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Evaluation of fatty acid content and nutritional properties of selected native and imported hazelnut (*Corylus avellana* L.) varieties grown in Iran

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Summary

Hazelnut (*Corylus avellana* L.) is one of the most important nuts rich in valuable nutrients. In this study, chemical composition of two Iranian native varieties namely 'Pashmineh' and 'Garche' and four imported varieties, 'Ghafghaze', 'Zakatala', 'Ronde dupimont' and 'Fertile decotard' were investigated. The main fatty acid in hazelnut varieties were oleic (71.02 %) and linoleic acid (14.45 %). The hazelnut varieties showed oil content in a range from 53.36 % to 63.5 %; protein, 16.03-23.26 %; energy, 653.4-707.65 %; ash, 2.46-3.5 %; carbohydrate, 13.16-20.14 %; total phenolic content, 6.4-16.42 mg GAE/g; antioxidant capacity, 57.17-72.38 %; oleic acid, 64.17-81.34 %; Linoleic acid, 10-21.07 %; Linolenic acid, 0-2 %; myristic acid, 0-0.5 %; stearic acid, 0-7.8 %; eicosenoic acid, 0-1.69 %; palmitic acid, 0.49-9.61 %; palmitoleic acid, 0-1.6 % and behenic acid, 0-0.25 %.

Introduction

Hazelnut is a popular nut worldwide. It is mainly distributed along the coasts of the Black Sea region of Turkey, southern Europe (Italy, Spain, Portugal and France), and in some areas of the United States (Oregon and Washington). Hazelnut is also grown in New Zealand, China, Azerbaijan, Chile, Georgia and Iran. Turkey is the world's largest producer of hazelnut, contributing around 70.3 % to the total global production, followed by Italy (11.9 %), USA (4.5 %), Azerbaijan (4.2 %), Georgia (3.8 %) and Spain (2.5 %). Other countries contribute only 2.8 % to the total global production (Alasalvar et al., 2010). Hazelnuts, due to their organoleptic characteristics constitute, are one of the most important raw materials for the pastry and chocolate industry. Hazelnut also add flavor and texture to bakery, confectionery, cereal, salad, entrée, sauce dairy, and dessert formulation (Alasalvar et al., 2003; Kaleoğlu et al., 2004; Oliveira et al., 2008; Ozdemir and Akinci, 2004). In addition, hazelnuts play a major role in human nutrition and health, because of their special composition of fat, protein, carbohydrate, vitamins, minerals and nutrients antioxidant. (Alasalvar et al., 2009; Garcia et al., 1994; Köksal et al., 2006; Oliveira et al., 2008). At the present, nutritional interest in the fatty acid composition of vegetable oils is increasing because the most important neutral lipid in most vegetable oils included in the human diet influences total fat and cholesterol absorption in the human lumen (Erener et al., 2007). Monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) as well as minor lipid components play an important role in human nutrition. Also, health diets rich in MUFA, such as hazelnut oil and olive oil, decrease blood pressure and total blood cholesterol levels in human (Karabulut et al., 2005). Every food plant contains numerous types of natural antioxidants with different properties. The actions of antioxidants have been attributed to their ability to scavenge free radicals, thereby reducing oxidative damage of cellular biomolecules such as lipids, proteins and DNA. The study of nut and kernel characteristic and nut composition helps to understand and define the relationship between internal quality and genotype, environmental and cultural factors. It provides information for culture evaluation and choice and a reference of varietal quality useful to growers, breeders and the food processing industry (Cristofori et al., 2008).

