African Journal of Soil Science Vol. 1 (3), pp. 037-044, December, 2013. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

The importance of Turkish hazelnut trace and heavy metal contents for human nutrition

Faruk Özkutlu[1] Yusuf Ziya Doğru[2] Nedim Özenç[3] Gizem Yazici[1] Metin Turan[5]* and Fatih Akçay[6]

[1]Universiy of Ordu, Faculty of Agriculture, Department of Soil Science, Ordu-Turkey.
[2]Universiy of Atatürk, Narman Vocational School, Erzurum-Turkey.
[3]Giresun Hazelnut Research Institute, Giresun-Turkey.
[4]University of Sabancı, Faculty of Engineering and Natural Science, Istanbul-Turkey
[5]Universiy of Atatürk Faculty of Agriculture, Department of Soil Science, Erzurum-Turkey.
[6]Universiy of Atatürk, Faculty of Medicine, Department of Biochemistry, Erzurum-Turkey.

Accepted 23 December, 2013

The trace and heavy metal concentration of eighteen different varieties of hazelnut were studied for variety and geographical region discussed for human nutrition and health. These results showed that average Al, As, B, Cr, Co, Cd, Cu, Fe, Mn, Mo, Ni, Se, Pb, and Zn concentrations in the varieties varied in the following ranges 0.91-9.74, 0.02-0.27, 14.60-29.90, 0.02-0.04, 0.07-0.61, 0.01-0.03, 13.76-21.71, 35.12-49.40, 41.11-116.81, 0.09-0.31, 0.81-2.97, 0.02-0.05, 0.03-0.07 and 23.52-35.52 mg kg^{-1}. According to the daily microelement requirements, 100 g Uzunmusa cv, Kargalak cv., Cakildak cv. hazelnut provided about 50% for Fe and Cd, 41% for Mo, 32% for Zn, 21% for Se, 21% for Cr, 5% for B, 1% Ni of the recommended daily amount. On the other hand 100 g hazelnut can supply easily, a daily consumption of Mn, Cu, As, Pb, Al and Co levels of human beings.

Key words: Human nutrition, heavy metal, recommended daily amount, trace element.

INTRODUCTION

Hazelnut (*Corylus avellana* L.) belongs to the Betulaceae family and is a popular tree nut worldwide, 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 US (Oregon and Washington) (Turkish Hazelnut Exporter's Union, 2008).

Turkey is by far the leading producer of hazelnuts, with 75% of world production (Anonymous, 2010). Italy holds the second place with 15%, followed by the USA (2.9%), Spain (2.4%) and Greece (0.3%). In the last two decades, Turkey has increased its share, mainly at the expense of Italy and Spain, and to a lesser extends the USA. Although production is concentrated mainly in the Black Sea region, it has shifted from the eastern part of the region to the western area, thereby increasing production share from 36 to 45% (FAO, 2004). Turkey dominates world hazelnut production and is the centre of origin of the hazelnut. Hazelnuts make a significant contribution to Turkey's exports, as well as being a source of income for a large number of family farms in the Black Sea region.

Hazelnuts are widely used in the food industry such as confectionery, baking, ice-cream and dairy, candy and chocolate products. Hazelnuts can be added to a wide array of dishes from cereals and breads to yogurts, soups, salads and main dishes to confections, ice creams and pastries. They are famed for their use in pies and their affinity with chocolate. Hazelnuts also are popular with vegetarians for their inclusion in nut loaves, nut bread and rissoles; they also make delicious nut butter (Mehlenbacher, 1990; Simsek and Aslantas, 1999; Simsek and Aykut, 2007). Moreover, hazelnut is widely considered as a potential rich source of energy (620-650 kcal), minerals (2-3.5%) and vitamins (vitamin B1, vitamin B2, vitamin B6, niacin and vitamin E) for human consump-

*Corresponding author. E-mail: m_turan25@hotmail.com.

Table 1. Sampling coordinates, location, and altitudes for selected study sites.

