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Full Length Research Paper

Effect of altitude on fatty acid composition in Turkish hazelnut (*Coryllus avellana* L.) varieties

Ömer Beyhan[1]*, Mahfuz Elmastaş[2], Nusret Genc[2] and Hüseyin Akşit[2]

[1]Sakarya University, Vocational School of Akyazı, 54400-Sakarya-TURKEY.
[2]Gaziosmanpaşa University, Faculty of Science and Arts, Department of Chemistry 60240-Tokat-TURKEY.

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The objective of this study was to evaluate the change of fatty acid composition in Delisava, Yomra, Sivri and Karayaglı Turkish hazelnut varieties with altitude. Fatty acid composition were determined by gas chromatography (GC) equiped with flame ionisation detector (FID) after obtained fatty acid methyl esters from crude oil. According to the obtained results, total unsaturated fatty acids (USFA) ranged between 90.71-91.69 as percent. Total USFA composition in Sivri and Karayaglı hazelnut varieties significantly increased with altitude (p≤0.05) and Delisava and Yomra hazelnut varieties increased but not significantly (p≥0.05). Oleic acid ranged from 75.39-82.33%, followed by linoleic acid ranging between 7.85-14.74% of total fatty acid. The remaining 6 unsaturated fatty acids contributed only ranged between 0.85-1.51%. Oleic acid concentration in Sivri, Yomra and Karayaglı varieties increased with altitude as statistical significant (p≤0.05). In Delisava variety, oleic acid content did not change with altitude (p≥0.05). Total saturated fatty acid (SFA) composition in all varieties decreased with altitude (p≤0.05) but the changes in Sivri variety did not significantly (p≥0.05). Palmitic acid and stearic acid were dominant saturated fatty acids (5.99-5.26 and 2.42-3.49%, respectively) in all samples.Tetradecanoic acid (C14:0), pentadecanoic acid (C15:0), heptadecanoic acid (C17:0) and eicosanoic acid (C20:0) concentration did not change with altitude in all varieties as statistical significant (p≥0.05). Stearic acid concentration in all varieties decreased with altitude as statistical significant (p≤0.05). Palmitic acid content in Delisava variety decreased with altitude (p≤0.05); however, haxadecanoic acid content in other varieties did not change with altitude statistically (p≥0.05).

Key words: Hazelnut, altitude, fatty acid, *Coryllus avellana* L., MUFA, PUFA.

INTRODUCTION

Besides being consumed as a fruit, hazelnut is mainly used as an ingredient in confectionary products, as raw materials for food industry especially pastry and chocolate. Also, add to food products such as bakery, cereal and dessert formulations for flavor and texture (Ozdemir and Akinci, 2004). Although, hazelnut is rich in fat, they are generally low in saturated fatty acids (SFA) and high in monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA). Structurally, fatty acids are the straight-chain monounsaturated and polyunsaturated and branched chain building blocks of dietary fats and oils (Wolfrum and Spener, 2000). Linoleic and oleic acids are two long-chain unsaturated fatty acids that are essential for human diets. As such, a lack of dietary essential fatty acid on their inefficient metabolism has been implicated in the etiology and progression of diseases (Brown, 2005). There is evidence that a MUFA rich diet can lower the risk on cardio vascular diseases (CHD) and also has preventive effects on atherosclerosis

*Corresponding authors: E-mail: obeyhan@sakarya.edu.tr or sobeyhan@hotmail.com.Tel: 90 264 419 05 10. Fax: 90 264 419 05 12.

Abbreviations: GC, Gas chromatography**; FID,** flame ionization detector; **USFA,** unsaturated fatty acids; **SFA,** saturated fatty acid; **MUFA,** monounsaturated fatty acid; **PUFA,** polyunsaturated; **CHD,** cardio vascular diseases; **FAMEs,** fatty acid methyl esters; **ANOVA,** analysis of variance.

