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Fatty Acids, Tocopherol and Phenolic Contents of Organic and Conventional Grown Hazelnuts

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ABSTRACT

The aim of this study was to determine the total phenolic content and antioxidant activity as well as fatty acids and tocopherol compositions of organic and conventionally grown hazelnut (*Corylus avellana*). Organic hazelnuts were found to be richer in terms of palmitoleic acid (P< 0.05). The production method did not influence other parameters, but the variety factor affected many parameters. In all varieties, oleic acid was the predominant fatty acid followed by linoleic, palmitic, and stearic acids. The lowest atherogenic index was determined at Sivri and no difference was detected in terms of thrombogenic index (P< 0.05). In all varietiesα, β, γ, δ-tocopherol were detected and α-tocopherol was dominant. The highest amount of tocopherol was detected in Mincane (549.73 mg kg^{-1} fat). The highest amount of phenolic substance (546.53 mg 100 g^{-1} GAE) and antioxidant activity (48.84%) were detected in Çakıldak, probably due to the plant exposure to stress in high and cold regions. Results of the extensive analyses showed that organic hazelnuts had no significant differences with the conventional ones in terms of the parameters examined.

Keywords: α-Tocopherol, Antioxidant, Atherogenicity, Conventional food, *Corylus avellana*, Organic food.

INTRODUCTION

Hazelnut within the *Betulaceae* family is one of the most consumed nuts around the world (Pelvan *et al*., 2018; Karaosmanoğlu and Üstün, 2017). The most important nut-producing countries are Turkey, Italy, Spain, and Portugal, while the United States and Georgia are the other major producer countries (Pelvan *et al*., 2012; Marzocchi *et al*., 2017). Although there are a total of 18 different varieties of hazelnut produced in Turkey, only seven of these varieties (Tombul, Foşa, Mincane, Palaz, Karafındık, Sivri, and Çakıldak) are of commercial significance (Pelvan*et al*., 2012). As well as its economic importance, hazelnut is a good source of energy and is an important food for human nutrition due to the carbohydrate, fat, protein, dietary fiber, vitamins and minerals present in its content (Alasalvar *et al*., 2003a; Kıralan *et al*., 2015; Malekjani *et al*., 2017).

According to the results of the purchasing surveys, consumers think that the nutritional content of organic foods is richer than conventional food, more beneficial for health and tastier, and they are willing to pay more (Crecente-Campo *et al*., 2012; Yadav and Pathak 2016; Chekima *et al*., 2017; Hansen *et al*., 2018; Asif *et al*., 2018). In parallel with the increasing demand for organic food, organic food production and organic farming have also been on the rise in recent years (Maggio *et al*., 2013). Approximately 80 billion Euros of organic food production has been made by 2.7 million producers in 57.8 million hectares (FiBL and IFOAM, 2018).

According to the data of 2016, the organic

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hazelnut production in Turkey was 12,962 kg, comprising about 2% of the total hazelnut production, and it is increasing as in other organic foods (GTHB, 2018). Numerous studies have been done to determine the nutrient content of organic and conventional foods, but only a few studies have been done to determine the nutritional content of organic hazelnut. In these studies, it was observed that there was no difference between raw fat and protein amount of nuts grown in organic and conventional conditions (Koç and Bostan, 2010; Turan *et al*., 2010).

It is important for consumers to know the content of oil and phenolics of organic hazelnuts since they are priced higher on the market than conventionally produced hazelnuts. While no studies have been found in the literature on the effects of organic farming practices on fatty acids and tocopherol compositions of hazelnut, very little work has been done on the amount of phenolics. In this study, fatty acid composition, tocopherol profile, total phenolic content and antioxidant activity of hazelnut varieties grown on organic and conventional conditions were investigated.

MATERIALS AND METHODS

Sample Collection

The material of the work were hazelnuts produced in Trabzon, Ordu, Samsun and Düzce according to certified organic and conventional agricultural systems, and harvested in 2015. Collected hazelnut samples were selected from commercially important varieties in each region. Foşa, Sivri and Mincane varieties from Trabzon Province; Tombul, Palaz and Çakıldak varieties from Ordu and Samsun Provinces; and Foşa, Sivri and Tombul varieties from Düzce Province. Each hazelnut variety from each province was represented with three kg of shelled hazelnuts from three different producers. Thus, for each province 18 samples, 9 of which were organic and 9 conventional, and totally 72 different samples were collected, of which 36 were organic and 36 conventional. The collected samples were stored in packages made of kraft paper until they were analyzed.