Sampling location	Coordinate	Growth Altitude, m
ACI	00 2 N 080 2 0 E 00 0 N 0 80 2 2 E	1/0
ALLAHVERDI	00 N 080 2 0 E 00 2 N 0 0 2 0 E	1- 31
CAVCAVA	00 2N 080 2 0 E 00 N 0 80 2 2 E	0/0
CAKILDAK	00 2N 0 80 2 0 E 00 2 N 0 80 2 0 E	0/20
FOSA	00 2N 080 2 0 E 00 2N 0 80 2 2 E	0/0
INCEKARA	00 2N 0 80 2 0 E 00 28N 0 80 2 02 E	0/21
K – 24	00 N 0 80 2 0 E 00 N 0 80 2 2 E	0/0
KALINKARA	00 2N 0 80 2 0 E 00 2 N 0 80 2 02 E	0/22
KAN	00 2N 080 2 0 E 00 2 N 0 80 20 E	0/30
KARGALAK	00 2 N 0 80 20 E 00 2 N 0 80 20 E	0/32
KUS	00 2 N 0 80 2 0 E 00 2 N 0 80 20 E	1 /35
MINCANE	00 N 0 80 2 0 E 00 0N 0 80 2 E	1 /3
PALAZ	00 N 080 2 0 E 00 2 N 0 80 2 0 E	1 /33
SIVRI	00 2N 080 2 0 E 00 28N 0 80 2 0 E	1 /32
TOMBUL	00 N 0 80 2 0 E 00 28N 0 80 2 0 E	0 /26
UZUNMUSA	00 2N 080 2 0 E 00 2 N 0 80 2 0 E	0 /23
YASSI BADEM	00 N 080 2 0 E 00 2 N 0 80 2 0 E	1 /15
YUVARLAK BADEM	00 N 0 80 2 0 E 00 28N 0 80 2 02 E	1 /20

sumption (Ackurt et al., 1999; Souci et al., 2000; Koksal et al., 2006). In spite of the known major mineral composition potassium (K), phosphorus (P), manganese (Mn), calcium (Ca), magnesium (Mg), etc.) of hazelnuts, there is scarce literature on its trace and heavy element contents, like As, Al, Co, Cr, Se, B, Pb and Ni.

In particular, hazelnut is known to be a concentrated food for major elements and it may become an interesting food for its trace elements for the human diet. Many conscious people prefer supplementary foods with rich contents. Therefore, in recent years, there has been an increasing interest in the use of trace elements as micronutrient supplements in medical treatment to pre-vent various diseases such as cancer, cardiovascular diseases, AIDS, Alzheimer’s disease, Kashin-Beck disease, Keshan disease, osteoporosis, osteoarthritis, asthma, goiter, cataracts, stroke, arthritis, ageing, ane-miaete, and to complete mineral deficiency (Hunt, 1996; Reilly, 1998; Rayman, 2000). It is important to evaluate the plant type and growth condition in view of the human healthy standard and so, many papers have been published in recent years on the biological functions of microelements in humans.

Objective of this study was to investigate 18 Turkish hazelnut cultivars in view of the trace and heavy metal concentration and to compare the interspecies differences of the levels of these elements for human nutrition and health.

MATERIALS AND METHODS

This study was conducted in Northern part of Turkey which has the highest production area between 2007 and 2009, to asses the heavy metal concentrations in soil and hazelnut for human nutrition. Soil type of this area was classified as alfisol (Soil Survey Staff, 1992). Mean annual temperature, precipitation (rainfall) and relative humidity were 13.8 ºC, 1183 mm and 74.7%, respectively. Wind direction was S-WSW14.

Eighteen sampling locations were selected for detailed analyses (Table 1). Soil and plant samples were taken from Giresun Hazelnut Research gardens which were located at different parts of the Black Sea Region of Turkey, at harvest of August 2007 and 2009, 10 plant samples (One-hundred-gram fruit per tree) for each cultivar (Aci, Allahverdi, Cavcava, Cakildak, Fosa, Incekara, Kalinkara, Kan, K-24, Kargalak, Kus, Mincane, Palaz, Sivri, Tombul, Uzunmusa, Yassibadem, and Yuvarlakbadem) were collected randomly from portions of about 3.0 kg within a 2000 m^2 area. Plant samples were packed into polyethylene bags and care were taken to avoid contamination.

Hazelnut fruit samples were washed carefully with deionized water to remove adsorbed dust, then oven dried for 48 h at 68^oC and powdered. Micro-elements (As, B, Se, Fe, Mn, Zn, Cu, Ni, Pb, Cr, Mo, Co, Al and Cd) were determined after wet digestion of dried and ground sub-samples using a HNO_3-H_2O_2 acid mixture (2:3 v/v) with three step (first step; 145ºC, 75%RF, 5 min; second step; 180ºC, 90%RF, 10 min and third step; 100ºC, 40%RF, 10 min) in microwave (Bergof Speedwave Microwave Digestion Equipment MWS-2) (Mertens, 2005a). Tissue macro and micro elements were determined using an Inductively Couple Plasma spectrophotometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA) (Mertens, 2005b).

