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Tocopherols and total phenolics in 10 different nut types

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Abstract

The study was conducted to assess the content of tocopherols (α-, β-, γ- and δ-) and carotenoids (α- and β-carotene, zeaxanthin, lutein, cryptoxanthin and lycopene) in the unsaponifiable matter as well as the amount of total phenols of 10 different types of nuts. Tocopherols and carotenoids were analysed with HPLC, total phenols photometrically. The mean value of α-tocopherol equivalents ranged from non-detectable (macadamias) to 33.1 mg/100 g extracted oil (hazelnuts). Among all nuts, almonds and hazelnuts had the highest mean α-tocopherol content (24.2 and 31.4 mg/100 g extracted oil, respectively). β- and γ-tocopherols were prevalent in Brazil nuts, cashews, peanuts, pecans, pines, pistachios and walnuts. Mean values oscillated between 5.1 (cashews) and 29.3 (pistachios). Traces of δ-tocopherol (<4 mg/100 g extracted oil) were analysed in cashews, hazelnuts, peanuts, pecans, pines, pistachios and walnuts. There were no carotenoids detected in the tested nuts with the exception of pistachios. The mean content of total phenolics varied between 32 mg gallic acid equivalents/100 g (pines) and 1625 mg (walnuts). The results show the heterogenic amounts of antioxidants in nuts, which emphasises the recommendation of a mixed nuts intake.

Keywords: Almonds; Brazil nuts; Cashews; Hazelnuts; Macadamias; Peanuts; Pecans; Pines; Pistachios; Walnuts; Antioxidants; Tocopherols; Total phenolics

1. Introduction

Nuts are recommended constituents of the daily diet, although their real intake differs remarkably. In particular, they are part of healthy diets such as the Mediterranean diet. In the traditional Mediterranean population, mortality rates from coronary heart disease (CHD) and cancer are low (Simopoulos, 2001). Results from several epidemiological studies and traditions suggest that there may be a connection between frequent nut consumption and a reduced incidence of CHD (Kris-Etherton, Zhao, Binkoski, Coval, & Etherton, 2001; Simopoulos, 2001). These effects are assumed to be mainly due to the less atherogenic plasma lipid profiles (Abbey, Noakes, Belling, & Nestel, 1994; Edwards, Kwaw, Matud, & Kurtz, 1999; Rajaram, Burke, Connell, Myint, & Sabaté, 2001; Spiller et al., 1998; Zambón et al., 2000). However, emerging proofs indicate that nuts may be a source of health promoting compounds that elicit cardioprotective effects (Kris-Etherton et al., 1999). In particular, nuts include plant protein, unsaturated fatty acids, dietary fibre, plant sterols, phytochemicals and micronutrients like tocopherols (Kris-Etherton et al., 2001). Foods of plant origin, such as fruits and vegetables and whole grain products have been suggested as a natural source for antioxidants. Since free radicals are discussed to play a key role in the pathology of diseases, such as cancer, atherosclerosis or inflammatory diseases (Scalbert & Williamson, 2000), the supply of antioxidants via the food chain is of high importance for a healthy life. However, comprehensive data on antioxidants in the unsaponifiable matter of nuts is scarce.

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Therefore, this study focused on the different concentrations of tocopherols and carotenoids and the total phenolics in typically consumed nuts: almonds, Brazil nuts, cashews, hazelnuts, macadamias, peanuts, pines, pistachios and walnuts. Most nuts are the seeds of trees, but the peanuts, also known as ground nuts, are actually legumes (Dreher & Maher, 1996).

Since it is not known whether some nuts are more beneficial than others for human health more information on their nutritional composition is important.

2. Materials and methods

2.1. Reagents

Acetonitrile LiChrosolv, methanol LiChrosolv, *n*-hexane HPLC, dichlormethane and sodium sulfate were purchased from Merck (Vienna, Austria). The standards α-, γ- and δ-tocopherol, α- and β-carotene and zeaxanthin were purchased from Sigma (Vienna, Austria). The standard lutein and the Folin–Ciocalteu's reagent were purchased from Fluka (Vienna, Austria) and cryptoxanthin was a gift from la Roche. All other chemicals were purchased from Riedel de Haën (Vienna, Austria).

2.2. Samples and sample preparations

Almonds, Brazil nuts, cashews, hazelnuts, macadamias, peanuts, pecans, pines, pistachios and walnuts were purchased in a local super market in Vienna (Austria) and from a public market in Ródos (Greece). Additionally, all kinds of nuts were purchased from the company Farmgold (Austria), which supplies different types of nuts and dried fruits for the Austrian stores and superstores. Thus, every kind of nut was analysed from three different providers, giving a broad sample base thereby considering the natural heterogeneity.

2.3. Analytical procedures

The samples were chopped in a coffee mill. Dry matter was determined gravimetrically at 103 °C for 12 h.

Lipid extraction for total fat determination was accomplished with a Soxhlet extraction using petroleum ether as a solvent; 9 g of the dried, homogenized sample was placed in an extraction cell and then extracted for 6 h. Thereafter, the solvent was evaporated. The remaining oil was dried under a nitrogen stream and placed in an oven at 100 °C for 1 h. The total fat content was determined gravimetrically.

Analyses of the unsaponifiable matter were undertaken with 2 g of oil. Homogenized samples were saponified with 40 ml of 0.8 M KOH in ethanol at 80 °C for 30 min. The extraction was carried out with 2×50 ml hexane. The combined solvents were washed with water, dried over Na_2SO_4, evaporated and dried in an oven at 103 °C for 2 h. The weight was obtained gravimetrically.

