Europ.J.Hort.Sci., **75** (2). S. 77–84, 2010, ISSN 1611-4426. © Verlag Eugen Ulmer KG, Stuttgart

Biochemical Content of Hazelnut (*Corylus avellana* L.) Cultivars from West Black Sea Region of Turkey

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Summary

Twelve hazelnut cultivars taken from Bolu-Akçakoca, West Black Sea Region of Turkey, were evaluated in terms of bioactive properties such as fat and fatty acid composition, protein and amino acid, water-soluble and water-insoluble vitamins, ash and mineral content at 2 consecutive years. Considerable differences were observed among cultivars for all properties ($P \leq 0.05$) with the exception of palmitoleic acid, leucine and threonine content ($P \geq 0.05$). In all cultivars, fat was the predominant component (56.45–64.11 %) followed by oleic acid (80.59–85.64 %), glutamic acid (2.342–3.543 g 100 g^{-1}), arginin (1.310–2.366 g 100 g^{-1}), α-tocopherol (19.24–378.80 mg 100 g^{-1}), ascorbic acid (1.430–3.207 mg 100 g^{-1}), potassium contents (560.20–893.90 mg 100 g^{-1}).

Key words. *Corylus avellana* L. – amino acids – fatty acids – vitamins – mineral composition

Introduction

Hazelnut kernels have been consumed all over the world either as natural, blanched and roasted or as processed food products such as chocolates, dairy, bakery, candy etc. for a long time. They are rich in unsaturated fatty acids (50–73 %) (Garcia et al. 1994; Köksal et al. 2006), phytosterols (Amaral et al. 2006a) and antioxidant phenols, which are assumed to help control adverse effects on hypertension (Alasalvar et al. 2006) and to decrease blood cholesterol (Plat and Mensink 2001). They also have phytochemical compounds such as vitamin B_1, B_6 and α-tocopherol (Amaral et al. 2006b, c; Köksal et al. 2006), carbohydrates, small quantities of organic acids and dietary fiber (Botta et al. 1994; Alasalvar et al. 2003). It has been recently reported that hazelnut extracts revealed a high antimicrobial activity against gram positive bacteria (Oliviera et al. 2008). This is the reason of why hazelnuts are considered as a functional fruit in recent years.

Nowadays, due to suitable growing conditions and as the centre of genetic origin of this species, Turkey has the largest share of hazelnut export (60 %) in the world, and is the biggest hazelnut producer supplying ca. 65 % of total world production followed by Italy, USA and Azerbaijan (Fao 2006). In Turkey, although hazelnuts are grown commercially in Black Sea Region, especially east part, 31.4 % of production is obtained from the West Black Sea region (Anonymous 2009). There are some studies on nutritional value of some hazelnut cultivars but most of them are focused on the cultivars grown in the East Black Sea Region (Ayfer et al. 1997; Özdemir et al. 2001; Alasalvar et al. 2003, 2006; Ozdemir and Akinci 2004; Köksal et al. 2006). In some studies, it was revealed that composition of hazelnut fruit regarding vitamin and mineral content could be influenced by geographical factors (Dundar and Altundag 2004; Amaral et al. 2006b, c). As mentioned above, very limited data are available on the nutritional value of cultivars grown in West Black Sea region (Açkurt et al. 1999; Dundar and Altundag 2004), determination of biochemical content of 12 cultivars grown in this region was mainly aimed in the present research. Additionally, it was aimed to find the reason of differences among the ecological regions by compairing previous findings reported (Köksal et al. 2006) on the same cultivars grown in the East Black Sea region.

Materials and Methods

Plant material

The unshelled nuts of 12 hazelnut (*Corylus avellana* L.) cultivars, such as 'Acı', 'Cavcava', 'Çakıldak', 'Foşa', 'Kalınkara', 'Karafındık', 'Mincane', 'Palaz', 'Sivri', 'Tombul', 'Uzunmusa' and 'Yassıbadem', were harvested at commercial harvest time from the same commercial orchard in Bolu-Akçakoca county located in West Black Sea region of Turkey during 2005 and 2006 period.

Methods

Total fat was extracted with n-hexane (60 °C) for 6 h by using Soxhlet extractor. Protein content determined by micro-Kjeldahl (James 1995) was calculated as total Nx 6.25. Fatty acid composition was analyzed as soon as possible after extraction procedure by gas chromatography (GC) (Thermo Quest, 2000) equipped with a

flame ionization detector and a fused silica capillary column (23.30 m × 0.25 mm × 25 μm film thickness) on fatty acid methyl esters prepared from hazelnut oil (AOCS 1990). Amino acids were extracted and analyzed without storing by high pressure liquid chromatography (HPLC) (Shimadzu LC 10 ADVP, SCL 10 AVP) according to SHUSTER (1988). Water-soluble and water-insoluble vitamins were determined without storing of aliquots by HLPC as in RIZZOLO et al. (1991) and YAO et al. (1992), respectively. All HPLC and GC peaks for each compound was identified by comparing the retention times of external standards (Sigma-Aldrich-Fluka Co. Ltd.). Total ash was measured as in KÖKSAL et al. (2006). Mineral composition was investigated by atomic absorption spectrophotometer (Varian Spectr AA-400 Plus). Phosphorus was spectrophotometrically analyzed in the form of vanadium phosphomolybdate (JAMES 1995). All analyses were completed within two weeks as soon as possible after harvest. During this period fruits were stored as inshell at room temperature conditions.

Statistics

This research was based on completely randomized experimental design over two years (2005, 2006). All analyses were conducted in triplicate for each cultivar and each replication included 100 fruits. Data were presented as average values of years ± standard error of mean for each cultivar. Analysis of variance (Anova) was performed on means of years by Minitab Statistical software (MINITAB INC. 814-238-3280) at $P \leq 0.05$ error level. Means were compared with Duncan's Multiple Range Test ($P \leq 0.05$) by using MSTAT–C software and differences were marked by letters.

Table 1. Total fat content and fatty acid composition of hazelnut cultivars. Values are mean of years± standard error of mean.