RESULTS AND DISCUSSION

Hazelnut is known to be a concentrated food for major elements and it may become an interesting food for its trace elements for the human diet. Trace elements are essential for human nutrition at low doses but may also be toxic for humans, animals and plants at higher doses (Tannenbaum et al., 1985; Ladipo, 2000). The toxic value for human of hazelnut is mainly depending on plant types and plant growth condition. So, it is important to evaluate the plant type and growth condition in view of the human health standards.

Hazelnut is the best source of essential element, amino acids, vitamin B and E among tree nuts (Holland et al., 1995) and serves as a good source of natural anti-oxidants (Ackurt et al., 1999; Bonvehi and Coll, 1997; USDA, 2008; Yurttas et al., 2000). Vitamin E or R-toco-pherol is a lipid soluble phenolic antioxidant. The antioxi-dant activity of phenolics is based on their ability to donate a hydrogen atom to free radicals. Because these compounds are able to scavenge free radicals, they are believed to have potential in the prevention of cancer, atherosclerosis, and diabetes (Thompson, 1994). Hazel-nut has also been reported to serve as a good source of essential elements, minerals, amino acids, and the B complex vitamins.

Boron deficiency has been reported in studies in rats, chickens, and humans. Boron appears to affect calcium and magnesium metabolism and may be needed for membrane function. Boron deficiency signs may be rela-ted to the level of vitamin D and possibly other nutrients in the diet. Boron has long been known to be essential for the growth of most plants.

The highest As and B element concentrations of hazelnut were found in the Uzunmusa cv, (0.39 and 29.9 mg kg^{-1}), the lowest were Aci and Palaz (0.07 and 14.6 mg kg^{-1}) in 18 cultivars, respectively. The B intake from hazelnut may promote bone and joint health, particularly in women (Hunt, 1996). Raisins, leafy vegetables, fruits such as grape, sour cherry, quince, peach, legumes and nuts such as almond, pistachio, and walnut are recom-mended as good sources of B by various researchers (Souci et al., 2000; Simsek et al., 2003a). Among the 18 cultivars, the B contents of hazelnuts are similar to those reported by Simsek et al. (2003b). Palaz varieties may be served as an excellent source of B. Consuming the recommended daily amount (RDA) of 100 g hazelnut supplies 5% of B (Tables 2 and 3).

Ni concentrations in the samples were found between 0.81 and 2.97 mg kg^{-1}. The Ni content of the Kargalak variety was found to be about two times higher than reported values (Souci et al., 2000). Consuming RDA of 100 g hazelnut supply 1% of Ni. In a recent study, nuts, cocoa and chocolate, soy beans, oatmeal, fresh and dried legumes were reported as foods that have very high Ni contents. On the other hand, the Ni content of foods is very important for dermatologists because larger amounts of Ni (600 mg/person/day) increase hand ecze-ma in Ni-sensitive women and men (Flyvholm et al., 1984; Dahiya et al., 2005). Consequently, excessive hazelnut consumption (more than 100 g day^{-1}) may cause Ni allergy and so should be avoided.

The only known nutritional, but very vital, function of cobalt is as an integral part of vitamin B12 and is also essential for the metabolism of glucose, insulin and fatty acids. Therefore it is proposed to increase muscle mass and decrease body fat in sportsman (Berger et al., 2002). Because vitamin B, is derived from bacterial synthesis, inorganic cobalt can be considered essential for animal species that depend totally on their bacterial flora for their vitamin B. This is the case for ruminant animal species in which cobalt deficiency is well known; it might also have some relevance for strict vegetarians whose intake of the preformed vitamin is severely limited. However, there is no evidence that the intake of cobalt is ever limiting in the human diet, and no RDA is necessary. While K-24 has the highest Co levels, the lowest Co levels were found in Kargalak varieties. The Co levels of hazelnuts changed between 0.07 and 0.61 mg kg^{-1}. K-24 varieties may be served as source of recommended daily intake of 100 g hazelnut supplies 100% of Co.

Depressed growth, impaired reproductive performance, and other changes have been reported in laboratory animals which fed diets extremely low in Cd and Pb and kept in an environment allowing the strictest control of contamination. Nutritional requirements, if they exist, are very low and easily met by the levels naturally occurring in foods, water, and air. The evidence for requirements and essentiality for human is weak. The highest Cd, Al, and Pb, element concentrations of hazelnut were found in the Uzunmusa cv, and Aci (0.03, 0.03 and 0.07 mg kg^{-1}), the lowest was K-24 (3.01, 0.01 and 0.02 mg kg^{-1}) in 18 cultivars, respectively. Uzunmusa cv, and Aci varieties may be served as source of RDA intake of 100 g hazelnut supplies 50% of Cd, 100 of Al, and Pb.