(Kris-Etherton, 1999; Perez et al., 1999, 2002).There is also a growing interest in evaluating nut's role in a heart-healthy diet and several studies have been made supporting the role for nuts in reducing CHD risk (Fraser et al., 1992; Durak et al., 1999; Sabate et al., 2000; Wolfrum and Spener, 2000).

Ecological conditions, variety, location, and technical and cultural practices can affect the quality and fatty acid composition of hazelnut. Fatty acid compositions of some Turkish hazelnut varieties have been reported and some studies also suggest that protein and fatty contents of hazelnut are influenced by different growing condition (Koyuncu et al., 1997 a, b; Karadeniz and Kup, 1997). Parcerisa et al. reported that the composition of hazelnut oil is influenced by the geographical origin. Hazelnut oil is becoming increasingly popular in nutrition. The main reason behind this demand is its nutritional composition and health-promoting components. Several studies on various chemical and fatty acid contents of hazelnut in Turkey have been reported but the literatures don't contain any information of altitude effect on fatty acid composition. Therefore, the objective of this study was to evaluate the change hazelnut fatty acid composition in Delisava (synonymous names; Çakıldak, Gökfındık), Yomra (synonymous name; Foşa), Sivri (synonymous name; Giresun Sivrisi) and Karayaglı (synonymous name; Kara findik) Turkish hazelnut varieties with altitude.

MATERIALS AND METHODS

Samples

This study was conducted in Sakarya province in Turkey. Sakarya have the annual average temperature of 14.4°C, mean relative humidity of 73.9% while average rainfall was 1016 mm. Hazelnut fruits were obtained from four *Coryllus avellana* L. cultivars: Delisava, Yomra, Sivri, and Karayagli that most widely grown and used varieties in this area (Anonymous, 2010). The samples were collected in different altitude (1:0-200; 2: 200-400 and 3:400-800 m). The samples were dried at 30°C for 24 h after collected harvested season and kept unshelled in a dark room until analysis.

Samples preparation

Before analysis, the hazelnuts were manually cracked and shelled, and then chopped in an appliance mill. For fatty acid analysis, crude oil was obtained from finely chopped nuts extracted with light petroleum ether (b.p. 40–60°C) in a Soxhlet. The solvent was removed by rotary evaporator. The extracted oil was used for fatty acids analysis.

The oils were saponified by the usual procedure according to the Standard IUPAC methods (IUPAC, 1988). Fatty acids were etherified by 10% (v/v) BF3-MeOH as reagent. The fatty acid methyl esters (FAMEs) of total lipids were obtained by transmethylation (AOAC, 1990). The temperature of the injector was 250°C and detector was 260°C. Gas chromatographic (GC) analyses were performed using a Perkin Elmer Clarus 500 Series GC system, in split mode, 50:1, equipped with a flame ionization detector (FID) equipped TR-FAME (Thermo Scientific) apolar capillary column (30 m x 0.25 mm and 0.25 m ID). Helium (0.5 mL/min) was used as carrier gas. The injector temperature was set at 250°C and the FID was operated at 260°C. An initial column oven temperature of 100°C was elevated to 220°C at a rate of 2°C/min and held for 0 min. Identification of fatty acid components was accomplished based on comparison of their retention times with those of authentic standards (Supelco 37 Comp. Fatty acid Mix, 18919). The relative peak area percentages of compounds were calculated based on the FID data.

Statistical analysis

The means of groups were compared through Duncan's Multiple-Range Test after all data were subjected to analysis of variance (ANOVA) (Norusıs, 2002).

RESULTS AND DISCUSSION

The saturated and unsaturated fatty acid compositions of hazelnut samples are given in Tables 1 and Table 2.

Saturated fatty acids (SFA)

Seven SFA were identified and quantitatively analyzed. Total saturated fatty acids ranged between 8.31 and 9.29% (Table 1). While palmitic acid (C16:0) and stearic acid (C18:0) were dominant saturated fatty acids (5.99-5.26 and 2.42-3.49%, respectively) in all samples, C15:0 and C21:0 were found in lowest quantity (0.01-0.026%).