Cultivar	Total fat (%)	Fatty Acids (%)			
		Stearic C18:0	Oleic C18:1	Linoleic C18:2	Linolenic C18:3
'Acı'	57.36 ± 0.35 def+	1.84 ± 0.04 bcd	84.20 ± 0.23 bc	8.76 ± 0.17 bc	0.07 ± 0.02 b
'Cavcava'	56.45 ± 1.39 f	1.99 ± 0.04 bc	80.59 ± 0.26 d	11.59 ± 0.16 a	0.14 ± 0.04 b
'Çakıldak'	62.57 ± 0.82 ab	2.14 ± 0.02 b	84.23 ± 0.57 bc	7.73 ± 0.46 c	0.47 ± 0.19 a
'Foşa'	59.35 ± 0.50 cde	1.69 ± 0.05 cd	83.72 ± 0.19 c	9.43 ± 0.10 b	0.10 ± 0.03 b
'Kalınkara'	62.39 ± 1.07 ab	1.66 ± 0.06 cd	84.27 ± 0.57 abc	9.07 ± 0.45 b	0.10 ± 0.02 b
'Karafındık'	60.02 ± 0.29 bcd	1.87 ± 0.04 bcd	85.21 ± 0.46 ab	7.89 ± 0.23 c	0.14 ± 0.04 b
'Mincane'	61.78 ± 0.98 abc	2.54 ± 0.10 a	84.80 ± 0.76 abc	7.72 ± 0.71 c	0.15 ± 0.05 b
'Palaz'	61.76 ± 1.07 abc	2.12 ± 0.16 b	85.64 ± 0.58 a	6.61 ± 0.27 d	0.10 ± 0.02 b
'Sivri'	57.29 ± 1.18 ef	1.58 ± 0.01 d	84.69 ± 0.24 abc	8.25 ± 0.40 bc	0.08 ± 0.04 b
'Tombul'	64.11 ± 0.76 a	2.02 ± 0.30 bc	83.81 ± 0.32 bc	8.74 ± 0.51 bc	0.11 ± 0.02 b
'Uzunmusa'	60.89 ± 0.27 bc	1.82 ± 0.05 bcd	84.16 ± 0.12 bc	8.31 ± 0.02 bc	0.11 ± 0.01 b
'Yassıbadem'	57.53 ± 0.45 def	1.54 ± 0.03 d	81.51 ± 0.11 abc	11.57 ± 0.17 a	0.13 ± 0.01 b
Mean	60.13 ± 0.76	1.90 ± 0.07	83.90 ±0.37	8.81 ± 0.30	0.14 ± 0.04

Cultivar	Fatty Acids (%)		Saturated (%)	Unsaturated (%)	Unsaturated/ Saturated (%)
	Palmitic C16:0	Palmitoleic C16:1			
'Acı'	4.79 ± 0.05 bcd	0.35 ± 0.01 NS	6.63 ± 0.04 bcde	93.37 ± 0.07 abcd	14.09 ± 0.09 abc
'Cavcava'	5.26 ± 0.08 a	0.43 ± 0.05 NS	7.25 ± 0.12 a	92.75 ± 0.20 e	12.79 ± 0.22 d
'Çakıldak'	5.14 ± 0.12 ab	0.29 ± 0.04 NS	7.28 ± 0.14 a	92.72 ± 0.24 e	12.75 ± 0.26 d
'Foşa'	4.73 ± 0.06 cd	0.34 ± 0.04 NS	6.41 ± 0.06 de	93.59 ± 0.11 ab	14.60 ± 0.15 ab
'Kalınkara'	4.55 ± 0.10 d	0.34 ± 0.05 NS	6.21 ± 0.08 e	93.79 ± 0.14 a	15.10 ± 0.21 a
'Karafındık'	4.56 ± 0.15 d	0.33 ± 0.04 NS	6.44 ± 0.18 cde	93.56 ± 0.32 abc	14.56 ± 0.44T ab
'Mincane'	4.55 ± 0.19 d	0.24 ± 0.06 NS	7.09 ± 0.24 ab	92.91 ± 0.42 de	13.14 ± 0.47 cd
'Palaz'	5.24 ± 0.18 a	0.29 ± 0.03 NS	7.37 ± 0.31 a	92.63 ± 0.55 e	12.63 ± 0.61 d
'Sivri'	4.99 ± 0.16 abc	0.40 ± 0.02 NS	6.57 ± 0.16 bcde	93.43 ± 0.28 abcd	14.23 ± 0.37 abc
'Tombul'	4.88 ± 0.08 abcd	0.43 ± 0.12 NS	6.90 ± 0.38 abcd	93.10 ± 0.66 bcde	13.58 ± 0.77 bcd
'Uzunmusa'	5.23 ± 0.05 a	0.37 ± 0.08 NS	7.04 ± 0.06 abc	92.96 ± 0.10 cde	13.20 ± 0.12 cd
'Yassıbadem'	4.76 ± 0.17 bcd	0.49 ± 0.05 NS	6.30 ± 0.15 de	93.70 ± 0.25 ab	14.88 ± 0.37 a
Mean	4.89 ± 0.11	0.36 ± 0.05	6.79 ± 0.16	93.21 ± 0.28	13.80 ± 0.34

NS: Not significant
+Means in the column followed by the same letters are not significantly different at P≤0.05