Trivalent chromium is required for maintaining normal glucose metabolism in laboratory animals; it acts as a cofactor for insulin. Experimental chromium deficiency has been induced in several animal species, resulting in impaired glucose tolerance in the presence of normal concentrations of circulating insulin and, in severe cases, in a diabetes-like syndrome (Schroeder, 1966). Three cases of pronounced chromium deficiency have been reported in patients on long-term total parenteral ali-mentation (Jeejeebhoy et al., 1977; Brown et al., 1986); all three had in common a relative insulin resistance and peripheral or central neuropathy. Chromium-responsive impairment of glucose tolerance has been reported in malnourished children, in some but not all studies of mild diabetics, and in middle-aged subjects with impaired glucose tolerance. (IPCS, 1988.)

Chromium concentrations in human tissues decline with age, except for the lungs in which chromium accu-mulates. Parity, juvenile diabetes, and coronary artery disease are associated with low-chromium concen-trations in hair or serum (IPCS, 1988).

The intestinal absorption of dietary chromium at daily intakes of 40 µg and more is approximately 0.5% of the total amount present; intakes less than 40 µg day^{-1} are absorbed with an increasing efficiency, up to about 2% of the total (Anderson and Kozlovsky, 1985). Absorbed chromium is excreted almost completely through the urine.

Table 2. Trace and heavy metal content of hazelnut varieties growth in Turkey (mg kg^{-1}).

	Al	As	B	Cd	Co	Cr	Cu
ACI	1.64	0.07	20.51	0.02	0.24	0.03	16.39
ALLAHVERDI	5.65	0.16	18.45	0.01	0.14	0.02	16.03
CAVCAVA	1.06	0.27	17.45	0.01	0.24	0.02	18.63
CAKILDAK	1.78	0.02	18.35	0.02	0.50	0.04	21.48
FOSA	1.61	0.17	17.03	0.02	0.19	0.02	21.38
INCEKARA	1.08	0.17	16.12	0.01	0.54	0.02	16.61
K – 24	0.91	0.13	19.12	0.01	0.07	0.03	12.80
KALINKARA	1.22	0.08	18.24	0.02	0.47	0.03	16.16
KAN	1.43	0.20	18.35	0.02	0.59	0.04	19.56
KARGALAK	9.74	0.07	15.91	0.01	0.61	0.05	17.89
KUS	1.50	0.08	18.57	0.01	0.35	0.04	15.39
MINCANE	1.28	0.14	21.35	0.01	0.18	0.04	21.71
PALAZ	1.18	0.10	14.60	0.01	0.61	0.04	19.90
SIVRI	1.27	0.06	16.10	0.01	0.60	0.04	13.76
TOMBUL	2.23	0.06	17.26	0.01	0.39	0.03	16.95
UZUNMUSA	18.11	0.19	29.90	0.03	0.37	0.02	15.36
YASSI BADEM	1.13	0.17	21.19	0.02	0.34	0.03	15.58
YUVARLAK BADEM	1.30	0.17	25.33	0.02	0.24	0.02	17.38
	Fe	**Mn**	**Mo**	**Pb**	**Zn**	**Ni**	**Se**
ACI	40.21	59.42	0.11	0.07	33.13	0.81	0.04
ALLAHVERDI	36.86	61.40	0.19	0.03	30.67	0.88	0.04
CAVCAVA	38.13	115.93	0.17	0.05	29.18	1.77	0.02
CAKILDAK	49.40	116.81	0.10	0.03	35.52	1.51	0.02
FOSA	39.84	75.46	0.11	0.07	31.92	2.46	0.03
INCEKARA	35.74	44.56	0.09	0.04	25.41	2.72	0.03
K – 24	38.97	48.83	0.29	0.02	33.39	1.36	0.04
KALINKARA	37.35	58.35	0.17	0.03	29.74	1.95	0.03
KAN	38.57	46.32	0.10	0.05	29.70	2.61	0.04
KARGALAK	36.73	46.05	0.09	0.05	27.88	2.97	0.04
KUS	36.51	52.70	0.10	0.04	26.39	2.20	0.04
MINCANE	39.94	41.11	0.21	0.04	25.35	0.83	0.05
PALAZ	35.12	63.83	0.11	0.03	26.04	1.89	0.04
SIVRI	35.25	70.08	0.09	0.04	23.52	1.56	0.04
TOMBUL	49.06	66.45	0.11	0.06	29.96	1.29	0.04
UZUNMUSA	37.62	67.75	0.31	0.04	29.84	1.54	0.05
YASSI BADEM	39.92	73.00	0.09	0.04	27.64	2.35	0.05
YUVARLAK BADEM	39.32	71.55	0.09	0.04	29.50	2.97	0.05

