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The Mineral Source for Human Nutrition of Nuts in Different Hazelnut (*Corylus avellana* L.) Cultivars

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Abstract

Hazelnuts (*Corylus avellana* L.) have a significant place among the types of dried nuts in terms of nutrition and health owing to their special composition of fats, protein, carbohydrates, vitamins, minerals, dietary fibers and phenolic antioxidants. Different hazelnut cultivars grown in Romania ('Cozia', 'Romavel', 'Valcea 22', 'Roverd' and 'Red Lambert') were evaluated for their mineral composition. Microelements were determined by using ICP-MS and a Flame AAS. The average microelements concentrations in the cultivars have varied in the following ranges (mg 100 g^{-1}): K, 591.75 - 639.13; P, 300.67 - 455.06; Mg, 205.02 - 335.54; Ca, 72.07 - 130.92; Mn, 8.77 - 19.07; Fe, 5.3 - 8.77; Cu, 1.62 - 3.07; Zn, 1.82 - 2.84; Cr, 0.12 - 0.84; Na, 0.36 - 0.97; Al, 0.23 - 0.35; Sr, 0.88 - 1.6; Rb,1.34 - 3.03. According to the daily microelement requirements, the quantity of 100 g hazelnut provided approximately 13% for K, 55% for P, 70% for Mg, 10% for Ca, 94% for Fe, 22 for Zn and 5.6% for Cr of the RDA. These results indicated that hazelnuts are a rich source of a number of important micro-elements and hazelnut can be an important source of microelements for human nutrition and health.

Keywords: *Corylus avellana,* healthy, nutritional composition, recommended daily amount

Introduction

Minerals are essential in maintaining the healthy nerve function and for keeping the body systems, bones and cells healthy and well balanced. There are foods that contain the necessary minerals which our bodies absolutely need. Fruits and vegetables are therefore getting broader attention in a strategy to increase the nutritional value of meals while reducing energy density and intake (Demigné *et al*., 2004). Hazelnuts (*Corylus avellana* L.) have a significant place among the types of dried nuts in terms of nutrition and health owing to their special composition of fats, protein, carbohydrates, vitamins, minerals, dietary fibers and phenolic antioxidants (Demirbas, 2007; Simsek and Aykut, 2007; Solar and Stampar, 2011). The nutritional and sensory properties of hazelnuts make them a unique and ideal raw material for food products. Hazelnut fruits are different in morphologic characteristics and mineral composition with an extremely high variability among genotypes of different origins (Ferreira *et al*., 2010; Rovira *et al*., 2005). They are a rich source of main nutritive matter that seem to have positive effect on human health (Cristofori *et al*., 2008; Oliveira *et al*., 2008; Schmitzer *et al*., 2011; Silva *et al*., 2007). Regarding mineral composition, Alasalvar *et al*. (2003) considered that the major minerals in hazelnut were potassium, phosphorus, calcium, magnesium, and selenium. Iron, copper, manganese and zinc content were reported by Dundar *et al*. (2002) in hulled kernels, which is 3.45, 1.61, 12.72, 2.63 mg/100 g, respectively. Hazelnut cultivars served as an excellent source of copper and manganese. Alasalvar *et al*. (2009) suggested that the consumption of the recommended daily amount of 42.5 g of hazelnut from different cultivars provides 44.4-83.6% of copper and 40.1-448% of recommended manganese intake for adults. According to the daily microelement requirements, 100 g of Turkish hazelnut cultivars has supplied about 50% for Fe and Cd, 41% for Mo, 32% for Zn, 21% for Se, 21% for Cr, 5% for B, 1% for Ni of the recommended daily amount (Özkutlu *et al*., 2011). Hazelnut is the best source of essential elements, amino acids, vitamin B and E among tree nuts (Açkurt *et al*., 1999; Oliveira *et al*., 2008; Xu and Hanna, 2011) and serves as a good source of natural antioxidants (Açkurt *et al*., 1999; Contini *et al*., 2008; Schmitzer *et al*., 2011). Several studies indicated that the nut composition of hazelnut is affected by cultivar, harvest year, soil and geographical origin (Açkurt *et al*., 1999; Amaral *et al*., 2006; Dundar *et al*., 2002; Seyhan *et al*., 2007).