Unsaturated fatty acids

Total unsaturated fatty acids ranged between 90.71 and 91.69% (Table 2). Eight unsaturated fatty acids (USFA) were identified and quantified among which oleic acid (C18:1n9) contributed and ranged between 75.39 and 82.33% to total fatty acid, followed by linoleic acid (C18:2n6) ranged between 7.85 and 14.74% to total. The remaining 6 unsaturated fatty acids contributed only ranged between 0.85 and 1.51% (Table 1, 2).

The total MUFA made up the highest proportion (75.55-82.38 %) of the total fatty acids of samples, whereas the total SFA were small proportion.

The individual fatty acid content is in agreement with previous studies to occur in other hazelnuts cultivars (Parcerisa et al., 1993, 1995, 1997; Ruggeri et al., 1998; Ozdemir et al., 2001; Alasalvar et al., 2003). As expected, MUFA was the main group of fatty acids in hazelnut. However, this relation was not observed for all the cultivars. The ratio of oleic to linoleic acid varied from 5.1 to 10.4 in this study and this can really point to different behaviors for several studies (Parcerisa et al.,

Table 1. Alteration of saturated fatty acid composition (%) with altitude in Turkish hazelnut (*Corylus avellana* L.) varieties.

Hazelnut variety	Altitude	C8:0	C14:0	C15:0	C16:0	C17:0	C18:0	C20:0	Other	Σ SFA
	1	0.15^{a}	0.05	0.01	5.99^{a}	0.06	3.13^{a}	0.01	1.10	9.29^{a}
Delisava	2	0.32^{b}	0.03	0.01	5.71^{a}	0.05	2.99^{a}	0.01	0.99	9.18^{a}
	3	0.43^{b}	0.03	0.02	5.40^{b}	0.05	2.94^{b}	0.02	1.17	8.83^{b}
	SEM	0.017	0.012	0.012	0.069	0.003	0.058	0.024	0.034	0.096
	P	≤0.05	>0.05	>0.05	<0.05	>0.05	<0.05	>0.05	>0.05	<0.05
	1	0.43^{a}	0.04	0.02	5.39	0.07	2.54^{a}	0.02	1.04	8.51
Sivri	2	0.28^{b}	0.03	0.01	5.47	0.06	2.51^{a}	0.02	1.13	8.41
	3	0.23^{b}	0.03	0.01	5.59	0.05	2.42^{b}	0.01	1.01	8.31
	SEM	0.026	0.0026	0.0017	0.059	0.003	0.003	0.002	0.034	0.029
	P	<0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
	1	0.48^{s}	0.03	0.02	5.28	0.05	3.2^{a}	0.02	0.93	9.08^{a}
Yomra	2	0.28^{b}	0.03	0.01	5.27	0.06	2.97^{a}	0.01	1.00	8.63^{b}
	3	0.29^{b}	0.03	0.01	5.38	0.05	2.82^{b}	0.01	0.94	8.59^{b}
	SEM	0.026	0.0036	0.0017	0.059	0.004	0.068	0.0028	0.034	0.12
	P	<0.05	>0.05	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05	<0.05
	1	0.29^{b}	0.03	0.02	5.30	0.06	3.49^{a}	0.01	0.94	9.65^{a}
Karayaglı	2	0.28^{b}	0.04	0.02	5.28	0.06	3.28^{b}	0.01	0.88	8.97^{b}
	3	0.34^{a}	0.03	0.01	5.26	0.05	3.04^{c}	0.01	0.49	8.74^{b}
	SEM	0.026	0.016	0.026	0.039	0.005	0.061	0.021	0.034	0.12
	P	<0.05	>0.05	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05	<0.05

Data are expressed as means ± SE (n = 3) on oil percentages basis. Values within a column with different superscript letters differ significantly (Altitude column 1:0-200 m; 2: 200-400 m; 3:400-800 m).

1995, 1997; Ruggeri et al., 1998; Ozdemir et al., 2001; Alasalvar et al., 2003).