Nut and kernel size, nut and kernel shape, percent kernel, shell thickness, low kernel defect, protein and high content of fatty acids are among the main characteristics considered in the evaluation of nut and kernel quality in hazelnut (Balta et al., 2006). Studies have indicated that the nutritional and chemical composition of hazelnut is affected by cultivar, ecology, harvest year, soil, irrigation and method of cultivation (Açkurt et al., 1999; Alasalvar et al., 2009; Balta et al., 2006; Caglarirmak and Batkan, 2005; Cristofori et al., 2008; Köksal et al., 2006; Oliveira et al., 2008; Silva et al., 2007). Recently, some studies on qualitative indices such as total phenol content, antioxidant capacity, fatty acid composition of kernel were conducted (Aydin, 2002; Botta, 1997; Contini et al., 2008; Maguire et al., 2004; Ozdemir and Akinci, 2004; Özdemir et al., 2001; Parcerisa et al., 1993; Serdar and Demir, 2005). Unfortunately, up to date, data of fatty acid contents and nutritional properties of hazelnuts grown in Iran are scarce. Hence, the objective of this study is to determine the chemical composition of different hazelnut varieties growing in Iran.

Martials and methods

Plant material and growth conditions

The nuts of two native variety named 'Pashmineh' and 'Garche' and four imported hazelnut varieties including 'Ghafghaz', 'Zakatala', 'Ronde dupimont' and 'Fertile decotard' were used in this study. Samples of each variety were obtained from the Hazelnut Research Institute in Astara (altitude, 22 m; latitude, 38°4 N'; longitude, 48°87 E') located in Western-Guilan province of Iran during the 2010 harvest season. Foreign hazelnuts were provided from Horticultural and Agricultural Experiments Station, Sochi, located in Russia. Shrubs were established with shrub training system at the spacing 4×4 meter. Harvest was performed during the early August. Pollinizer was 'Daviana'.

Chemical analysis

Protein, ash, total oil, carbohydrate and energy

Evaluation of total oil, protein and ash contents were carried out in triplicate according to AOAC Official Methods (AOAC, 1995). Total oil was determined by oil extraction from five grams of dried weight of sample using diethyl ether by a Soxhlet apparatus (Cristofori et al., 2008; Köksal et al., 2006; Silva et al., 2007). Protein was determined by the micro Kjeldahl method. Protein content was calculated as total N × 6.25 (Köksal et al., 2006). Ash content was determined by incineration at 600 °C (Balta et al., 2006; Köksal et al., 2006). Carbohydrate content was quantified by calculation of the difference between total weight and other components using the following formula:

Carbohydrate content = 100 % - (% moisture + % protein + % fat + % ash). (1)

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Energy was expressed as kilocalories using the following formula (Alasalvar et al., 2003; Oliveira et al., 2008; Ozdemir and Akinci, 2004).

Energy (kcal) = 4 × (Protein $_{(g)}$ + Carbohydrate $_{(g)}$) + 9 × (fat $_{(g)}$). (2)

Determination of total phenol content

Total phenolics in hazelnut extracts were determined spectrophotometrically using Folin–Ciocalteu reagent with minor modifications as method described by Oliveira et al. (2008). Values of total phenolics were estimated by comparing the absorbance of each sample with a standard response curve generated using gallic acid. Results are expressed as mg gallic acid equivalents (GAE) on a dry weight (DW) basis (mg GAE/g DW). Tests were carried out for three replications.

Antioxidant capacity determined by DPPH

This spectrophotometric assay uses the stable radical DPPH (1, 1-diphenyl-2-picrylhydrazyl) as a reagent. DPPH radical scavenging activity was determined according to the method of Du et al. (2009) with a minor modification. 50 μL of different hazelnut extract were added to 950 μL of a 6.25 × 10^{-5} M solution of DPPH in methanol. After 30 min incubation period at room temperature (in the dark place), the absorbance was read against a blank at 517 nm. Inhibition of free radicals by DPPH was calculated by the following formula.

% inhibition = $[(A_{blank} - A_{samp}) / A_{blank}] \times 100$

Where A_{blank} is the absorbance of control, and A_{samp} is the absorbance of the test compound.

Tests were carried out for three replications.