Oil Extraction

Extraction of lipids from hazelnut samples was done according to the method used by Bligh and Dyer (1959).

Fatty Acid Analysis

To obtain the fatty acid methyl esters (ISO, 1978), 0.5 g of oil was weighed into Erlenmeyer flask and mixed with 4 mL of iso-octane and 2 mL of methanolic KOH solution, followed by shaking for 30 seconds. Then, the Erlenmeyer was closed and left in the dark for 6 minutes, then, 2 drops of 1% methyl orange indicator were dropped and the solution was titrated with 1M HCl until pink color appeared. After the content was rested for 15 minutes, the colorless upper layer was transfered into glass vials and analyzed in GC. Composition of fatty acids was determined using Shimadzu brand (Model GC-2010, Japan) gas chromatography with a flame ionization detector (FID) and TR-CN100 column (60 m×0.25 mm ID, 0.20 μm) (Teknokroma, Spain). The injector temperature was set at 250°C and the detector temperature was set at 250°C. The amount of sample injected was 1.0 μL and helium at pressure of 200 kPa was used as carrier gas. Injection was performed at a ratio of 1:100. The column temperature was maintained at 90°C for 7 minutes, then, the temperature was increased to 240°C increasing by 5°C min^{-1}. Finally, it was held at 240°C for 15 minutes. Fatty acids were identified by comparison with the time of arrival of the FAME mixture (Supelco 37 Component FAME Mixture, Cat. No. 18919-1AMP, Bellefonte PA, USA) consisting of 37 standard components (Karaosmanoğlu and Üstün, 2019). The

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results were expressed in relative percentage of each fatty acid, calculated by the chromatographic peak areas.

Atherogenicity and Thrombogenicity Indexes

The atherogenic and thrombogenic indexes of hazelnut oils were calculated according to the following equations as defined by Ulbricht and Southgate (1991) (Bezerra *et al*., 2017).

$$AI = \frac{C12:0 + 4 \times C14:0 + C16:0}{\sum MUFA + \sum FA\omega 6 + \sum FA\omega 3}$$

$$TI = \frac{C14:0 + C16:0 + C18:0}{(0.5 \times \sum MUFA) + (0.5 \times \sum FA\omega 6) + (3 \times FA\omega 3)}$$

MUFA: Monounsaturated fatty acids
FAw6: omega-6 fatty acids
FAw3: omega-3 fatty acids

Tocopherol analysis

The standard method specified in AOCS Ce 8-89 (1997) was used to determine the tocopherol composition of the samples. The extruded 1 g hazelnut oil was completed with 10 mL hexane and the resulting mixture was injected into the HPLC device through a 0.45 µm PTFE syringe filter. Shimadzu-Prominence LC-20A was analyzed in the following conditions. HPLC Conditions: Column: C-8 (250×4 mm) 5 µm, Flow rate: 1 mL min^{-1}, Mobile phase:Hexane:Isopropyl alcohol (99:1), Wavelength: 295 nm, Column temperature: 25°C. Tocopherol content of hazelnut was expressed as mg tocopherol per kg of hazelnut oil.

Total Phenolics Content and Antioxidant Activity

The total amount of phenolics was determined with UV-visible spectrophotometer by modifying the Folin-Ciocalteu colorimetric method (Singleton and Rossi, 1965). The results are expressed as Gallic Acid Equivalent (GAE).

The DPPH radical (2,2-DiPhenyl-1-PicrylHydrazyl) reduction power method was used to determine the antioxidant capacity of oil removed from hazelnut extracts. Antioxidant analysis of extracts according to the DPPH method was carried out by modification of the method of Atoui *et al.* (2005). The reduction power of % DPPH radical of the samples was determined by the following formula.

% Inhibition= [(ADPPH-AS)/ADPPH]×100

Where, ADPPH: Absorbance of the control, AS: Absorbance of the Sample.

Statistical Analysis

The experiments were performed in triplicates in a completely randomized block design. Descriptive statistics were obtained using the SPSS v22.0 software. Statistical tests were performed using the SAS-JAMP v10.0 software, and one-way ANOVA was conducted for significant differences among the results, followed by the Least Significance Difference (LSD) test for the multiple comparisons of means. Results were tested for significant difference at $P< 0.05$.