Results

Total fat content and fatty acid composition

The highest fat content, being averagely higher than 50 %, determined in 'Tombul' (64.11 %) was not considerably different from 'Çakıldak', 'Kalınkara', 'Mincane', 'Palaz'. The lowest fat level was measured in 'Cavcava' (56.45 %). Six fatty acids were identified, among which oleic acid by far the most abundant one was followed by linoleic, palmitic, stearic, palmitoleic, and linolenic acids (Table 1). Cultivars showed significant differences based on each fatty acid content, with the exception of palmitoleic acid ($P \leq 0.05$) (Table 1). While palmitic acid ranged from 4.55 % ('Kalınkara' and 'Mincane') to 5.26 % ('Cavcava'), palmitoleic acid changed between 0.24 % ('Mincane') and 0.49 % ('Yassıbadem'). Significantly highest stearic acid amount was determined in 'Mincane' (2.54 %). All hazelnut cultivars contained oleic acid averagely at a rate of 83.90 % and significantly higher value was measured in 'Palaz' (85.64 %). 'Cavcava' (11.59 %) and 'Yassıbadem' (11.57 %) cultivars presented significantly the highest linoleic acid while 'Palaz' had the lowest one (6.61 %) ($P \leq 0.05$). In the current research, significantly the highest linolenic acid content was found in 'Çakıldak' (0.47 %). 'Palaz' had significantly the highest saturated fatty acid content (7.37 %) ($P \leq 0.05$), but it had significantly the lowest unsaturated fatty acid content. The lowest saturated fatty acid amount was determined in 'Kalınkara' (6.21 %).

Protein and non-essential amino acids

Considerable differences were observed among the cultivars regarding protein content ($P \leq 0.05$) (Table 2). 'Yassıbadem' (18.69 %) and 'Mincane' (18.47 %) had

Table 2. Protein content and non-essential amino acid composition of hazelnut cultivars. Values are mean of years ± standard error of mean.

Cultivar	Protein (N x 6.25) (%)	Non-essential amino acids (g 100 g^{-1})		
		Glutamic Acid	Aspartic acid	Alanine
'Acı'	14.68 ± 0.08 ef+	2.575 ± 0.06 cde	1.460 ± 0.01 c	0.830 ± 0.03 ab
'Cavcava'	16.39 ± 0.22 cd	2.483 ± 0.10 de	1.461 ± 0.02 c	0.712 ± 0.04 cd
'Çakıldak'	17.31 ± 0.38 b	2.364 ± 0.02 e	1.421 ± 0.03 c	0.741 ± 0.01 c
'Foşa'	14.45 ± 0.14 f	2.575 ± 0.16 cde	1.641 ± 0.01 a	0.730 ± 0.01 cd
'Kalınkara'	12.61 ± 0.14 g	2.737 ± 0.13 bcd	1.544 ± 0.02 b	0.749 ± 0.01 c
'Karafındık'	15.87 ± 0.14 d	2.789 ± 0.05 bcd	1.466 ± 0.01 c	0.871 ± 0.01 a
'Mincane'	18.47 ± 0.28 a	3.543 ± 0.04 a	1.638 ± 0.00 a	0.848 ± 0.02 a
'Palaz'	15.21 ± 0.20 e	2.342 ± 0.06 e	1.455 ± 0.02 c	0.674 ± 0.01 d
'Sivri'	15.95 ± 0.13 d	2.912 ± 0.08 b	1.538 ± 0.01 b	0.747 ± 0.02 c
'Tombul'	16.81 ± 0.26 bc	2.876 ± 0.14 bc	1.685 ± 0.01 a	0.744 ± 0.02 c
'Uzunmusa'	17.12 ± 0.12 b	2.985 ± 0.12 b	1.628 ± 0.04 a	0.775 ± 0.02 bc
'Yassıbadem'	18.69 ± 0.16 a	2.877 ± 0.02 bc	1.649 ± 0.01 a	0.726 ± 0.01 cd
Mean	16.13 ± 0.19	2.575 ± 0.08	1.550 ± 0.02	0.760 ± 0.02

Cultivar	Non-essential amino acids (g 100 g^{-1})			
	Serine	Glycine	Proline	Tyrosine
'Acı'	0.849 ± 0.00 a	0.673 ± 0.01 ab	0.529 ± 0.01 de	0.447 ± 0.01 c
'Cavcava'	0.674 ± 0.01 c	0.651 ± 0.02 bc	0.548 ± 0.00 cd	0.438 ± 0.00 c
'Çakıldak'	0.511 ± 0.01 f	0.629 ± 0.01 cd	0.543 ± 0.01 cd	0.441 ± 0.01 c
'Foşa'	0.652 ± 0.00 c	0.547 ± 0.01 f	0.543 ± 0.01 cd	0.570 ± 0.02 a
'Kalınkara'	0.670 ± 0.00 c	0.598 ± 0.01 de	0.840 ± 0.02 a	0.444 ± 0.01 c
'Karafındık'	0.751 ± 0.02 b	0.587 ± 0.01 e	0.654 ± 0.01 b	0.454 ± 0.00 c
'Mincane'	0.727 ± 0.00 b	0.650 ± 0.00 bc	0.570 ± 0.01 c	0.450 ± 0.00 c
'Palaz'	0.727 ± 0.01 b	0.708 ± 0.01 a	0.626 ± 0.01 b	0.436 ± 0.01 d
'Sivri'	0.850 ± 0.01 a	0.643 ± 0.01 bc	0.494 ± 0.00 ef	0.489 ± 0.00 b
'Tombul'	0.618 ± 0.00 d	0.651 ± 0.00 bc	0.535 ± 0.01 d	0.445 ± 0.01 c
'Uzunmusa'	0.573 ± 0.01 e	0.648 ± 0.01 bc	0.553 ± 0.01 cd	0.443 ± 0.01 c
'Yassıbadem'	0.856 ± 0.02 a	0.584 ± 0.01 e	0.467 ± 0.01 f	0.503 ± 0.01 b
Mean	0.700 ± 0.01	0.630 ± 0.01	0.580 ± 0.01	0.460 ± 0.01

+Means in the column followed by the same letters are not significantly different at $P \leq 0.05$.

significantly the highest protein content. 'Foşa' (14.45 %) and 'Acı' (14.68 %) had significantly the lowest protein content (Table 2).

