy-Güneş Z, Ünal M, Dülger B, Ertaş E, Kızılkaya B (2012) Evaluation of fatty acid composition, antioxidant and antimicrobial activity, mineral composition and calories values of some nuts and seeds from Turkey. Rec Nat Prod 6:339–349

Kodad O, Gracia Gomez MS, Socias i Company R (2004) Fatty acid composition as evaluation criterion for kernel quality in almond breeding. Acta Hortic 663:301–304

Kodad O, Socias i Company R, Prats MS, López Ortiz MC (2006) Variability in tocopherol concentrations in almond oil and its use as a selection criterion in almond breeding. J Hortic Sci Biotechnol 81:501–507

Koski A, Psomiadou E, Tsimidou M, Hopia A, Kefalas P, Wahala K, Heinonen M (2002) Oxidative stability and minor constituents of virgin olive oil and cold-pressed rapeseed oil. Eur Food Res Technol 214:294–298

Martins A, Gomes NC, Ferreira L (2000) Almond production and characteristics in Algarve, Portugal. NUCIS 9:6–9

Matthäus B, Özcan MM (2006) Quantitation of fatty acids, sterols, and tocopherols in turpentine (*Pistacia terebinthus* Chia) growing wild in Turkey. J Agric Food Chem 54(20):7667–7671

Matthäus B, Özcan MM (2011) Chemical evaluation of flower bud and oils of tumbleweed (*Gundelia tourneforti* L.) as a new potential nutrition sources. J Food Biochem 35(4):1257–1266

Moayedi A, Rezaei K, Moini S, Keshavarz B (2011) Chemical composition of oils from several wild almond species. J Am Oil Chem Soc 88:503–508

Nanos GD, Kazantzis L, Kefalas P, Petrakis C, Stavroulakis GG (2002) Irrigation and harvest time affect almond kernel quality and composition. Sci Hortic 96:249–256

Özcan MM, Ünver A, Erkan E, Arslan D (2011) Characteristics of some almond kernel and oils. Sci Hortic 127:330–333

Piscopo A, Romeo FW, Petrovicova B, Poiana M (2010) Effect of the harvest time on kernel quality of several almond varieties (*Prunus dulcis* (Mill.) D.A.Webb). Sci Hortic 125:41–46

Püskülcü H, İkiz F (1989) Introduction to statistic. Bilgehan Press, Bornova, p 333 **(in Turkish)**

Roncero JM, Alvarez-Orti M, Pardo-Gimenez A, Gomez R, Rabadan A, Pardo JE (2016) Virgin almond oil: extraction methods and composition. Grasas Aceites 67(3):143

Sathe SK, Seeram NP, Kshirsagar HH, Heber D, Lapsley KA (2008) Fatty acid composition of California grown almonds. J Food Sci 73(9):607–614

Socias ICR, Kodad O, Alonso JM, Gradziel TM (2008) Almond quality: a breeding perspective. Hortic Rev 34:197–238

Soler L, Canellas J, Saura Calixto F (1988) Oil content and fatty acid composition of developing almond seeds. J Agric Food Chem 36:695–697

Viorica-Mirela P, Nicoleta RD, Camelia M, Gabriela DD, Constantin M, Alexandra G (2013) The possibilities of obtaining,

characterizing and valorification of almond oil (*Prunus amygdalus*). J Agroaliment Process Technol 19(4):455–458

Yada S, Lapsley K, Huang G (2011) A review of composition studies of cultivated almonds: Macronutrients and micronutrients. J Food Comp Analysis 24:469–480

Yıldırım AN, Akıncı-Yıldırım F, Şan B, Sesli Y (2016) Total oil content and fatty acid profile of some almond (*Amygdalus communis* L.) cultivars. Pol J Food Nutr Sci 66:173–178