Chromium intake from typical western diets varies widely between 25 µg day^{-1} in elderly persons in England to approximately 200 µg in Belgian and Swedish diets, but in the most recent international studies (IPCS, 1988), intakes below 100 µg day^{-1} were reported. The concentrations of Cr ranged from 0.02 to 0.05 mg kg^{-1} for the analyzed hazelnut varieties. Cr values of some cultivars were found to be seven times and four times higher than those reported by Souci et al. (2000), respectively. According to in present study results, an average 10% of dietary Cr intake can be easily obtained from consumption of hazelnut at 100 g day^{-1}.

Some authors suggested that the Cr intake for athletes may have an effect with a high-energy diet because low-energy diets cause both deficiencies in Cr and lower body weights. Hazelnut has especially high carbohydrate (10-22%) and lipid concentration (55-65%), obtaining the full benefits from Cr (Simsek and Aslantas 1999).

Molybdenum plays a biochemical role as a constituent of several mammalian enzymes, such as aldehyde oxidase, xanthine oxidase, and sulfite oxidase (Rajagopalan, 1988); however, induction of characteristic

Table 3. The some mineral nutrition to feel the need for human beings (Alasalvar et al., 2009).

Nutrient	RDA	RNI	UL	SUL
Fe (mg day^{-1})	8-15	11.4	54	17
Zn(mg day^{-1})	11	9.5	40	25
Mn(mg day^{-1})	2-5	>1.4	11	4
Cu(mg day^{-1})	0.9-2.0	1.2	10	10
Se (µg day^{-1})	35-55	75	400	450
Mo (µg day^{-1})	45-75	50-400	2000	NS
Cr (µg day^{-1})	25-35	>25	NS	NS
B (mg day^{-1})	<20	NS	20	9.6
Ni (mg day^{-1})	35	NS	1000	260
As (µg day^{-1})	NS	NS	NS	NS
Pb (µg day^{-1})	20	NS	NS	NS
Al (µg day^{-1})	NS	NS	NS	NS
Co (µg day^{-1})	NS	NS	NS	NS
Cd (µg day^{-1})	60	NS	NS	NS

pathological lesions in animals due to nutritional molybdenum deficiency has been difficult (Mills and Bremner, 1980).

Two last decades some of investigations have suggested a role for molybdenum in human nutrition. The foods that contributed the most to the molybdenum intake were milk, beans, breads, and cereals. Pennington and Jones (1987) found lower molybdenum content in the 1984 collection of the Food and Drug Administration's Total Diet Study ranging from 76 to 109 µg day^{-1} for adult (females and males). In this study, all of the hazelnut varieties have got high Mo potential to supplies daily human intake.

The highest Mo element concentrations of hazelnut were found in the K-24 (0.29 mg kg^{-1}), the lowest was Kargalak (0.09 mg kg^{-1}) in 18 cultivars, respectively. All of the hazelnut supplies would be expected to contribute between 90-310 µg of molybdenum per day which would constitute 41% or less of the amount of the provisional recommended intake.

Iron is a constituent of hemoglobin, myoglobin, and a number of enzymes and, therefore, is an essential nutrient for humans (Bothwell et al., 1979). In addition to these functional forms, as much as 30% of the body iron is found in storage forms such as ferritin and hemosiderin (mainly in the spleen, liver, and bone marrow), and a small amount is associated with the blood transport protein transferring.

The average loss of iron in the healthy adult man is estimated to be approximately 1 mg day^{-1} (Green et al. 1968). In adult women, there is an additional loss of about 0.5 mg day^{-1}, the amount of iron in the average menstrual blood flow averaged over 1 month (Hallberg et al., 1966). In approximately 5% of normal women, however, menstrual losses of more than 1.4 mg day^{-1} have been observed. As menstrual losses deplete iron stores, absorption of dietary iron increases. Concordant figures are found using radio-labeled iron loss from circulating erythrocytes. This method gives reliable turnover information for adults and indicates that average requirements to replace daily losses for adults ages 20 to 50 are approximately 14 µg of iron per kilogram of body weight for males (1.10 mg 79 kg^{-1}) and 22 µg for premenopausal females (1.38 mg 63 kg^{-1}) (Bothwell and Finch, 1968).