Non-essential amino acid content was significantly different between cultivars ($P \leq 0.05$) (Table 2). Glutamic acid being predominant in all cultivars was the highest in 'Mincane' and lowest in 'Çakıldak', 'Palaz', 'Cavcava', 'Acı' and 'Foşa'. In respect to aspartic acid content, 'Tombul' (1.685 g 100 g^{-1}) had the highest amount and 'Çakıldak' (1.421 g 100 g^{-1}) had trace amount. Alanine content ranged from 0.674 g 100 g^{-1} ('Palaz') to 0.871 g 100 g^{-1} ('Karafındık'). Serine content was the highest in 'Yassıbadem' (0.856 g 100 g^{-1}) and the lowest in 'Çakıldak' (0.511 g 100 g^{-1}). Significantly highest glycine levels were recorded in 'Palaz' (0.708 g 100 g^{-1}), the lower amounts were determined in 'Yassıbadem' (0.584 g 100 g^{-1}) and 'Karafındık' (0.587 g 100 g^{-1}). While 'Kalınkara' had the highest proline amount (0.840 g 100 g^{-1}), 'Yassıbadem' (0.467 g 100 g^{-1}) showed the lowest one ($P \leq 0.05$). Although all cultivars contained tyrosine at trace quantities, 'Foşa' had significantly the highest (0.570 g 100 g^{-1}) and 'Palaz' had the lowest amount (0.436 g 100 g^{-1}).

Essential amino acids

Apart from leucine and threonine, differences among cultivars regarding essential amino acid content were significant and arginine was the predominant one ($P \leq 0.05$) (Table 3). Arginine content ranged from 1.310 g 100 g^{-1} ('Tombul') to 2.366 g 100 g^{-1} ('Çakıldak'). Leucine amount changed from 0.956 g 100 g^{-1} ('Palaz') to 1.257 g 100 g^{-1} ('Cavcava'). While significantly the highest valine content was determined in 'Kalınkara' (0.784 g 100 g^{-1}), the lowest value was measured in 'Mincane' (0.618 g 100 g^{-1}). Trace amount of phenylalanine was present in

Table 3. Essential amino acid compositon of hazelnut cultivars. Values are mean of years ± standard error of mean.

Cultivar	Essential amino acids (g 100 g^{-1})				
	Arginine	Leucine	Valine	Phenylalanine	Isoleucine
'Acı'	2.140 ± 0.10 ab+	1.177 ± 0.06 NS	0.673 ± 0.01 b	0.557 ± 0.01 g	0.567 ± 0. 01 bc
'Cavcava'	1.851 ± 0.30 b	1.257 ± 0.01 NS	0.740 ± 0.01 a	0.653 ± 0.01 de	0.655 ± 0.01 a
'Çakıldak'	2.366 ± 0.16 a	1.194 ± 0.01 NS	0.657 ± 0.01 bc	0.533 ± 0.01 g	0.525 ± 0.01 cd
'Foşa'	1.949 ± 0.18 ab	1.066 ± 0.02 NS	0.652 ± 0.01 bc	0.669 ± 0.05 cde	0.354 ± 0.02 e
'Kalınkara'	2.047 ± 0.10 ab	1.199 ± 0.03 NS	0.784 ± 0.02 a	0.712 ± 0.01 abcd	0.633 ± 0.01 ab
'Karafındık'	1.798 ± 0.12 b	1.145 ± 0.03 NS	0.643 ± 0.02 bc	0.759 ± 0.02 a	0.470 ± 0.02 d
'Mincane'	1.829 ± 0.13 b	1.218 ± 0.05 NS	0.618 ± 0.01 c	0.742 ± 0.02 ab	0.564 ± 0.07 bc
'Palaz'	1.343 ± 0.09 c	0.956 ± 0.04 NS	0.620 ± 0.00 bc	0.738 ± 0.04 abc	0.531 ± 0.05 cd
'Sivri'	2.034 ± 0.07 ab	1.197 ± 0.02 NS	0.644 ± 0.01 bc	0.674 ± 0.00 bcde	0.631 ± 0.01 ab
'Tombul'	1.310 ± 0.07 c	1.097 ± 0.27 NS	0.679 ± 0.03 b	0.567 ± 0.02 fg	0.648 ± 0.01 ab
'Uzunmusa'	2.109 ± 0.13 ab	1.192 ± 0.04 NS	0.626 ± 0.01 bc	0.601 ± 0.02 efg	0.679 ± 0.01 a
'Yassıbadem'	2.197 ± 0.03 ab	1.066 ± 0.09 NS	0.632 ± 0.01 bc	0.633 ± 0.02 ef	0.626 ± 0.01 ab
Mean	1.914 ± 0.12	1.150 ± 0.06	0.660 ± 0.01	0.650 ± 0.02	0.570 ± 0.02

Cultivar	Essential amino acids (g 100 g^{-1})			
	Threonine	Lysine	Histidine	Methionine
'Acı'	0.481 ± 0.03 NS	0.530 ± 0.00 a	0.514 ± 0.03 ab	0.142 ± 0.01 de
'Cavcava'	0.417 ± 0.01 NS	0.504 ± 0.01 ab	0.378 ± 0.01 c	0.147 ± 0.00 de
'Çakıldak'	0.454 ± 0.01 NS	0.457 ± 0.02 bc	0.492 ± 0.02 b	0.130 ± 0.01 f
'Foşa'	0.481 ± 0.03 NS	0.418 ± 0.03 cd	0.367 ± 0.01 c	0.174 ± 0.00 ab
'Kalınkara'	0.419 ± 0.00 NS	0.454 ± 0.02 bc	0.360 ± 0.02 c	0.134 ± 0.00 ef
'Karafındık'	0.461 ± 0.03 NS	0.459 ± 0.03 bc	0.550 ± 0.02 a	0.159 ± 0.01 cd
'Mincane'	0.524 ± 0.01 NS	0.385 ± 0.00 de	0.374 ± 0.01 c	0.128 ± 0.00 f
'Palaz'	0.461 ± 0.03 NS	0.474 ± 0.00 ab	0.531 ± 0.01 ab	0.181 ± 0.01 a
'Sivri'	0.440 ± 0.02 NS	0.379 ± 0.01 de	0.388 ± 0.01 c	0.174 ± 0.01 ab
'Tombul'	0.463 ± 0.02 NS	0.451 ± 0.03 bc	0.335 ± 0.02 c	0.159 ± 0.01 cd
'Uzunmusa'	0.453 ± 0.01 NS	0.453 ± 0.01 bc	0.369 ± 0.01 c	0.166 ± 0.00 bc
'Yassıbadem'	0.467 ± 0.01 NS	0.348 ± 0.02 e	0.566 ± 0.01 a	0.159 ± 0.00 cd
Mean	0.460 ± 0.02	0.440 ± 0.01	0.440 ± 0.01	0.150 ± 0.01

NS: Not significant.
+Means in the column followed by the same letters are not significantly different at $P \leq 0.05$.