RESULTS AND DISCUSSION

Fatty Acid Composition, Atherogenic and Thrombogenic Indexes of Organic and Conventional Hazelnuts

The fatty acid composition of hazelnut cultivated by organic and conventional methods is given in Table 1. It was determined that cultivation method was effective only on palmitoleic acid. This value was 0.17% in organic hazelnut and 0.16% in conventional hazelnut ($P< 0.05$). The method of production was not effective on the amounts of other fatty acids ($P> 0.05$). In the literature, no studies on comparision of fatty acids of organic and conventional hazelnut oils were found.

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Table 1. Fatty acid composition of organic and conventional hazelnuts (%).

Fatty Acids	Cultivar Agr Meth	Çakıldak	Foşa	Mincane	Palaz	Sivri	Tombul	Agr Meth mean
Palmitic acid	Organic	5.69±0.10	5.21±0.09	5.67±0.14	5.60±0.09	5.19±0.10	5.27±0.08	5.44±0.04
	Conv	5.53±0.10	5.17±0.09	5.78±0.14	5.45±0.09	5.16±0.10	5.17±0.08	5.37±0.04
	Cultivar Mean	5.61±0.07 A	5.19±0.07 B	5.72±0.10 A	5.53±0.07 A	5.17±0.07 B	5.22±0.06 B	
Palmitoleic acid	Organic	0.19±0.01	0.16±0.01	0.17±00.1	0.20±0.01	0.16±0.01	0.17±0.01	0.17±0.01a
	Conv	0.17±0.01	0.15±0.01	0.18±00.1	0.18±0.01	0.16±0.01	0.15±0.01	0.16±0.01b
	Cultivar Mean	0.18±0.01 AB	0.15±0.01 D	0.17±0.01 BC	0.19±0.01 A	0.16±0.01 CD	0.16±0.01 C	
Margaric acid	Organic	0.04±0.00	0.04±0.00	0.04±0.00	0.03±0.00	0.04±0.00	0.04±0.00	0.04±0.00
	Conv	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	0.03±0.00	0.04±0.00	0.04±0.00
	Cultivar Mean	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	0.04±0.00	
Heptade-cenoic acid	Organic	0.08±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00
	Conv	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00
	Cultivar Mean	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	0.07±0.00	
Stearic acid	Organic	2.34±0.11	2.70±0.11	2.50±0.15	2.44±0.11	2.59±0.11	2.41±0.09	2.50±0.05
	Conv	2.47±0.11	2.65±0.11	2.35±0.15	2.73±0.11	2.38±0.11	2.54±0.09	2.52±0.05
	Cultivar Mean	2.41±0.08	2.67±0.08	2.42±0.11	2.59±0.08	2.48±0.08	2.47±0.06	
Oleic acid	Organic	81.54±0.70	82.20±0.70	84.30±0.98	81.92±0.70	81.80±0.70	81.42±0.57	82.19±0.30
	Conv	83.24±0.70	82.08±0.70	84.13±0.98	82.35±0.70	81.47±0.70	81.90±0.57	82.52±0.30
	Cultivar Mean	82.39±0.49	82.14±0.49	84.21±0.70	82.14±0.49	81.64±0.49	81.66±0.40	
Linoleic acid	Organic	9.76±0.69	9.27±0.69	6.91±0.98	9.36±0.69	9.74±0.69	10.25±0.56	9.22±0.30
	Conv	8.11±0.69	9.47±0.69	7.12±0.98	8.79±0.69	10.34±0.69	9.76±0.56	8.93±0.30
	Cultivar Mean	8.94±0.50 A	9.37±0.50 A	7.02±0.70 B	9.08±0.49 A	10.04±0.50 A	10.00±0.40 A	
Arachidic acid	Organic	0.12±0.00	0.13±0.00	0.12±0.00	0.12±0.00	0.12±0.00	0.12±0.00	0.12±0.00
	Conv	0.13±0.00	0.13±0.00	0.11±0.00	0.13±0.00	0.12±0.00	0.12±0.00	0.12±0.00
	Cultivar Mean	0.12±0.00 AB	0.12±0.00 AB	0.11±0.00 C	0.13±0.00 A	0.12±0.00 ABC	0.12±0.00 BC	
Eicosenoic acid	Organic	0.16±0.00	0.16±0.00	0.15±0.01	0.16±0.00	0.18±0.00	0.17±0.00	0.16±0.00
	Conv	0.15±0.00	0.18±0.00	0.15±0.01	0.16±0.00	0.17±0.00	0.17±0.00	0.16±0.00
	Cultivar Mean	0.16±0.00 CD	0.17±0.00 AB	0.15±0.00 D	0.16±0.00 BC	0.18±0.00 A	0.17±0.00 AB	
Linolenic acid	Organic	0.08±0.00	0.07±0.00	0.08±0.00	0.08±0.00	0.09±0.00	0.08±0.00	0.08±0.00
	Conv	0.08±0.00	0.07±0.00	0.08±0.00	0.08±0.00	0.09±0.00	0.08±0.00	0.08±0.00
	Cultivar Mean	0.08±0.00 AB	0.07±0.00 C	0.08±0.00 BC	0.08±0.00 BC	0.09±0.00 A	0.08±0.00 B	
∑SFA	Organic	8.18±0.18	8.07±0.18	8.32±0.25	8.20±0.18	7.95±0.18	7.83±0.14	8.09±0.07
	Conv	8.17±0.18	7.98±0.18	8.27±0.25	8.35±0.18	7.70±0.18	7.86±0.14	8.05±0.07
	Cultivar Mean	8.17±0.13 AB	8.02±0.13 ABC	8.30±0.18 A	8.28±0.13 A	7.82±0.13 BC	7.85±0.10 C	
∑MUFA	Organic	81.97±0.67	82.59±0.67	84.69±0.97	82.36±0.69	82.22±0.69	81.84±0.56	82.61±0.30
	Conv	83.64±0.67	82.48±0.67	84.53±0.97	82.77±0.69	81.87±0.69	82.30±0.56	82.93±0.30
	Cultivar Mean	82.81±0.49	82.53±0.49	84.61±0.69	82.56±0.49	82.05±0.49	82.07±0.40	
∑PUFA	Organic	9.84±0.70	9.33±0.70	6.99±0.98	9.43±0.69	9.83±0.69	10.34±0.57	9.30±0.30
	Conv	8.19±0.70	9.54±0.70	7.18±0.98	8.88±0.69	10.43±0.69	9.84±0.57	9.01±0.30
	Cultivar Mean	9.02±0.49 A	9.44±0.49 A	7.09±0.69 B	9.16±0.49 A	10.13±0.49 A	10.09±0.40 A	
∑UFA	Organic	91.82±0.13	91.93±0.26	91.68±0.09	91.80±0.29	92.05±0.13	92.17±0.12	91.91±0.07
	Conv	91.83±0.05	92.02±0.23	91.73±0.15	91.65±0.17	92.30±0.11	92.14±0.15	91.95±0.07
	Cultivar Mean	91.83±0.13 BC	91.98±0.13 ABC	91.71±0.18 C	91.73±0.13 C	92.18±0.13 AB	92.16±0.10 A	