In people without genetic defects that increase iron absorption, there are no reports of iron toxicity from foods other than long-term ingestion of home brews made in iron vessels (Walker and Arvidsson, 1953). Deleterious effects of daily intakes between 25 and 75 mg are unlikely in healthy persons (Finch and Monsen, 1972). On the other hand, there are approximately 2,000 cases of iron poisoning each year in the United States, mainly among young children who ingest the medicinal iron supplements formulated for adults. The amount of Fe is found to be between 35.7 and 49.4 mg kg^{-1} in hazelnut cultivars. The highest Fe concentration was found in Cakildak (49.4 mg kg^{-1}), but the amounts of Fe in Fosa, Yassi Badem, Yuvarlak Badem and Mincane were found to be quite similar to one another. Results show that hazelnut can be served as an excellent source of Fe. Consuming the RDA of 100 g hazelnut supplies 50% of Fe (Tables 2 and 3).

Zinc, a constituent of enzymes involved in most major metabolic pathways, is an essential element for plants, animals, and humans (Hambidge et al., 1986). Relatively large amounts of zinc are deposited in bone and muscle, but these stores are not in rapid equilibrium with the rest of the organism. The body pool of readily available zinc appears to be small and to have a rapid turnover rate, as shown by the prompt appearance of deficiency signs in laboratory animals. No single enzyme function has yet been identified that could explain the rapid onset of physiological and biochemical changes that follow the induction of zinc deficiency, but the requirement for zinc by many enzymes involved in gene expression (Chesters, 1982) could explain the immediate effect of deficiency on cell growth and repair.

The signs and symptoms of dietary zinc deficiency in humans include loss of appetite, growth retardation, skin changes, and immunological abnormalities. Studies in laboratory and domestic animals have shown that zinc deficiency during pregnancy may lead to developmental disorders in the offspring (Hurley and Baly, 1982).

The zinc content of typical mixed diets of North American adults has been reported to furnish between 10 and 15 mg day^{-1}. Pennington et al. (1984), in a survey of U.S. foods, found 13.2 mg of zinc in a 2,850 kcal diet. Infant and toddler diets containing 880 and 1,300 kcal contained 5.5 and 8.5 mg zinc, respectively. Elderly people generally have been found to consume 7 to 10 mg zinc daily (Greger, 1989). An evaluation of the most reliable balance studies indicates that at least 12 mg of zinc in a mixed U.S. diet is required to maintain the existing zinc status of healthy young men (Sandstead, 1985, Table 3).

These study results show that hazelnut can be important for completing the deficiency of Zn in dairy intake about 32% levels. The highest Zn element concentrations of hazelnut were found in the Cakildak (35.5 mg kg^{-1}), the lowest was Sivri (23.5 mg kg^{-1}) in 18 cultivars, respectively.

Manganese has been shown to be an essential element in every animal species studied. Signs of deficiency include poor reproductive performance, growth retardation, congenital malformations in the offspring, abnormal formation of bone and cartilage, and impaired glucose tolerance (Hurley and Keen, 1987). Several enzymes, such as decarboxylases, hydrolases, kinases, and transferases, are nonspecifically activated by manganese *in vitro*. There are two known manganese metalloenzymes: pyruvate carboxylase and superoxide dismutase, both localized in the mitochondria.

Whole grains and cereal products are the richest dietary sources of manganese, and fruits and vegetables are somewhat less so. Dairy products, meat, fish, and poultry are poor sources. Tea is a rich source of manganese, but typical drinking water consumed at the rate of 2 liters daily contributes only about 40 to 64 µg, or about 2 to 3% of the amount furnished by diet (NRC, 1980).

The Total Diet Study conducted in the United States between 1982 and 1986 indicated that the mean daily dietary manganese intake was 2.7 and 2.2 mg for adult men and women, respectively (Pennington et al. 1989). Teenage boys consumed an average of 2.8 mg day^{-1}, whereas girls consumed only 1.8 mg day^{-1}. Mean manganese intakes were 1.1 and 1.5 mg day^{-1} for 6- to 11-month-old babies and 2-year-old toddlers, respectively.