Table 4. Water-insoluble vitamin composition of hazelnut cultivars. Values are mean of years± standard error of mean.

Cultivar	Retinol (Vitamin A) (mg 100 g^{-1})	α-Tocopherol (Vitamin E) (mg 100 g^{-1})	γ-Tocopherol (μg 100 g^{-1})	δ-Tocopherol (mg 100 g^{-1})	Total Tocopherol (mg 100 g^{-1})
'Acı'	22.85 ± 0.86 ab^{+}	19.24 ± 0.32 f	–	2.13 ± 0.01 c	21.37 ± 0.33 f
'Cavcava'	20.44 ± 1.62 bc	28.52 ± 6.20 ef	–	1.77 ± 0.04 d	30.29 ± 6.19 ef
'Çakıldak'	11.14 ± 1.04 e	27.16 ± 0.96 ef	0.895 ± 0.05 b	1.30 ± 0.07 e	29.35 ± 0.99 ef
'Foşa'	13.17 ± 0.37 de	29.71 ± 1.66 ef	3.583 ± 0.07 a	1.78 ± 0.04 d	35.07 ± 1.70 ef
'Kalınkara'	19.32 ± 0.57 c	26.75 ± 4.48 ef	–	2.32 ± 0.06 c	29.07 ± 4.49 ef
'Karafındık'	22.26 ± 0.56 ab	29.62 ± 1.25 ef	–	0.93 ± 0.03 f	30.55 ± 1.23 ef
'Mincane'	23.17 ± 0.92 a	276.19 ± 6.29 b	–	1.37 ± 0.05 e	277.56 ± 6.27 b
'Palaz'	14.95 ± 0.83 d	76.00 ± 1.48 d	0.419 ± 0.01 c	3.28 ± 0.11 b	79.69 ± 1.37 d
'Sivri'	5.13 ± 0.27 f	378.80 ± 11.30 a	–	3.56 ± 0.16 a	382.36 ± 11.20 a
'Tombul'	11.78 ± 1.04 e	278.34 ± 1.02 b	–	2.30 ± 0.09 c	280.64 ± 0.93 b
'Uzunmusa'	14.87 ± 0.25 d	130.89 ± 0.98 c	–	2.39 ± 0.03 c	133.28 ± 1.00 c
'Yassıbadem'	12.26 ± 0.53 e	37.17 ± 1.42 e	–	1.12 ± 0.16 ef	38.29 ± 1.26 e
Mean	22.85 ± 0.74	111.53 ± 3.11	1.630 ± 0.04	2.02 ± 0.07	113.96 ± 3.08

–: Not detected by HPLC analysis.
$^{+}$Means in the column followed by the same letters are not significantly different at P≤0.05.

Table 5. Water-soluble vitamin composition of hazelnut cultivars. Values are mean of years± standard error of mean.

Cultivar	Ascorbic acid (Vitamin C) (mg 100 g^{-1})	Niacin (mg 100 g^{-1})	Pyridoxine (Vitamin B_6) (mg 100 g^{-1})	Thiamin (Vitamin B_1) (mg 100 g^{-1})	Riboflavin (Vitamin B_2) (mg 100 g^{-1})	Folic Acid (μg 100 g^{-1})	Biotin (Vitamin H) (mg 100 g^{-1})
'Acı'	1.553 ± 0.069 d^{+}	2.118 ± 0.010 a	0.740 ± 0.003 b	0.316 ± 0.004 f	0.067 ± 0.002 a	46.00 ± 1.15 e	14.00 ± 0.00 b
'Cavcava'	3.133 ± 0.046 a	1.628 ± 0.015 c	0.692 ± 0.002 c	0.237 ± 0.005 g	0.063 ± 0.001 a	25.67 ± 1.20 g	–
'Çakıldak'	3.207 ± 0.044 a	1.459 ± 0.015 e	0.638 ± 0.002 d	0.189 ± 0.003 ı	0.057 ± 0.001ab	48.00 ± 1.73 e	13.33 ± 0.88 b
'Foşa'	2.793 ± 0.083 b	1.807 ± 0.032 b	0.587 ± 0.004 e	0.534 ± 0.005 a	0.055 ± 0.002ab	75.00 ± 1.15 c	18.00 ± 1.00 a
'Kalınkara'	1.430 ± 0.023 d	2.084 ± 0.037 a	0.702 ± 0.002c	0.119 ± 0.001 j	0.067 ± 0.002 a	16.00 ± 1.73 h	–
'Karafındık'	2.757 ± 0.056 b	1.387 ± 0.006 e	0.755 ± 0.010 a	0.187 ± 0.002 ı	0.064 ± 0.001 a	65.33 ± 0.88 d	17.33 ± 1.20 a
'Mincane'	1.870 ± 0.059 c	1.226 ± 0.058 f	0.641 ± 0.002 d	0.333 ± 0.005 e	0.049 ± 0.001 b	83.00 ± 1.15 b	–
'Palaz'	1.483 ± 0.032 d	1.844 ± 0.013 b	0.587 ± 0.001 e	0.517 ± 0.003 b	0.052 ± 0.002ab	11.00 ± 1.15 ı	–
'Sivri'	2.837 ± 0.098 b	1.616 ± 0.012 c	0.317 ± 0.002 g	0.178 ± 0.005 ı	0.059 ± 0.001ab	26.00 ± 1.15 g	–
'Tombul'	2.730 ± 0.070 b	0.823 ± 0.006 g	0.586 ± 0.002 e	0.202 ± 0.002 h	0.044 ± 0.002 b	36.00 ± 1.15 f	–
'Uzunmusa'	2.773 ± 0.069 b	1.409 ± 0.004 e	0.223 ± 0.002 h	0.389 ± 0.004 d	0.051 ± 0.002ab	91.00 ± 1.15 a	9.20 ± 0.12 c
'Yassıbadem'	3.107 ± 0.048 a	1.534 ± 0.006 d	0.533 ± 0.009 f	0.475 ± 0.003 c	0.067 ± 0.001 a	27.67 ± 0.88 g	–
Mean	2.470 ± 0.058	1.580 ± 0.017	0.580 ± 0.003	0.310 ± 0.003	0.060 ± 0.001	45.89 ± 1.21	14.37 ± 0.64