Fatty acid composition of extracted oil

The fatty acids composition was determined as methyl esters by gas chromatography (GC) coupled to a mass spectrophotometer, according to methods described in regulation of EEC 2568/91. Fatty acid methyl esters were prepared by vigorous shaking of a solution of each hazelnut oil sample in n-hexane (0.2 g in 3 mL) with 0.4 mL 2 N methanolic potassium hydroxide solution. Chromatographic analysis was performed on a Hewlett Packard 5890N gas chromatograph equipped with a FID detector (Hewlett Packard, Palo Alto, CA, USA), using a fused-silica capillary column (30 m × 0.25 μm i.d. × 0.25 μm film thickness, HP Supelco, Inc., Bellefonte, PA, USA). The injector and detector temperatures were maintained at 220 °C and 260 °C, respectively; the oven temperature was set at 210 °C. Helium was employed as the carrier gas with a flow rate of 1 mL/min according to the method of European Regulation 2568/91 (EEC, 1991). Fatty acids were identified by comparing retention times with those of standard compounds (Hashempour et al., 2010). SFA (saturate fatty acid), USFA (unsaturated fatty acid), MUFA (monounsaturated fatty acids), PUFA (polyunsaturated fatty acids) was calculated using the following equation:

SFA= palmitic acid+ stearic acid + behenic acid + myristic acid (1)

MUFA= oleic acid + palmitoleic acid + eicosenoic acid (2)

PUFA= linoleic acid + linolenic acid (3)

USFA=MUFA + PUFA (4)

Statistical analysis

In the experiment, the design of a randomized complete block with three replications was used. The results were presented as means ± SE. Analysis of variance was performed by GLM procedures (SAS 9.1 for Windows). Significant differences were calculated according to LSD's multiple range tests. Differences at $P < 0.05$ were considered statistically significant.

Results and discussion

Nutritional properties of the six hazelnut varieties are given in Tab. 1. There were significant differences among the hazelnut varieties in terms of oil, energy, protein, carbohydrate and ash. The range in hazelnut genotypes was 63.5 % ('Fertile decotard') – 53.4 % ('Pashmineh') in oil of the kernel, 707.7 kcal ('Fertile decotard') – 653.4 kcal ('Pashmineh') in energy, 23.3 % ('Pashmineh') – 16.0 % ('Ghafghaze') in protein and 20.1 % ('Pashmineh') – 13.2 % ('Fertile decotard') in carbohydrate. The highest ash of kernel was detected in 'Ghafghaze' (3.5 %). 'Fertile decotard' had the lowest ash of kernels (2.5 %). Antioxidant capacity and total phenolic content of the hazelnut samples are shown in Tab. 1. 'Garche' had the highest (72.4 %) scavenging free radicals whereas 'Pashmineh' had the lowest (57.2 %). Kernel of 'Ghafghaze' had the highest total phenolic content (16.4 mg GAE/g) whereas 'Pashmineh', had the lowest total phenolic content (6.4 mg GAE/g). As can be seen from Tab. 1, hazelnuts are a good source of energy, oil and carbohydrate. When these results were compared with the results of previous studies on hazelnut varieties, great differences were found in the contents of these analyzed compounds (Köksal et al., 2006; Oliveira et al., 2008; Ozdemir and Akinci, 2004). With respect to the nutritional values and fatty acid composition of hazelnuts, many studies have been conducted. But none of them have reported values and composition for hazelnuts grown under the ecological conditions of Iran.