[a] Values are expressed as mean ± standart error. Tombul n= 9; Foşa, Sivri, Palaz n= 6; Mincane n= 3. Values in the same parameters and column with different lower-case are significantly different (P< 0.05). Values in the same row with different capital letters are significantly different (P< 0.05).

Samman *et al*. (2008) reported that the production methods of coconut, olive, canola, mustard seeds and sesame oils have no consistent effect on the fatty acid profile. The highest content of fatty acids in all hazelnut varieties observed for MonoUnsaturated Fatty Acids (MUFA) ranged from 82.05% (Sivri) to 84.61% (Mincane). It was determined that the oleic acid (81.64-84.21%) was the most abundant MUFA fatty acid. PolyUnsaturated Fatty Acids (PUFAs) were the second most common and their rates varied between 7.09-10.13%. Linoleic acid was the most abundant PUFA and it ranged between 10.04% (in Sivri)-7.02% (in Mincane). There was a significant difference in terms of Unsaturated Fatty Acids (UFA) between varieties. Significant differences were observed among the varieties in terms of Saturated Fatty Acids (SFA), with the highest rate in Mincane (8.30%) and the lowest in Tombul (7.85%). In all varieties, the highest amount of saturated fatty acid was palmitic acid, the highest amount of which was found in Mincane (5.72%) and the lowest in Sivri (5.17%); and stearic acid varied from 2.41 to 2.67%.