–: Not detected by HPLC analysis.
$^{+}$ Means in the column followed by the same letters are not significantly different at P≤0.05.

'Çakıldak' (0.533 g 100 g^{-1}) while maximum amount of phenylalanine was detected in 'Karafındık' (0.759 g 100 g^{-1}). Isoleucine amounts were determined between 0.354 g 100 g^{-1} ('Foşa') and 0.679 g 100 g^{-1} ('Uzunmusa'). Threonine content ranged from 0.417 g 100 g^{-1} ('Cavcava') to 0.524 g 100 g^{-1} ('Mincane'). Lysine was between 0.348 g 100 g^{-1} ('Yassıbadem') and 0.530 g 100 g^{-1} ('Acı'). Histidine content varied from 0.335 g 100 g^{-1} ('Tombul') to 0.566 g 100 g^{-1} ('Yassıbadem'). Methionine content was the highest in 'Palaz' (0.181 g 100 g^{-1}) and the lowest in 'Mincane' (0.128 mg 100 g^{-1}).

Water-insoluble vitamins

Significant differences were observed among cultivars with respect to water-insoluble vitamin content (P ≤ 0.05) (Table 4). Significantly the highest retinol level was observed in 'Mincane' (23.17 mg 100 g^{-1}) and the lowest

value was measured in 'Sivri' (5.13 mg 100 g^{-1}). The last cultivar contained the highest α-tocopherol as 378.80 mg 100 g^{-1} and that is why it had significantly highest total tocopherol content (382.36 mg 100 g^{-1}). 'Acı', 'Foşa', 'Karafındık', 'Cavcava', 'Çakıldak' and 'Kalınkara' cultivars contained considerably the lowest α-tocopherol content. γ-tocopherol detected in only three cultivars ranged from 3.58 μg 100g^{-1} ('Foşa') to 0.41 μg 100g^{-1} ('Palaz'). Significantly the highest δ-tocopherol content was recorded in 'Sivri' (3.56 mg 100 g^{-1}) and the lowest values were measured in 'Karafındık' (0.93 mg 100 g^{-1}) and 'Yassıbadem' (1.12 mg 100 g^{-1}).

Water-soluble vitamins

Hazelnut cultivars contained niacin and ascorbic acid at higher levels than other water-soluble vitamins. Considerable differences were observed among cultivars ($P \leq 0.05$) (Table 5). Significantly the highest and the lowest vitamin B_1 contents were recorded in 'Foşa' (0.534 mg 100 g^{-1}) and 'Kalınkara' (0.119 mg 100 g^{-1}), respectively. Vitamin B_2 levels changed from 0.044 mg 100 g^{-1} ('Tombul') to 0.067 mg 100 g^{-1} ('Acı', 'Yassıbadem' and 'Kalınkara'). Significantly the highest folic acid content was measured in 'Uzunmusa' (91.00 μg 100 g^{-1}) and the lowest one was in 'Palaz' (11.00 μg 100 g^{-1}). Pyridoxine content was between 0.223 mg 100 g^{-1} ('Uzunmusa') and 0.755 mg 100 g^{-1} ('Karafındık'). In this study, biotin determined in only 5 cultivars and ranged from 9.20 mg 100 g^{-1} ('Uzunmusa') to 18.00 mg 100 g^{-1} ('Foşa'). Significantly the highest niacin content was recorded in 'Acı' (2.118 mg 100 g^{-1}) but this was in the same statistical group with 'Kalınkara' (2.084 mg 100 g^{-1}). Significantly the lowest niacin amount was detected in 'Tombul' (0.823 mg 100 g^{-1}). Ascorbic acid content of hazelnut cultivars changed from 1.430 mg 100 g^{-1} ('Kalınkara') to 3.207 mg 100 g^{-1} ('Çakıldak').

Mineral nutrients

Ash content was significantly different between the cultivars and measured between 1.75 % ('Mincane') and 2.28 % ('Cavcava') and averagely 2.02 % ($P \leq 0.05$) (Table 6). Similarly, each cultivar had significantly different mineral levels ($P \leq 0.05$) (Table 6). The most abundant mineral was potassium followed by phosphorus and calcium. Potassium content was considerably the highest in 'Yassıbadem' (893.90 mg 100 g^{-1}) and the lowest in 'Tombul' (560.20 mg 100 g^{-1}). Significantly the highest phosphorus content was found in 'Cavcava' (324.00 mg 100 g^{-1}) and the lowest value was in 'Karafındık' (191.68 mg 100 g^{-1}). Calcium amount ranged from 95.73 mg 100 g^{-1} ('Kalınkara') to 149.44 mg 100 g^{-1} ('Cavcava'). The highest magnesium content was in 'Çakıldak' (72.88 mg 100 g^{-1}) and the minimum value was detected in 'Tombul' (54.12 mg 100 g^{-1}). Significantly the highest sodium level was determined in 'Çakıldak' (14.55 mg 100 g^{-1}) and the lowest value in 'Uzunmusa' (6.81 mg 100 g^{-1}). 'Çakıldak' and 'Karafındık' had significantly the highest (15.22 mg 100 g^{-1}) and the lowest (2.08 mg 100 g^{-1}) manganese amounts, respectively. While 'Tombul' had significantly the highest copper level (5.07 mg 100 g^{-1}), 'Yassıbadem' had trace amount (3.05 mg 100 g^{-1}) of copper. 'Acı' had the highest level of iron (3.71 mg 100 g^{-1}) and 'Karafındık' showed the lowest (2.36 mg 100 g^{-1}) iron level. The highest zinc content was measured as 3.31 mg 100 g^{-1} in 'Çakıldak' while the lowest amount (1.70 mg 100 g^{-1}) was detected in 'Sivri' cultivar.