Tab. 1: Some nutritional properties of hazlnuts (*Corylus avellana* L.) varieties

Variety	Protein (% dry weight)	Oil (% dry weight)	Energy (% dry weight)	Ash (% dry weight)	Carbohydrate (% dry weight)	Total phenolic Content mg/g (DW)	Antioxidant capacity (DPPH %)
'Fertile decotard'	20.9 ± 1.0ab	63.5 ± 0.6a	707.7 ± 3.6a	2.5 ± 0.2b	13.2 ± 1.2c	14.0 ± 0.3a	70.3 ± 1.4a
'Zakatala'	20.3 ± 1.9ab	57.9 ± 2.1bc	677.7 ± 11.9bc	3.0 ± 0.4ab	18.8 ± 0.7a	13.2 ± 1.7a	67.3 ± 0.4a
'Garche'	23.2 ± 0.9a	58.7 ± 0.4ab	680.5 ± 2.3b	3.2 ± 0.1a	14.1 ± 1.2bc	9.1 ± 1.4b	72.4 ± 0.0a
'Ghafghaze'	16.0 ± 1.9c	60.5 ± 1.6ab	688.4 ± 8.3ab	3.5 ± 0.1a	19.9 ± 0.7a	16.4 ± 1.3a	69.2 ± 0.9a
'Pashmineh'	23.3 ± 0.4a	53.4 ± 0.4c	653.4 ± 2.10c	3.4 ± 0.1a	20.1 ± 0.1a	6.4 ± 1.0b	57.2 ± 4.8b
'Rondedupimont'	17.2 ± 1.4bc	61.4 ± 2.8ab	694.6 ± 13.3ab	3.3 ± 0.1a	17.7 ± 1.6ab	13.6 ± 0.2a	68.9 ± 0.1a

Mean in each column followed by the same letters are not significantly different at $P < 0.05$ according to LSD's multiple range test. Data expressed as means ± SE.

KÖKSAL et al. (2006) determined that some Turkish hazelnut varieties such as 'Tombul' and 'Siviri' contain ash content 1.87-2.72 g/100 g and protein 11.7-20.8 g/100 g. In the present study, the highest ash content in 'Ghafghaze' was 3.5 g/100 g which is nearly double. Highest protein content was found in 'Pashmineh' (23.3 g/100 g) which is considerably higher than their reported data. Higher ash and protein content shows higher quality indices of the varieties grown in Iran. It has been reported in many studies that the nut compositions of hazelnut were affected by variety, harvest year, soil, irrigation, climate and method of cultivation (AÇKURT et al., 1999; ALASALVAR et al., 2009; BALTA et al., 2006; CRISTOFORI et al., 2008; KÖKSAL et al., 2006; OLIVEIRA et al., 2008; SILVA et al., 2007). The analysis of variance indicated significant differences in fatty acid composition among varieties, as shown in Tab. 2. The main fatty acids were oleic acid (C18:1) and Linoleic acid (C18:2). Oleic acid (C18:1) ranged from 64.2 % in 'Zakatala' to 81.3 % in 'Fertile decotard'. Linoleic acid (C18:2) showed pronounced differences among varieties, the lowest content was found in 'Pashmineh' (10 %) and the highest in 'Zakatala' (21.1 %). Linolenic acid (C18:3) ranged from 2% in 'Zakatala' to non-detected in 'Ronde dupimont', 'Fertile decotard' and 'Pashmineh'. Oil of 'Pashmineh' had the highest palmitic acid (C16:0), (9.61 %) whereas 'Ghafghaze', had the lowest palmitic acid (0.49 %). The highest palmitoleic acid (C16:1) of oil was detected in 'Garche' (1.6 %). 'Ronde dupimont' and 'Pashmineh' had the lowest palmitoleic acid of oil (0.0 %). The range of myristic acid (C14:0) of oil varied from 0.5 % ('Zakatala') to 0.0 % in 'Ronde dupimont' and 'Pashmineh', and the range of stearic acid (C18:0) of oil varied from 7.8 ('Zakatala') to 0.0 % ('Fertile decotard'). The highest behenic acid (C22:0) was in 'Ghafghaze' (0.25 %) and it was not detected in 'Ronde dupimont', 'Fertile decotard', 'Zakatala' and 'Pashmineh'. Oil of 'Zakatala' had the highest eicosenoic acid (C20:1), (1.7 %) whereas not detected in 'Ronde dupimont', 'Ghafghaze' and 'Pashmineh'. The analysis of variance indicated significant differences in fatty acid parameters of oil extracted among varieties, as shown in Tab. 3. The main contributing saturated fatty acids for all varieties included palmitic acid (C16:0) and stearic acid (C18:0) with traces of myristic acid (C14:0) and behenic acid (C22:0). Oil of 'Ronde dupimont' had the highest saturated fatty acids (13.93 %). The main unsaturated fatty acids in the studied nuts included oleic acid (C18:1), linoleic acid (C18:2), linolenicacid (C18:3), eicosenoic acid (C20:1) and palmitoleic acid (C16:1). The range of unsaturated fatty acids of oil varied from 97.8 % ('Fertile decotard') to 79.3 % in 'Pashmineh'. Oil of 'Fertile decotard' and 'Zakatala', had the highest and the lowest monounsaturated fatty acids respectively (Tab. 3).