According to Tüfekci and Karataş (2018), predominant fatty acid in hazelnut was oleic acid (82.35%), followed by linoleic acid (9.10%), palmitic acid (5.18%) and stearic acid (2.56%) and these results were similar to our results. Safari and Alizadeh (2007) reported that oleic acid was the major fatty acid (76.21%) in hazelnut grown in İran. According to Alasalvar *et al*. (2010), oleic acid content was 77.77-86.91%, linoleic acid content 3.86-13.77%, palmitic acid 5.00-6.62% and stearic acid 2.08-3.31% in Turkish hazelnuts. Taş and Gökmen (2015) stated that the ΣSFA changed between 7.49% and 10.75% and the ΣUFA changed between 87.9% and 91.1%. In another study, among Sivri, Mincane, Tombul, Palaz, Foşa and Çakıldak varieties, the results of the highest and the lowest values were found as; palmitic acid 6.35% (Palaz) and 5.58% (Sivri), stearic acid 3.00% (Tombul) and 2.19% (Çakıldak), oleic acid 84.11% (Mincane, Palaz) and 81.80% (Foşa), linoleic acid 9.07% (Foşa) and 6.07% (Palaz) (Kıralan *et al*., 2015).

The Atherogenic (AI) and Thrombogenic Indexes (TI) are given in Table 2. While the type of production method has no consistent effect on AI and TI values, the variety factor has been effective on AI. The highest AI value was found in Mincane (0.25) and the lowest in Sivri (0.22). TI value was found to vary between 0.17-0.18. AI and TI are used to determine the lipid quality of foods, since low (near zero) AI and TI values are desirable for human health, particularly for the prevention of coronary diseases (Bezerra *et al*., 2017). Due to the low AI and TI values, Sivri hazelnut is important in this regard.

Tocopherol Compositions of Organic and Conventional Hazelnuts

In terms of tocopherol profile of hazelnut oil, the chromatograms of all hazlnut varieties showed great similarity. A typical chromatogram showing the tocopherol profile of hazelnut oil is given in Figure 1. Tocopherol compositions of hazelnuts grown by organic and conventional methods are given in Table 3. The total tocopherol content of organic hazelnuts was determined as 477.31 mg kg^{-1} fat and the conventional ones as 480.71 mg kg^{-1} fat, and the difference was not significant ($P>0.05$). The varietal factor was effective on total tocopherol ($P<0.05$), and the highest amount of tocopherol was found in Mincane (549.73 mg kg^{-1} fat) and lowest in Palaz (451.95 mg kg^{-1} fat). No research was found in the literature on the amount of tocopherols in organic hazelnuts. According to the report of Taş and Gökmen (2015), the total tocopherol amount of Turkish hazelnuts vary between 194-412 mg kg^{-1} fat. Alasavar *et al*. (2009) found 463 mg kg^{-1} fat total tocopherol in Tombul and 426.5 mg kg^{-1} fat in Sivri. Köksal *et al*. (2006) reported total tocopherol content as follows: 272 mg kg^{-1} fat in Çakıldak, 249 mg kg^{-1} fat in Foşa, 226

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Table 2. Atherogenic and thrombogenic indexes of organic and conventional hazelnuts.[a]

Parameters	Cultivar Agr Meth	Çakıldak	Foşa	Mincane	Palaz	Sivri	Tombul	Agr Meth mean
Atherogenic İndex	Organic	0.25±0.00	0.23±0.00	0.25±0.01	0.24±0.00	0.23±0.00	0.23±0.00	0.24±0.00
	Conv	0.24±0.00	0.22±0.00	0.25±0.01	0.24±0.00	0.22±0.00	0.22±0.00	0.23±0.00
	Cultivar Mean	0.24±0.00 A	0.23±0.00 B	0.25±0.00 A	0.24±0.00 A	0.22±0.00 B	0.23±0.00 B	
Trombogenic İndex	Organic	0.17±0.00	0.17±0.00	0.18±0.01	0.17±0.00	0.17±0.00	0.17±0.00	0.17±0.00
	Conv	0.17±0.00	0.17±0.00	0.18±0.01	0.18±0.00	0.16±0.00	0.17±0.00	0.17±0.00
	Cultivar Mean	0.17±0.00	0.17±0.00	0.18±0.00	0.18±0.00	0.17±0.00	0.17±0.00	

[a] Values are expressed as mean ± standart error. Tombul n= 9; Foşa, Sivri, Palaz n= 6; Mincane n= 3. Values in the same parameters and column with different subscripts are significantly different (P< 0.05). Values in the same row with different capital letters are significantly different (P< 0.05).