USFA accounted for 90.21% of the total fatty acids in the present study. The major fatty acids found in the present study are, in general, comparable to those reported in the literature on different hazelnut varieties (Parcerisa et al., 1995; Maguire et al., 2004; Amaral et al., 2006a; Amaral et al., 2006b; Alasalvar et al., 2006). However, the composition and amount of fatty acids both between and within the same hazelnut varieties may be influenced by a number of factors such as variety, geographic origin, growing condition, maturity, fertilization, time of harvest season, soil type, climate, latitude, and storage conditions, among others (Savage et al., 1997; Alasalvar et al., 2006).

Beneficial effects of a MUFA-rich diet for human health have been reported (Fraser et al., 1992; Durak et al., 1999). As compared to other nut and vegetable oils, hazelnut oil has been reported to contain the highest proportion of oleic acid (Maguire et al., 2004; Amaral et al., 2006a; Alasalvar et al., 2006). This study shows that hazelnut oil contained trace amount of transfatty acids (0.02%).

This result is in agreement with the report of Amaral et al. (2006b), similar to SFA, the consumption of a high amount of transfatty acids increases LDL cholesterol and decrease HDL cholesterol concentrations, therefore, increasing the risk of heart disease development, stroke, and certain types of cancer, among others (Mensink and Katan, 1990; Gomez et al., 2001; Stender and Dyerberg, 2003).

Change of fatty acids composition with altitude

In this study, the change fatty acid composition in Delisava, Yomra, Sivri and Karayaglı hazelnut varieties was evaluated with altitude. The statistical ANOVA showed that some SFAs (Table1) and USFAs (Table 2) were present in different concentration in all hazelnut variety with different altitude. Tetradecanoic acid (C14:0), pentadecanoic acid (C15:0), heptadecanoic acid (C17:0) and eicosanoic acid (C20:0) concentration have not changed with altitude in all varieties as statistical significant (Table 1). While caprylic acid (C8:0) content in Delisava and Karayaglı varieties increased; Sivri and

Table 2. Alteration of unsaturated fatty acid composition (%) with altitude in Turkish hazelnut (*Coryllus avellana* L.) varieties.

Hazelnut variety	Altitude	C16:1	C18:1 n9t	C18:1 n9c	C20:1	C18:2 n6t	C18:2 n6c	C18:3 n6	C18:3 n3	Σ MUFA	Σ PUFA
	1	0.15	0.01	78.11	0.02	0.01	11.10	0.01	0.20^{a}	78.29	11.32
	2	0.16	0.01	78.44	0.02	0.02	10.95	0.01	0.17^{b}	78.63	11.18
Delisava	3	0.16	0.01	78.03	0.02	0.02	11.63	0.01	0.14^{c}	78.20	11.89
	SEM	0.006	0.006	0.312	0.006	0.006	0.06	0.005	0.004	0.06	0.05
	P	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05
	1	0.14	0.02	75.39^{c}	-	0.02^{c}	14.74^{a}	-	0.15^{a}	75.55^{b}	14.91^{a}
Sivri	2	0.15	0.01	77.34^{b}	-	0.05^{b}	12.76^{b}	-	0.14^{a}	77.50^{b}	12.95^{b}
	3	0.14	0.01	79.85^{a}	-	0.32^{a}	10.26^{c}	-	0.09^{b}	80.00^{a}	10.67^{c}
	SEM	0.005	0.006	0.853	-	0.002	0.022	-	0.003	0.46	0.08
	P	>0.05	>0.05	<0.01	-	<0.01	<0.01	-	<0.01	<0.05	<0.05
	1	0.10	0.02	81.03^{b}	0.09^{a}	0.02	8.69^{a}	0.04^{a}	0.21	81.24	8.75
	2	0.12	0.01	81.25^{b}	0.06^{b}	0.03	8.64^{a}	0.03^{b}	0.23	81.44	8.93
Yomra	3	0.12	0.02	82.21^{a}	0.03^{c}	0.03	7.85^{b}	0.02^{c}	0.2	82.38	8.10
	SEM	0.004	0.006	0.474	0.004	0.006	0.02	0.004	0.005	0.38	0.06
	P	>0.05	>0.05	<0.01	<0.01	>0.05	<0.01	<0.05	>0.05	>0.05	>0.05
	1	0.11	-	79.2^{b}	0.16^{a}	0.01	9.78^{a}	0.07^{a}	0.09^{a}	79.48^{c}	9.94^{a}
	2	0.10	-	80.87^{b}	0.14^{b}	0.01	8.95^{a}	0.06^{b}	0.05^{b}	81.11^{b}	9.07^{b}
Karayaglı	3	0.11	-	82.33^{a}	0.10^{c}	0.02	8.14^{b}	0.05^{c}	0.01^{c}	82.54^{a}	8.22^{c}
	SEM	0.004	-	0.337	0.003	0.004	0.021	0.0037	0.002	0.46	0.07
	P	>0.05	-	<0.05	<0.01	>0.05	<0.01	<0.05	<0.01	<0.05	<0.05