The present study is focused on the mineral content of four Romanian hazelnut cultivars ('Cozia', 'Romavel', 'Valcea 22', and 'Roverd') and one foreign one ('Red Lambert'), analyzed in mineralized samples with a previously validated method under optimized conditions for each element. The study has also evaluated the contribution of hazelnut to the total dietary intake of Na, K, Ca, Mg, Fe, Mn, Cu, Al, Cr, Zn, Sr, Rb, and P. The growing consumption of nuts on the basis of its nutritional properties and beneficial effects requires a periodical control of the mineral presence.

Materials and methods

Material

The study was conducted by using five hazelnut (*Corylus avellana* L.) cultivars 4 Romanian bred cultivars ('Cozia', 'Romavel', 'Valcea 22', and 'Roverd') and one foreign one ('Red Lambert') for determinations. The Romanian cultivars are the results of the breeding program for hazelnut from the Valcea Research Station (Botu *et al*., 2005). The material of study (fruit) comes from the germplasm collection of Valcea Research Station, located in Sub-Carpathian area in Oltenia Region, Romania (45°6'17" N, 24°22'32" E). The area has a temperate climate and is known to be favorable for hazelnut culture. Samples were taken from germplasm collection, 10 plant samples (100 g fruit per tree) for each cultivar were collected randomly at the beginning of the harvest season (2011). Hazelnut samples were packed into polyethylene bags, stored as in-shell at room temperature conditions for two weeks and were cracked by using mechanical crackers. Kernels were homogenized in a blender.

Mineral analysis

A commercial system of Inductively coupled plasma mass spectrometry (ICP-MS; Perkin-Elmer Elan 9000), a Flame atomic absorption spectrometer (Flame AAS; Avanta PM) and a Milestone digestion microwave system were used. The experimental operating parameters are summarized in Tab. 1.

Reagent and chemicals

Etalon standards were obtained from multi-element stock solutions ICP–MS calibration STD 3, etalon solutions mono-element 1000 ppm K, nitric acid 65% puriss p.a (Fluka, Germany), oxygenated water 33% reactive p.a and ultrapure water, of 1st degree, according to ISO 3696:1987.

Tab. 1. ICP-MS and the Atomic Absorption Spectrometer in flame operating conditions

ICP-MS, model Elan 9000	
Rf power(W)	1000
ICP torch	Fassele type
Torch injector	Ceramic alumina
Nebulizer	Type cross flow
Nebulizer gas flow (l/min)	0.93
Spray chamber	
Sweeps/reading	20
Reading/replicate	2
Number of replicates	5
Flame AAS, model AvantaPM	
Optics	Double fascicle
Flame	Air-Acetylene
Flame Control	Programmed

Method

For solid sample mineralization, a Milestone digestion microwave system was used. The amounts of approximately 0.5 g per sample, 6 ml of 65% nitric acid and 2 ml of 33% oxygenated water, were introduced in Teflon recipients, and were put under thermic treatment programme under pressure: heating them up to 180°C by a rate of 4.5°C/min and keeping them for 20 minutes at 180°C. After cooling down, the liquid samples were transferred into marked glass balloons; they were brought to 50 ml volume, by using ultrapure water, and were analyzed according to specific procedures in the two spectrometer instruments. Control sample (blank) was made of 6 ml nitric acid 65% and 2 ml oxygenated water 33%; and it was processed under the same conditions as the analyzed sample. Mineral elements P, Mg, Ca, Mn, Fe, Zn, Cu, Rb, Sr, Na, Cr and Al (method 985.35, 999.10, 986.24) and K (method 985.35) were determined according to the official methods of the Association of Official Analytical Chemists (AOAC 2000). Three independent samples were performed for each determination and the resulting data were used to obtain average values and standard deviations for all tests. The method was previously described by Cosmulescu *et al*. (2010).