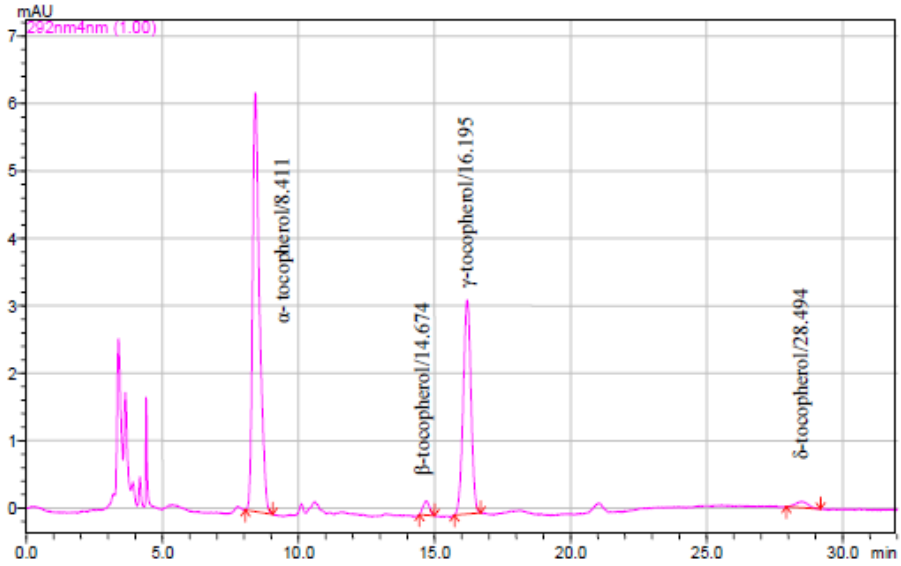

Figure 1. A sample from HPLC chromatograms showing tocopherol composition (α, β, γ, δ tocopherol) in Tombul hazelnut samples.

mg kg^{-1} fat in Mincane, 275 mg kg^{-1} fat in Palaz, 283 mg kg^{-1} fat in Sivri, and 414 mg kg^{-1} fat in Tombul.

Factors such as variety, geographical origin, cultivation practices, fertilizer use, harvesting time, climate, light, temperature, humidity and storage conditions are thought to be effective on fatty acids and tocopherol compositions of hazelnuts (Alasalvar *et al.*, 2003b; Amaral *et al.*, 2006; Oliveira *et al.*, 2008). Venkatachalam and Sathe (2006) argued that genetic factors and environmental conditions could change the distribution of fatty acids. In our study, differences in the distribution of fatty acids profile and tocopherol of hazelnut varieties are thought to be caused by genetic factors, climate, and soil type.

Total Amount of Phenolics and Antioxidant Activity in Organic and Conventional Hazelnuts

Antioxidant activity, measured by DPPH method, and the total amount of phenolics of hazelnuts grown by organic and conventional methods are given in Table 4.

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Table 3. Tocopherol compositions of organic and conventional hazelnuts (mg kg^{-1} oil).[a]