Data are expressed as means ± SE (n = 3) on oil percentages basis. Values within a column with different superscript letters differ significantly (Altitude column 1:0-200 m; 2: 200-400 m; 3:400-800 m).

Yomra varieties decreased with altitude statistically significant (Table 1). Hexadecanoic acid (C16:0) content in Delisava variety decreased with altitude, however, haxadecanoic acid content in other varieties did not change with altitude statistically (Table1). Octadecanoic acid (C18:0) concentration in all varieties decreased with altitude as statistical significant (Table 1).

Cis-9-hexadecenoic acid (C16:1; n: 7), tr-9-octadecenoic acid (trC18:1; n:9) and tr-6-Linoelaidic acid (trC18:2; n:6) content in all varieties did not change with altitude (Table 2). While 6,9,12-octadecatrienoic acid (C18:3; n:6) content was not detected in Sivri variety; this fatty acid content in Delisava variety did not change with altitude. However, the content of this fatty acid decreased with altitude as statistical significant in Yomra and Karayaglı varieties (Table2).

Cis-9-Octadecenoic acid (C18:1; n:9) concentration in Sivri, Yomra and Karayaglı varieties increased with altitude as statistical significant. In Delisava variety, Cis-9-Octadecenoic acid (C18:1; n:9) content did not change with altitude. Cis-11-Eicasenoic acid (C20:1; n:9) content was not detected in Sivri variety. In Delisava variety, cis-11-Eicasenoic acid (C20:1; n:9) content did not change with altitude. In Yomra and Karayaglı varieties, the content of cis-11-Eicasenoic acid (C20:1; n:9) decreased with altitude as statistical significant. Cis-9,12-octadecadienoic acid (C18:2; n:6) concentration did not change in Delisava variety with altitude. But the concentration of Cis-9,12-octadecadienoic acid (C18:2; n:6) decreased with altitude in other varieties significantly (Table2). Cis-5,9,12-octadecatrienoic acid (C18:3; n:3) decreased with altitude in Delisava, Sivri and Karayaglı varieties as statistical significant. But in Yomra variety, the content of cis-5,9,12-octadecatrienoic acid (C18:3; n:3) did not change with altitude significantly (Table 2).

It has been well established by many authors that fatty acid composition of olive oil had been strongly influenced by cultivar (Tsimidou and Karakostas, 1993). Maturation stage of fruit (Koyuncu et al., 1997a, b) and the zone of origin, characterized by certain pedoclimatic factors as well as other minor areal parameters have been changed the fatty acid composition of hazelnut (Parcerisa et al., 1993; Karadeniz and Kup, 1997). But there was not well evaluated effect of altitude on hazelnut fatty acid profile. In the present study, USF composition in Sivri and Karayaglı hazelnut varieties significantly increased with altitude and in Delisava and Yomra hazelnut varieties increased but not significantly (Table 2). SFA composition in all varieties decreased but in Sivri variety not significantly (Table 1).

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