The highest polyunsaturated fatty acids (linoleic acid + linolenic acid) of oil were detected in 'Zakatala' (23.1 %). 'Pashmineh' had the lowest polyunsaturated fatty acids of oil (10 %). Analysis of the fatty acid profile of the varieties indicates a high unsaturated/saturated fatty acid ratio in 'Fertile decotard' (56.2 %). The range of saturated / unsaturated fatty acid ratio of oil varied from 0.17 % ('Pashmineh') to 0.02 % in 'Fertile decotard'. Oil of 'Pashmineh' had the highest saturated / monounsaturated (oleic acid + palmitoleic acid + eicosenoic acid) fatty acid ratio (0.19 %). Palmitic acid is the main saturated fatty acid in hazelnuts followed by stearic acid. The major unsaturated fatty acids found in hazelnut oil are oleic acid (C18:1) and linoleic acid (C18:2) whereas linolenic acid (C18:3) exists at trace levels. The ratios of these fatty acids to each other are important to the economic and nutritional value of the hazelnuts.

(KOYUNCU, 2004). KÖKSAL et al. (2006) investigated chemical composition of the 17 different hazelnut varieties grown in the Black Sea region of Turkey and reported the following values: palmitic acid 4.72-5.87 %, stearic acid 0.86-2.49 %, oleic acid 74.2-82.8 %,

Tab. 2: Fatty acid contents (% of total oil) of hazlnuts (*Corylus avellana* L.) varieties

Variety	Oleic acid	Linoleic acid	Linolenic acid	Palmitic acid	Palmitoleic acid	Myristic acid	Stearic acid	Behenic acid	Eicosenoic acid
'Fertile decotard'	81.3 ± 0.3a	14.7 ± 0.1c	ND	1.6 ± 0.01c	1.3 ± 0.01b	0.11 ± 0.0c	ND	ND	0.5 ± 0.05c
'Zakatala'	64.2 ± 0.2f	21.1 ± 0.1a	2 ± 0.01a	0.76 ± 0.00d	0.6 ± 0.00c	0.5 ± 0.01a	7.8 ± 0.01a	ND	1.7 ± 0.00a
'Garche'	68.2 ± 0.2e	14.9 ± 0.1b	1.63 ± 0.12b	0.65 ± 0.01de	1.6 ± 0.01a	0.3 ± 0.01b	4.1 ± 0.12c	0.24 ± 0.0b	1.3 ± 0.06b
'Ghafghaze'	68.2 ± 0.2d	14.9 ± 0.3b	0.15 ± 0.00c	0.49 ± 0.01e	1.59 ± 0.0a	0.3 ± 0.00b	4.1 ± 0.13c	0.25 ± 0.0a	ND
'Pashmineh'	69.3 ± 0.3c	10 ± 0.1e	ND	9.6 ± 0.12a	ND	ND	3.5 ± 0.10d	ND	ND
'Rondedupimont'	74.9 ± 0.3b	11.1 ± 0.1d	ND	9.3 ± 0.13b	ND	ND	4.6 ± 0.10b	ND	ND

Mean in each column followed by the same letters are not significantly different at $P < 0.05$ according to LSD's multiple range test. Data expressed as means ± SE.