Tocopherol	Cultivar / Agr meth	Çakıldak	Foşa	Mincane	Palaz	Sivri	Tombul	Agricultural method mean
α-Tocopherol	Organic	341.01±32.01	342.87±32.01	371.51±45.39	310.48±32.09	350.28±32.09	320.09±26.02	339.37±13.81
	Conv	319.63±32.01	317.45±32.01	419.24±45.38	330.45±32.09	364.28±32.09	319.19±26.20	345.04±13.81
	Cultivar Mean	330.32±22.69	330.16±22.69	395.37±32.09	320.47±22.69	357.28±22.70	319.65±18.53	
β- Tocopherol	Organic	29.47±1.24	31.23±1.24	30.33±1.76	27.27±1.24	31.12±1.24	29.40±1.01	29.80±0.53
	Conv	30.69±1.24	30.17±1.24	29.70±1.76	28.08±1.24	31.12±1.24	28.54±1.01	29.72±0.53
	Cultivar Mean	30.08±0.88	30.70±0.88	30.01±1.24	27.68±0.88	31.12±0.88	28.97±0.72	
γ- Tocopherol	Organic	82.10±12.89	57.28±12.89	106.29±18.23	94.45±12.89	88.26±12.89	76.90±10.53	84.21±5.54
	Conv	74.83±12.89	84.07±12.89	92.44±18.23	63.34±12.89	77.33±12.89	93.44±10.53	80.91±5.55
	Cultivar Mean	78.47±9.11	70.67±9.12	99.36±12.90	78.89±9.12	82.80±9.11	85.17±7.44	
δ- Tocopherol	Organic	21.20±1.80	24.27±1.80	25.03±2.56	25.26±1.81	25.47±1.80	22.28±1.47	23.92±0.78
	Conv	25.64±1.80	25.35±1.80	24.93±2.56	24.57±1.81	24.60±1.80	25.20±1.47	25.05±0.78
	Cultivar Mean	23.42±1.28	24.81±1.28	24.98±1.81	24.91±1.28	25.04±1.28	23.74±1.04	
Total tocopherol	Organic	473.77±25.99	455.65±25.99	533.15±36.77	457.46±26.00	495.13±26.00	448.68±21.23	477.31±11.19
	Conv	450.79±25.99	457.03±25.99	566.30±36.77	446.43±26.00	497.34±26.00	466.38±21.23	480.71±11.19
	Cultivar Mean	462.28±18.38 B	456.34±18.38 B	549.73±26.00 A	451.95±18.38 B	496.24±18.38 AB	457.53±15.01 B	

[a] Values are expressed as mean±standart error. Tombul n= 9; Foşa, Sivri, Palaz n= 6; Mincane n= 3. Values in the same parameters and column with different lower-case are significantly different (P< 0.05). Values in the same row with different capital letters are significantly different (P< 0.05).

Table 4. Total amount of phenolics and antioxidant activities in organic and conventional hazelnuts.[a]

Parameters	Cultivar / Agr meth	Çakıldak	Foşa	Mincane	Palaz	Sivri	Tombul	Agricultural method mean
Total phenolics (mg 100 g^{-1} GAE)	Organic	591.94±43.27	257.78±43.27	215.56±61.19	331.11±43.27	301.67±43.27	389.44±35.32	347.91±18.61
	Conv.	501.11±43.27	277.50±43.27	271.67±61.19	385.83±43.27	293.06±43.27	392.22±35.33	353.56±18.61
	Cultivar Mean	546.53±30.60 A	267.64±30.60 D	243.61±43.27 D	358.47±30.60 BC	297.36±30.60 CD	390.83±24.98 B	
%DPPH	Organic	49.81±4.28	20.91±4.28	14.60±6.06	21.89±4.28	21.84±4.28	31.50±3.50	26.76±1.84
	Conv.	47.87±4.28	19.10±4.28	12.07±6.06	33.12±4.28	21.50±4.28	36.25±3.50	28.32±1.84
	Cultivar Mean	48.84±3.03 A	20.00±3.03 CD	13.33±4.28 D	27.50±3.03 BC	21.67±3.03 CD	33.87±2.47 B	

[a] Values are expressed as mean ± standart error. Tombul n= 9; Foşa, Sivri, Palaz n= 6; Mincane n= 3. Values in the same parameters and column with different lower-case are significantly different (P< 0.05). Values in the same row with different capital letters are significantly different (P< 0.05).

The amounts of phenolics in organic hazelnuts were determined as 347.91 mg 100 g^{-1} GAE and those of conventional ones as 353.56 mg 100 g^{-1} GAE, but the difference was not significant (P> 0.05). In contrasr, it was determined that the effect of the variety factor on the amount of phenolics in hazelnuts was significant: the highest amount was found in Çakıldak (546.53 mg 100 g^{-1} GAE) and the lowest in Mincane (243.61 mg 100 g^{-1} GAE) (P< 0.0001). According to Pelvan *et al*. (2012), the total amount of phenolic substances in Çakıldak, Foşa, Mincane, Palaz, Sivri and Tombul was 246, 178, 337, 727, 486, 432 mg 100 g^{-1} GAE, respectively. According to Pelvan *et al*. (2018), the total amount of phenolics in Tombul hazelnut was 171 mg 100 g^{-1} GAE. The percentage of radical scavenging activity of the organic nuts was found to be 26.76% and for conventional nuts 28.32%, with no difference between them (P> 0.05). In parallel with the total amount of phenolic substances, the highest antioxidant capacity was in Çakıldak (48.84%) and the lowest in Mincane (13.33%). Altun *et al*. (2011) reported that scavenging activity was 55, 52, 57, 53, 54 and 42% in Foşa, Mincane, Palaz, Çakıldak, Sivri and Tombul, respectively. Arcan and Yemenicioğlu (2009) reported that the total amount of phenolics in organic walnut was 538 mg 100 g^{-1} GAE and conventional walnut had 589 mg 100 g^{-1} GAE, not significantly different.