Statistical analysis

Results were expressed as means ± standard deviation (SD). The statistical significance (t-test) was determined using Minitab Statistical software. Differences at $p < 0.05$ were considered to be significant.

Results and discussion

Hazelnuts are considered to be a good source of dietary minerals (Özkutlu *et al.,* 2011). As they contains significant amounts of essential minerals that are associated with an improved health status when consumed at doses beyond those required for preventing a deficiency state (Alasalvar *et al*., 2009). The composition of mineral elements in five hazelnut cultivars was analyzed. Thirteen essential minerals were determined in the hazelnut cultivars and the results are given in Tab. 2 and Tab. 3 and the results indicated significant differences between the cultivars analyzed ($p \leq 0.05$). With regard to nutritional aspects, the percentage of RDA/AI for minerals need for human beings is given in Tab. 4. The order of nutritive elements depending on their content/100 g of produce was: K > P > Mg > Ca > Mn > Fe > Zn > Cu > Rb > Sr > Na > Cr > Al.

Among the identified elements, the highest amount was obtained in potassium, between 591.75 mg 100 g^{-1} ('Red Lambert') and 639.13 mg 100 g^{-1} ('Valcea 22'). Potassium concentrations in our study were lower than those reported by the Koksal *et al*. (2006) for Turkish varieties

(863 mg 100 g^{-1}) and were similar (655 mg 100 g^{-1}) by reported Alphan *et al*. (1997). Potassium is important for a healthy nervous system and a normal heart rate (Demigné *et al*., 2004). The recommended intake of potassium for all adult males and females is 4.7 grams per each day (Tab. 4); hazelnut is a good source of potassium. The consumption of 100 g hazelnut supplies about 13% of potassium intake (Tab. 2 and 3).

Phosphorus content ranged from 300.67 mg 100 g^{-1} ('Romavel') to 455.06 mg 100 g^{-1} ('Roverd'). The average phosphorus content (385.73 mg 100 g^{-1}) determined here was higher than the one reported by Gunes *et al*. (2010) for the hazelnut cultivars grown in the West Black Sea Region of Turkey (231.34 mg 100 g^{-1}). Phosphorus is a component of bones, cells, in energy processing and many other functions. The recommended intake of phosphorus is 700 mg daily for both adult males and females (Tab. 4). According to the present study results, the consumption of 100 g hazelnut supplies about 55% of phosphorus intake (Tab. 2 and 3).

Magnesium plays an essential role in reducing the risk of cardio-vascular disease. Fruits analyzed have recorded a higher content of magnesium; the values were 205.02 mg 100 g^{-1} in 'Romavel' cultivar and 335.54 mg 100 g^{-1} in 'Roverd' cultivar. Magnesium content is higher than that one found (173 mg 100 g^{-1}) by Koksal *et al*. (2006) or the one found (1588 - 1867 mg kg^{-1}) by Ozdemir and Akinci (2004) in cultivars grown in Turkey. The recommended intake for adult is 400 mg daily; consuming RDA of 100g hazelnut supplies 70% of magnesium.

Calcium content varied between 72.07 mg 100 g^{-1} ('Romavel') and 130.92 mg 100 g^{-1} ('Roverd'); the average content in analyzed cultivars is 104.81 mg 100 g^{-1}; higher than that one found (83.5 mg 100 g^{-1}) by Açkurt *et al*. (1999). The recommended amount of calcium for adults (ages 19-50), is 1000 mg daily; consumption of 100 g hazelnut is supplying 10% of calcium intake (Tab. 2 and 3). According to Alasalvar *et al*. (2009), among the minerals in Turkish hazelnut varieties, potassium was the most abundant (519 - 857 mg 100 g^{-1}), followed by phospho-