Discussion

In this study, biochemical content of different hazelnut cultivars grown in West Black Sea region was investigated. The fat content of hazelnut cultivars was higher than 50 %, consistent with the findings of most of the other researchers (Özdemir et al. 2001; Alasalvar et al. 2003; Amaral et al. 2006a; Köksal et al. 2006; Oliveira et al. 2008). Six fatty acids were identified (Table 1) and fatty acid profile of cultivars was similar to the previous studies (Garcia et al. 1994; Amaral et al. 2006a; Köksal et al. 2006; Oliveira et al. 2008). In the recent study, little bit higher palmitic acid levels were measured in the cultivars grown in West Black Sea region than cultivars from East Black Sea region (4.72–5.87 %) (Köksal et al. 2006). Although, palmitoleic and stearic acid amounts were almost parallel with the cultivars from East Black Sea region (Köksal et al. 2006), stearic acid value (2.01 %) of these cultivars was higher than that of presented in this study (1.90 %). Oliveira et al. (2008) reported average stearic acid amount as 1.80 % for 'Daviana', 'Fertille de Coutard' and 'M. Bollwiller' cultivars. Amaral et al. (2006a) found average stearic acid content as 2.73 % in nineteen hazelnut cultivars such as 'Butler', 'Campanica', 'Cosford', 'Morell' etc. grown in Portugal. The average oleic acid level (83.90 %) determined here was higher than reported by Köksal et al. (2006) for the cultivars from East Black Sea region (79.58 %). Our finding on oleic acid content of especially 'Palaz' and 'Cavcava' cultivars is different from data of previous study (Köksal et al. 2006). Average linoleic acid (8.81 %) content measured here was lower than reported (13.0 %) by Köksal et al. (2006). Similar finding was observed for 'Tombul' cultivar as well. ($P \leq 0.05$) (Table 2).

Average protein amount (16.13 %) and distribution of this parameter in the cultivars taken from West Black Sea region were highly different from the cultivars of East Black Sea region. For the samples of East Black Sea region, this value attained upto 20.8 % ('Cavcava') (Köksal et al. 2006). In another study, Oliveira et al. (2008) reported lower protein amounts (14.8–15.7 %) for three hazelnut cultivars grown in Portugal.

Our finding on glutamic acid, being predominant, was consistent with the finding of other researchers (Alasalvar et al. 2003; Köksal et al. 2006). Our mean values for non-essential aminoacids (Table 2) in cultivars are consistent with those of previous study (Köksal et al. 2006). But in another study, lower non-essential amino acid content was reported for 'Tombul' taken from East Black Sea region (Alasalvar et al. 2003).

Apart from leucine and threonine, differences among all cultivars regarding essential amino acid content were significant and arginine was the predominant one (Table 3) as in Köksal et al. (2006) and Alasalvar et al. (2003). However, Alasalvar et al. (2003) reported lower arginine content for 'Tombul' (0.204 g 100 g^{-1}) taken from East Black Sea region than the content measured by us (1.310 g 100 g^{-1}). In this study, our average values for

Table 6. Ash content and mineral composition of hazelnut cultivars. Values are mean of years± standard error of mean.

Cultivar	Ash (%)	Minerals (mg 100 g^{-1})			
		K	P	Ca	Mg
'Acı'	2.08 ± 0.03 de^{+}	782.60 ± 14.20 bcd	195.81 ± 1.67 c	139.69 ± 2.36 ab	71.46 ± 0.59 ab
'Cavcava'	2.28 ± 0.02 a	842.49 ± 4.84 ab	213.40 ± 11.40 c	149.44 ± 3.62 a	67.33 ± 0.77 c
'Çakıldak'	2.15 ± 0.02 bc	748.30 ± 11.60 de	324.00 ± 12.70 a	118.07 ± 2.11 cd	72.88 ± 0.77 a
'Foşa'	2.13 ± 0.01 cd	880.30 ± 10.60 a	201.04 ± 7.07 c	129.14 ± 0.26 bc	70.48 ± 0.89 b
'Kalınkara'	1.99 ± 0.02 fg	791.03 ± 7.18 bcd	235.10 ± 11.30 c	95.73 ± 5.10 f	63.92 ± 0.15 de
'Karafındık'	1.91 ± 0.01 h	691.20 ± 30.10 ef	191.68 ± 1.33 c	144.05 ± 4.35 a	59.56 ± 0.23 g
'Mincane'	1.75 ± 0.01 j	630.50 ± 15.30 f	244.40 ± 31.10 c	98.91 ± 3.74 f	65.49 ± 0.88 cd
'Palaz'	2.04 ± 0.01 ef	762.90 ± 15.90 cd	300.00 ± 17.30 ab	129.36 ± 2.08 bc	61.17 ± 0.66 fg
'Sivri'	1.99 ± 0.00 g	826.40 ± 8.37 abc	194.79 ± 2.38 c	105.60 ± 3.53 ef	59.69 ± 0.58 g
'Tombul'	1.85 ± 0.02 i	560.20 ± 58.90 g	243.30 ± 47.40 bc	124.23 ± 7.96 ef	54.12 ± 1.26 h
'Uzunmusa'	1.97 ± 0.03 g	743.28 ± 9.25 de	212.30 ± 12.60 c	127.04 ± 3.05 c	62.16 ± 0.93 ef
'Yassıbadem'	2.20 ± 0.01 b	893.90 ± 16.60 a	220.21 ± 3.11 c	112.41 ± 0.39 de	64.32 ± 0.40 de
Mean	2.03 ± 0.02	762.76 ± 16.09	231.34 ± 13.27	122.81 ± 3.21	64.38 ± 0.68