In humans, toxicity has been observed only in workers exposed to high concentrations of manganese dust or fumes in air, but not as a consequence of dietary intake by people consuming 8 to 9 mg of manganese per day in their food (WHO, 1973). In view of the remarkably steady tissue concentrations of manganese in the U.S. population (Schroeder et al., 1966) and the low toxicity of dietary manganese, an occasional intake of 10 mg day^{-1} by adults can be considered safe. To include an extra margin of safety, however, the subcommittee recommends a range of manganese intake from 2 to 5 mg day^{-1} for adults (Table 3).

The highest Mn element concentrations of hazelnut were found in the Cakildak (116.8 mg kg^{-1}), the lowest was Mincane (41.1 mg kg^{-1}) in 18 cultivars, respectively. According to our study result 18 hazelnut cultivar has got high Mn potential and may supply all of human daily needs.

Several abnormalities have been observed in copper-deficient animals, including anemia, skeletal defects, demyelination and degeneration of the nervous system, defects in pigmentation and structure of hair or wool, reproductive failure, myocardial degeneration, and decreased arterial elasticity. There are a number of important copper-containing proteins and enzymes, some of which are essential for the proper utilization of iron (Davis and Mertz, 1987).

Under normal circumstances, dietary copper deficiency is not known to occur in adults, but it has been observed in malnourished children in Peru; its manifestations are anemia, neutropenia, and severe bone demineralization (Cordano et al., 1964). In the early 1970s in the United States, similar findings were recognized in a few very small premature infants who were hospitalized for long periods and exclusively fed modified cow's milk formula or received prolonged parenteral alimentation. Presumably, these aberrations reflected a deficient dietary intake of copper (Cordano, 1974). More recently, copper deficiency has been shown to impair the growth of Chilean infants recovering from malnutrition (Castillo-Duran and Uauy, 1988).

Older analytical data indicating that most U.S. diets provide a daily copper intake between 2 and 5 mg are now being reexamined and questioned (Klevay, 1984). The Total Diet Study, based on the extensive dietary analyses performed by the U.S. Food and Drug Administration, showed that the daily intake of copper for adult males and females averaged about 1.2 and 0.9 mg, respectively, (Pennington et al., 1989). The intakes for infants 6 to 11 months old and toddlers 2 years old were 0.45 and 0.57 mg daily (Table 3).

In the past, estimates of the copper requirement for humans were derived from metabolic balance studies. However, the balance technique can lead to false estimates of nutritional requirements because the efficiency of copper absorption is increased or decreased in response to low or high copper intakes, respectively (Turnlund et al., 1989). Older balance studies suggested that the adult requirement for copper ranged from 2.0 to 2.6 mg/day, whereas later studies indicated that intakes less than 2.0 mg day^{-1}, and often not much more than 1.0 mg day^{-1}, could maintain positive copper balance (Mason, 1979).

The average Cu levels in varieties range from 12.8 to 21.7 mg/kg. We observed the highest amount of Cu in Mincane (21.7 mg/kg), but K-24 (12.8 mg/kg) hazelnuts had the lowest. Hazelnut varieties of 100 g amount can be source of Cu to supply 100% of Cu daily human intake.

Selenium is recognized as an essential trace element for human body at low concentrations (NRC, 1989). This element may be toxic if excess amounts are found in food and water (Bermejo- Barrera et al., 2002). This nutrient is also an important part of antioxidant enzymes that protect cells against the effects of free radicals that contribute to the development of some chronic diseases (Combs et al., 1998; Reilly, 1998; Rayman, 2000).

Average Se content of the varieties varied from 0.02 to 0.04 mg kg^{-1}. Se contents of hazelnuts were found lower to those reported (2.0-5.1 mg/100 g) in the Food Composition and Nutrition Tables (Souci et al., 2000), but similar those reported (0.47-1.69 mg 100 g^{-1}) in the literature (Dundar and Altundag, 2004). Results show that the contents of Se of our samples are higher than oilseeds walnuts (0.005-0.04 mg kg^{-1}), pistachio nuts (0.006-0.02 mg kg^{-1}), almonds (0.003-0.01 mg kg^{-1}) and peanuts (0-0.054 mg kg^{-1}) (Alarcon et al., 1996; Reilly, 1998; Souci et al., 2000). The present study show that hazelnuts and their products can also be a significant natural source of dietary Se instead of Se-fortified food products, and recommend to prevent diseases (about 40) linked with Se deficiency in some countries where the soil is extremely low in Se (Reilly, 1998). Moreover, hazelnuts have an advantage due to the fact that the bioavailability of Se in vegetable products is higher than that in animal foods such as meat, fish, seafood and offal (Alaejos et al., 2000).