Tab. 2. Essential mineral[a] content of hazelnut varieties

Mineral composition (mg/100 g)	Cultivar				
	'Cozia'	'Romavel'	'Valcea 22'	'Roverd'	'Red Lambert'
Sodium, Na	0.97±0.11*	0.36±0.03	0.85±0.05	0.52±0.03	0.67±0.07
Potassium, K	629.75±59.5	592.38±3.05	639.13±1.07	633.86±3.58	591.75±5.97
Calcium, Ca	108.42±7.99	72.07±2.61	107.74±1.85	130.92±1.47*	104.90±2.77
Magnesium, Mg	280.74±26.71	205.02±4.28	265.46±1.19	335.54±1.05	314.93±7.85
Iron, Fe	7.82±0.56	5.30±0.15	7.98±0.06	7.85±0.05	8.77±0.19
Manganese, Mn	8.77±0.54	9.96±0.03	9.95±0.06	19.07±0.14*	15.87±0.78
Copper, Cu	2.05±0.11	1.62±0.03	1.98±0.04	3.07±0.06*	2.69±0.27
Aluminium, Al	0.35±0.02*	0.29±0.02	0.31±0.01	0.30±0.04	0.23±0.02
Chromium, Cr	0.68±0.06	0.12±0.031	0.84±0.03	0.81±0.07	0.69±0.05
Zinc, Zn	2.84±0.26*	1.82±0.02	2.38±0.03	2.53±0.09	2.53±0.04
Strontium, Sr	1.35±0.12	1.12±0.03	0.88±0.03	1.60±0.03*	1.19±0.06
Rubidium, Rb	1.34±0.13	1.38±0.08	1.77±0.05	3.03±0.04*	1.67±0.08
Phosphorus, P	374.76±13.29	300.67±2.90	360.74±1.44	455.06±1.38	437.45±8.29

[a] Data are expressed as means ± SD (n=3). Means ± SD followed by different lowercases indicate significant difference among cultivars *vs*. mean (* $p<0.05$)

Tab. 3. Descriptive statistics (summary) for mineral elements (mg/100 g)

Mineral composition	Minimum	Maximum	Mean (mg/100 g)	Standard Deviation
Sodium, Na	0.36	0.97	0.67	0.24
Potassium K	591.75	639.13	617.34	23.34
Calcium Ca	72.07	130.92	104.81	21.06
Magnesium Mg	205.02	335.54	280.33	50.34
Phosphorus, P	300.67	455.06	385.73	62.17
Iron, Fe	5.30	8.77	7.53	1.31
Manganese, Mn	8.77	19.07	12.72	4.50
Zinc, Zn	1.82	2.84	2.42	0.37
Aluminium, Al	0.23	0.35	0.29	0.04
Chromium, Cr	0.12	0.84	0.62	0.29
Copper, Cu	1.62	3.07	2.28	0.58
Rubidium, Rb	1.34	3.03	1.83	0.69
Strontium, Sr	0.88	1.60	1.22	0.26

Tab. 4. Recommended dietary allowances (RDA) or adequate intake (AI) level of a nutrient*

Nutrient	Recommended Dietary Allowances		Average content in cultivars studied (mg/100 g)
	Unit	RDA/AI	
Calcium, Ca	mg	1000	105.75
Iron, Fe	mg	8	7.47
Magnesium, Mg	mg	400	278.82
Phosphorus, P	mg	700	386.22
Potassium, K	mg	4700	612.40
Sodium, Na	mg	1500	0.64
Zinc, Zn	mg	11	2.35
Copper, Cu	µg	900	2.26
Manganese, Mn	mg	2.3	12.66
Selenium, Se	µg	55	undetermined
Chromium, Cr	µg	35	0.59

*Source: http://en.wikipedia.org/wiki/Dietary_Reference_Intake#Vitamins_and_minerals

rus (256 - 314 mg 100 g^{-1}), calcium (161 - 264 mg 100 g^{-1}), and magnesium (34.9 - 152 mg 100 g^{-1}). Manganese is needed for bone development, healthy nerves, metabolism, a healthy immune system and regulating the blood sugar. Manganese content varied between 8.77 mg 100 g^{-1} ('Cozia') and 19.07 mg 100 g^{-1} ('Roverd'); higher than the one obtained (6.09 mg 100 g^{-1}) in varieties cultivated in Turkey (Açkurt *et al.*, 1999). The recommended intake for adult is 2.3 mg daily. According to the present study results, the five hazelnut cultivars have high Mn potential and may supply all of the human daily needs.