Tab. 3: Summary of the important fatty acid parameters of oil extracted from hazlnuts (*Corylus avellana* L.) varieties

Variety	S FA	USFA	MUFA	PUFA	SFA/USFA	USFA/SFA	SFA/MUFA
'Fertile decotard'	1.74 ± 0.01e	97.8± 0.4a	83.1 ± 0.2a	14.7 ± 0.1d	0.02 ± 0.00d	56.2 ± 0.1a	0.02 ± 0.00d
'Zakatala'	9.06 ± 0.01c	89.5 ± 0.4b	66.4 ± 0.2f	23.1 ± 0.1a	0.10 ± 0.00b	9.9 ± 0.0c	0.13 ± 0.00b
'Garche'	5.32 ± 0.13d	87.6 ± 0.5c	71.0± 0.3c	16.5 ± 0.2b	0.06 ± 0.00c	16.5 ± 0.3b	0.07 ± 0.00c
'Ghafghaze'	5.17 ± 0.14d	84.8 ± 0.5d	69.8 ± 0.3d	15.1 ± 0.3c	0.06 ± 0.00c	16.4 ± 0.3b	0.07± 0.01c
'Pashmineh'	13.11 ± 0.13b	79.3 ± 0.4f	69.3 ± 0.3d	10 ± 0.1f	0.17 ± 0.00a	6.1 ± 0.0d	0.19 ± 0.00a
'Rondedupimont'	13.93 ± 0.25a	86.0 ± 0.4c	74.9 ± 0.3b	11.1 ± 0.2e	0.16 ± 0.00a	6.2 ± 0.1d	0.19 ± 0.00a

Mean in each column followed by the same letters are not significantly different at $P < 0.05$ according to LSD's multiple range test.
SFA (Saturate fatty acid), USFA (Unsaturated fatty acid), MUFA (Monounsaturated fatty acid), PUFA (Polyunsaturated fatty acids).
Data expressed as means ± SE.

linoleic acid 0.03-0.08 % and linolenic acid 0.029-0.076 %. In the present study, 'Fertile decotard' had the highest oleic acid (81.3 %), monounsaturated fatty acids (83.1 %), unsaturated fatty acid (97.8 %), and unsaturated fatty acid / saturate fatty acid (56.23 %). The highest polyunsaturated fatty acids (23.1 %), stearic acid (7.8 %), linolenic acid (2 %), linoleic acid (21.1 %), myristic acid (0.5 %), eicosenoic acid (1.7 %) was determined in 'Zakatala' whereas the highest saturate fatty acid / unsaturated fatty acid (0.17 %), saturate fatty acid / monounsaturated fatty acids (0.19 %) and palmitic acid (9.6 %) content was in 'Pashmineh'. The highest palmitoleic acid (1.6 %), behenic acid (0.25 %) and saturate fatty acid (13.93 %) were recorded in 'Garche', 'Ghafghaze' and 'Ronde dupimont', respectively.

Conclusion

In conclusion, findings concerning nutritional composition revealed that many hazelnuts varieties grown in Iran contain a high amount of carbohydrate, protein, and fatty acid contents which could be useful for future production and breeding goals. As an excellent source of monounsaturated fatty acids, hazelnuts may be beneficial, preventing from cholesterol-based atherosclerosis and ischemic cardiovascular diseases. Besides their high energetic and nutritional value, hazelnuts also provide bioactive compounds such as antimicrobial and antioxidant agents, suggesting that the fruits could also be useful in the prevention of diseases in which free radicals are implicated. Overall, it seems that more studies are required to decipher the role (s) of environmental factors in quality of hazelnut, as well as with the comparison of essential substances in different hazelnut varieties, researchers can introduce the varieties with high quality in future works.

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