Direct evidence of a requirement for selenium in human nutrition was lacking until 1979, when Chinese scientists reported an association between low selenium status and Keshan disease, a cardiomyopathy that affects primarily young children and women of childbearing age (Keshan Disease Research Group, 1979a). Sea foods, kidney, and liver, and to a lesser extent other meats, are consistently good sources of selenium, whereas grains and other seeds are more variable, depending on the selenium content of the soils in which they are grown (WHO, 1987; Keshan Disease Research Group, 1979b). Fruits and vegetables generally contain little selenium. Drinking water usually makes only a small contribution to selenium intake (WHO, 1987). Studies in animals have shown that the bioavailability of selenium in certain fish is less than that in other foods (Mutanen, 1986). Few data exist on the bioavailability of selenium in foods consumed by humans. However, bioavailability trials conducted in subjects with poor selenium status indicated that organically bound forms of se-tested caused similar increases in glutathione peroxidase activity (Levander et al., 1987; Thomson et al., 1982).

Analyses of national food composites in the United States indicate that the overall adult mean dietary selenium intake was 108 µg day^{-1} (Pennington et al., 1984), but 35-55 mg day according to Table 3. Several balance studies have been conducted to investigate selenium requirements of humans. However, humans apparently can adjust their selenium homeostatic mechanisms to remain in balance over rather wide ranges of dietary intakes. Therefore, the balance technique is of little help in delineating the selenium requirements of humans (Levander, 1987).

The level of dietary selenium exposure needed to cause chronic poisoning in humans is not known with certainty, but approximately 5 mg day^{-1} from foods resulted in fingernail changes and hair loss in a seleniferous zone of China (Yang et al., 1983). The Chinese investigators also reported that a person who had consumed 1 mg of selenium daily as sodium selenite for more than 2 years had thickened but fragile nails and a garlic odor in dermal excretions.

In this study, most common hazelnut cultivars in the Turkey were analyzed and found to contain significant quantities of variety of essential nutrients. All of the hazelnut varieties may be served as an excellent source of Se. Consuming the RDA of 100 g hazelnut supplies 21% of Se.

Conclusion

According to variance analysis, the effect of cultivars on microelements is found to be significant. The Mn concentration in hazelnut varieties was determined to be the highest level among the microelements, followed by Fe, Zn, B, Cu, Al, Ni, Co, Se, Mo, Pb, As, Cd,and Cr. The highest Se (0.05 mg kg^{-1}), Al (18.1 mg kg^{-1}), As (0.19 mg kg^{-1}), B (29.9 mg kg^{-1}), Cd (0.03 mg kg^{-1}) and Mo (0.31 mg kg^{-1}) element concentrations of hazelnut were found in the Uzunmusa cv, the highest Co (0.61 mg kg^{-1}), Cr (0.05 mg kg^{-1}), Pb (0.05 mg kg^{-1}), and Ni (2.9 mg kg^{-1}) in the Kargalak cv., and the highest Cu (21.5 mg kg^{-1}), Fe (49.4 mg kg^{-1}), Mn (166.8 mg kg^{-1}) and Zn (35.5) in the Cakildak cv. The levels of microelement changes according to varieties may have resulted from differences in use of fertilizers, the methods of cultivation and irrigation, soil composition of the production zone, the climate and the geographical region. Data obtained from hazelnut plants show that they had a very high nutritional potential, and their mineral content of 100 g hazelnut was greater than that of human daily consumption for this required level. Our results show that an important part of daily Co, Pb, Mo, Al, Cd, Mn, Pb, Cr, Cu, B, Zn, Fe, Ni and Se requirement for human nutrition can be supplied by the consumption of 100 g Uzunmusa cv, Kargalak cv., Cakildak cv. hazelnut daily. Hazelnut consumption with fruit juices containing particularly high ascorbic acid levels may be useful to enhance Fe absorption. Besides, hazelnuts are a good source to enrich dairy products for Fe. According to the daily microelement requirements, 100 g hazelnut provided about 50% for Fe and Cd, 41% for Mo, 32% for Zn, 21% for Se, 10% for Cr, 5% for B and 1% Ni of the RDA. On other hand, Mn, Cu, As, Pb, Al, and Co levels of 100 g hazelnuts are higher than the respective daily requirements, but slight overdoses of these elements are non-toxic for human health.

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