Iron content, in hazelnut cultivars here studied, was higher than the one found in Turkish hazelnut cultivars (Açkurt *et al.*, 1999; Koksal *et al.*, 2006; Özkutlu *et al.*, 2011). Iron concentration in the present study was found between 5.3 mg 100 g^{-1} ('Romavel') and 8.77 mg 100 g^{-1} ('Red Lambert'); the average iron content was 7.53 mg 100 g^{-1}. The results showed that hazelnut can be served as an excellent source of Fe. Consumption of 100 g hazelnut supplies 94% of iron intake (Tab. 2 and 3).

Copper, zinc, rubidium and strontium have recorded lower values in all cultivars studied (between 1 - 3.07 mg 100 g^{-1}); the rest of elements (Na, Al, Cr) were found in lower amounts, less than 1 mg 100 g^{-1}. Zinc and copper are two trace minerals, essential for important biochemical functions and necessary for maintaining health throughout life (Ma and Betts, 2000). The average copper level in cultivars is 2.28 mg 100 g^{-1}. It was observed the highest amount of Cu in 'Roverd' (3.07 mg 100 g^{-1}), while 'Romavel' cultivar hazelnuts had the lowest (1.62 mg 100 g^{-1}). Hazelnut varieties of 100 g amount can be a source of Cu to supply 100% of Cu daily human intake (900 µg).

Zinc is an essential mineral that is naturally present in some foods, added to others, and is available as a dietary supplement. Zinc is involved in numerous aspects of cellular metabolism. It is required for the catalytic activity of approximately 100 enzymes (Sandstead, 1994). The results of this study showed that hazelnut can be important for completing the deficiency of Zn in daily intake about 22% levels. The highest Zn element concentrations of hazelnut were found in the 'Cozia' cultivar (2.84 mg 100 g^{-1}) while the lowest was found in 'Romavel' cultivar (1.82 mg 100 g^{-1}); the average content is 2.42 mg 100 g^{-1}.

Chromium is an essential mineral. Chromium works with insulin to improve the transportation of glucose out of the blood and into the cell (Cefalu and Hu, 2004). According to the present study results, an average 5.6% of dietary Cr intake can be easily obtained from consumption of hazelnut at 100 g/day. The concentrations of Cr ranged from 0.12 to 0.84 mg 100 g^{-1} for the analyzed hazelnut varieties. Özkutlu *et al.* (2011) reported the content of Cr that varied between 0.02 to 0.05 mg kg^{-1}.

The health benefits of sodium play a pivotal role in enzyme operation and muscle contraction. It is important for osmo-regulation and fluid maintenance of the human body. Other health benefits of sodium include heart performance, nervous system and glucose absorption (Murphy and Eisner, 2009). Sodium concentration in this study was found to be between 0.36 ('Romavel') and 0.97 mg 100 g^{-1} ('Cozia'). The highest sodium content was found in Turkish hazelnut cultivars (the amount of Fe is found to be between 1.24 - 2.65 mg 100 g^{-1}) by Alasalvar *et al.* (2009).

Conclusions

The data obtained in this study do confirm that hazelnuts are a rich source of a number of important microelements, and their mineral content within the 100 g hazelnut was greater than human daily consumption for this required level. The results showed that an important part of daily K, P, Mg, Ca, Mn, Fe, Zn, Cu, Rb, Sr, Na, Cr, and Al requirement for human nutrition can be supplied by the daily consumption of 100 g hazelnut. According to the daily micro-element requirements and results of the present study, the amount of 100 g hazelnut has supplied about 13% for K, 55% for P, 70% for Mg, 10% for Ca, 94% for Fe, 22% for Zn and 5.6% for Cr of the RDA. For Mn and Cu, the levels of 100 g hazelnuts are higher than the respective daily requirements.

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