The use of different solvent and extraction techniques in the extraction of antioxidant components of foods makes it difficult to compare the results of studies on the antioxidant capacities of foods (Tsao and Deng, 2004). Genetic, variety, soil structure, growing conditions, maturity level, and post-harvest conditions affect the antioxidant activities and the amount of phenolic compounds in plant foods and conditions that put the plant into stresses such as pathogenic attack, exposure to ultraviolet light, and heat change, which have an increasing effect (Wu *et al*., 2004, Faller and Fialho, 2009). The differences with the literature values are thought to originate from reasons outside the variety. In addition, Çakıldak hazelnut is common in high regions, where there is danger of spring late frost due to late foliation feature (Balık *et al*., 2016). The reason for the high content of phenolics and antioxidant capacity of Çakıldak may be due to the stress conditions such as cold and heat change.

CONCLUSIONS

Fatty acids and tocopherol profiles, antioxidant activity, and phenolics contents of six commercially important hazelnut cultivars grown by organic and conventional methods were extensively analyzed. Results showed that variety factor influenced many features. It was determined that oleic acid was the highest fatty acid in all varieties and linoleic, palmitic, and stearic acids followed. The atherogenic index was found to be quite low in Sivri. *α-, β-, γ-* and *δ*-tocopherol were detected in all varieties and the dominant tocopherol was α-tocopherol. It is thought that Çakıldak has higher antioxidant activity and phenolics content than other varieties because it is exposed to stress-producing factors such as heat change and cold. It was found that the production method did not significantly affect the studied parameters, except content of palmitoleic acid, and the fatty acids, tocopherol, phenolics, and antioxidant properties of organic hazelnuts were equal to the conventional ones, contrary to what is expected. Considering the damage of conventional agriculture to the environment and the producer's health, it will be beneficial to support organic farming.

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اسیدهای چرب، توکوفرل، و محتوای فنولی فندق ارگانیک وفندق کاشت معمول

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چکیده

هدف این پژوهش تعیین محتوای فنولی و فعالیت آنتی اکسیدانی و نیز مقدار اسیدهای چرب و توکوفرل فندق(*Corylus avellana*) تولیدشده به روش ارگانیک وبه روشهای رایج بود. نتایج به دست آمده حاکی از بیشتر بودن پالمیتولئیک اسید($P<0.05$) در فندق ارگانیک بود. روش تولید اثری بر پارامترهای دیگر نداشت ولی عامل واریته یا رقم گیاه بر بسیاری از پارامترها اثر گذاشت. در همه واریته ها اولئیک اسید بیشترین مقدار اسید چرب بود و به دنبال آن لینولئیک، پالمیتیک، و استئاریک اسید قرار داشت. کمترین شاخص آتروژنیک (atherogenic index) در واریته Sivri بود و هیچ تفاوتی از نظر شاخص ترومبوژنیک (thrombogenic) مشاهده نشد($P<0.05$). در همه واریته ها مواد β, γ, δ-tocopherol تشخیص داد شد و α-tocopherolماده غالب بود. بیشترین مقدار توکوفرل در واریته Mincane (به مقدار 549.73میلی گرم در یک کیلو گرم چربی) مشاهده شد. بیشترین مقدار مواد فنولی (546.53 mg 100 g^{-1} GAE) و فعالیت آنتی اکسیدانی (۴۸/۸۴٪) در واریته Çakıldak دیده شد که احتمالا به علت این بود که این واریته در معرض تنش در مناطق مرتفع و سرد قرار داشت. نتایج تجزیه های گسترده نشان داد که فندق ارگانیک از نظر پارامترهای مطالعه شده در این پژوهش هیچ اختلاف معناداری با فندق کشت شده به روش های رایج و معمولی نداشت.

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