Cultivar	Minerals (mg 100 g^{-1})				
	Na	Mn	Cu	Fe	Zn
'Acı'	9.36 ± 0.50 b	13.10 ± 0.26 b	3.70 ± 0.09 cd	3.71 ± 0.08 a	1.95 ± 0.07 def
'Cavcava'	12.73 ± 0.53 a	4.26 ± 0.16 g	3.90 ± 0.13 c	3.39 ± 0.14 ab	2.05 ± 0.08 cdef
'Çakıldak'	14.55 ± 1.43 a	15.22 ± 0.34 a	5.05 ± 0.13 b	3.65 ± 0.07 a	3.31 ± 0.16 a
'Foşa'	9.92 ± 1.51 b	8.34 ± 0.11 e	3.62 ± 0.08 cd	2.57 ± 0.06 ef	1.73 ± 0.06 ef
'Kalınkara'	8.87 ± 0.96 b	11.04 ± 0.28 cd	3.52 ± 0.20 cd	2.91 ± 0.07 cd	2.30 ± 0.15 c
'Karafındık'	7.93 ± 0.21 b	2.08 ± 0.06 h	3.35 ± 0.13 cd	2.36 ± 0.11 f	1.92 ± 0.09 def
'Mincane'	7.00 ± 0.50 b	11.59 ± 0.03 c	3.47 ± 0.11 cd	3.11 ± 0.08 bc	2.06 ± 0.02 cde
'Palaz'	8.16 ± 0.23 b	6.43 ± 0.12 f	3.50 ± 0.04 cd	3.14 ± 0.13 bc	2.87 ± 0.21 b
'Sivri'	7.70 ± 1.42 b	9.00 ± 0.20 e	3.27 ± 0.10 cd	3.00 ± 0.14 cd	1.70 ± 0.03 f
'Tombul'	13.58 ± 1.26 a	8.53 ± 0.58 e	5.07 ± 0.73 a	3.35 ± 0.17 ab	1.72 ± 0.03 ef
'Uzunmusa'	6.81 ± 0.48 b	10.68 ± 0.34 d	3.32 ± 0.08 cd	2.76 ± 0.07 de	1.97 ± 0.13 cdef
'Yassıbadem'	8.44 ± 0.64 b	5.70 ± 0.12 f	3.05 ± 0.04 d	3.00 ± 0.04 cd	2.09 ± 0.04 cd
Mean	9.59 ± 0.81	8.83 ± 0.22	3.74 ± 0.16	3.08 ± 0.09	2.14 ± 0.09

$^{+}$ Means in the column followed by the same letters are not significantly different at P≤0.05.

individual essential amino acid content were close to data of East Black Sea region's cultivars (Köksal et al. 2006).

Our data on α-tocopherol levels was not parallel with data of Köksal et al. (2006) (Table 4). For example in the current study, 'Sivri' (382.36 mg 100 g^{-1}) cultivar contained much more α-tocopherol than the samples from East Black Sea region (27.0 mg 100 g^{-1}) (Köksal et al. 2006). Additionally, Simsek (2004) reported higher total tocopherol amounts for 'Tombul', 'Palaz' and 'Foşa' cultivars taken from East Black Sea region than our data on these cultivars. In another study, Açkurt et al. (1999) did not identify α-tocopherol amount in 'Çakıldak' and 'Mincane' taken from Akçakoca region but measured higher levels of α-tocopherol in 'Karafındık' (41.2 mg 100 g^{-1}) than reported here. Although it seems that both the research year and the ecological regions may have effect on tocopherol content, Amaral et al. (2006b) determined some minor differences based on tocopherol content among 19 hazelnut cultivars and researchers concluded that factors such as crop year and geographical localities did not seem to cause significant differences in tocopherol content of cultivars.

Hazelnut cultivars contained niacin and ascorbic acid at higher levels than other water-soluble vitamins (Table 5). The average soluble vitamin contents in cultivars in this study were close to data of Köksal et al. (2006). It seems that ecological differences may not affect the water-soluble vitamin content except biotin and folic acid. On the other side, Açkurt et al. (1999) determined the highest levels of niacin, vitamin B_1 and B_2 in the samples of East Black Sea region and the highest levels of vitamin B_6 in the samples of West Black Sea region.

Ash content was averagely determined as 2.02 % in hazelnuts. This value was reported as 2.33 % for cultivars from East Black Sea Region (Köksal et al. 2006). In recent

study, the most abundant mineral was potassium followed by phosphorus and calcium (Table 6). Our data are reasonably higher concerning sodium, copper and manganese but lower in all of other minerals than the values reported by KÖKSAL et al. (2006). Similarly, AÇKURT et al. (1999) determined higher zinc, copper, manganese and sodium levels in the samples from West Black Sea region (Akçakoca) than data of KÖKSAL et al. (2006). It seems that different soil conditions in different ecological regions might cause differences in mineral levels.

According to the results presented here, hazelnut cultivars taken from West Black Sea region of Turkey, Akçakoca showed significant differences based on all biochemical compounds with the exception of palmitoleic acid, leucine and threonine. We thought that these variations could be caused from cultivar characteristic. Data obtained in this research are comparable with most of the other studies and it can be concluded that hazelnuts from West Balck Sea region are also a good source for biochemical compounds. When the nutritional values of hazelnut cultivars grown in East and also West Black Sea regions was compared, there were some differences in protein and fatty acid contents, α-tocopherol and consequently total tocopherol amounts. The latter was reasonably higher than those found for the same cultivars taken from East Black Sea region (KÖKSAL et al. 2006). It could be suggested that geographical regions and/or years might influence tocopherol amounts in hazelnuts.

Acknowledgement

This research was financially supported by Black Sea Hazelnut Exporter's Union of Turkey.

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Received April 26, 2009 / Accepted November 19, 2009

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