Lipid extraction for chemical analysis was performed with petroleum ether. Approximately 5 g of chopped nuts were placed in a 100 ml extraction glass and than extracted with 100 ml of the solvent for 12 h. After, the solvent was removed by vacuum distillation (max. 40 °C) and the extract dried under nitrogen. The extracted oils were kept in tubes, flushed with nitrogen and stored at 4 °C until the analyses were carried out.

α-, β-, γ-, and δ-tocopherols were measured by RP-HPLC and UV-detection at 295 nm based on the method by Elmadfa and Wagner (1997) with minor modifications. Around 20 mg of the extracted nut oil was extracted with 5 ml *n*-hexane, thereof 0.5 ml was evaporated with nitrogen. The remnant was dissolved in 150 μl mobile phase and 100 μl injected into a 250×4 mm Merck RP-18 column, equipped with a Merck Hitachi UV-detector. The mobile phase was methanol/dichlormethane (85:15 v/v) at a flow rate of 0.8 ml/min. The amounts of each tocopherol were calculated by standard samples and a Merck Hitachi integrator was used to calculate the peak areas. The analyses were carried out with dimmed light and the samples were flushed with nitrogen in order to prevent oxidation. β-tocopherol was not resolved from γ-tocopherol by RP-chromatography. For that reason, we describe β- and γ-tocopherol together.

Carotenoids were analysed by using the method of Jakob and Elmadfa (1995). The samples were screened for α- and β-carotene, zeaxanthin, lutein, cryptoxanthin and lycopene. Therefore, the oil (100 mg) was extracted with 3 ml hexane, of which 2 ml was evaporated. The remnant was resolved in 150 μl methanol/dichlormethane, and 100 μl was injected. The system consisted of a 250×4.5 μm LiCrospher RP-18 column, a Merck Hitachi L-6200 a intelligent pump, Merck Hitachi L 4250 UV-detector and a Merck Hitachi D-2500 integrator. The detection wavelength was set to 450 nm. Methanol/dichlormethane (85:15 v/v) was used as mobile phase. The VYDAC-column 201TP54 was used for a better determination of lutein and β-carotene in the pistachios. Extracted lipids (20 mg) were dissolved in 1 ml methanol/dichlormethane (1:1 v/v) and injected (20 μl). The mobile phase was methanol/acetonitrile/dichlormethane (85:10:1 v/v).

Total phenolics were measured by the Folin–Ciocalteu-reagent mentioned by Linkens and Jackson (1988). A total phenolic extract was prepared by a lightly modified procedure of Anderson et al. (2001). The chopped nuts were extracted with a solution of 75% acetone and 25% of 526 μmol/L sodium metabisulfite. The supernatant was pipetted and centrifuged. Then, the extraction solution was evaporated and extracted with hexane. The water soluble phase was used for determin-

ing the concentration of total phenolics expressed as gallic acid equivalents (GAE) per 100 g nuts.

The quality criterion of the analytical methods was the coefficient of variation (CV): CV%: Lipid extraction for total fat determination: 1.7; dry matter: 0.2; unsaponifiable matter: 5.5; tocopherols: <5.8; lutein: 1.0; β-carotene: 8.2 and total phenolics: 4.2.

3. Results and discussion

3.1. Total lipid and dry content

It is known that genetics, harvest season, origin, environmental conditions, soil composition, maturity level and the methods of cultivation highly influence the composition of nuts (Lavedrine, Ravel, Villet, Ducros, & Alary, 2000; Parcerisa et al., 1995; Wakeling, Mason, D'Arcy, & Caffin, 2001). In order to consider the latter, the samples were chosen heterogeneously from different places and suppliers. In Austria, there is no tradition of nut harvesting, therefore, the presented data take into account that most nuts available in Austria are imported from other countries.

Dry matter, fat content and the unsaponifiable matter of the investigated samples are shown in Table 1. The data are expressed as mean and range. Nuts are characterized by a high oil and dry matter content. The mean value of dry matter ranged from 93.9% (peanuts) to 98.1% (macadamias). These results are in agreement with previously reported values (Alasalvar, Shahidi, Liyanapathirana, & Ohshima, 2003a, 2003b; Amaral, Casal, Pereira, Seabra, & Oliveira, 2003). Kaijser, Dutta, and Savage (2000) reported that fresh macadamias can have a moisture content of 30%. Because of better storage options, this nut type is dried to a moisture content of ~2%. Beyond, Singanusong, Mason, D'Arcy, and Nottingham (2003) suggested that the moisture content in pecans may be an index of maturity. In addition, early-harvested pecans show higher moisture content and they have to be dried to a lower moisture content percentage to obtain good quality.

The highest fat content was detected in macadamias (mean value = 76.2% of dry matter) and the lowest in cashews (mean value = 47.1%). The fat content in descending order was macadamias > pecans > pines > Brazil nuts > walnuts > hazelnuts > almonds > pistachios > peanuts > cashews. The oil content in different nuts was similar to that reported previously by other authors (Grosso, Nepoto, & Guzmán, 2000; Savage, 2001; Savage, McNeil, & Dutta, 1997). Our results differ from a recently published work by Maguire, O'Sullivan, Galvin, O'Connor, and O'Brien (2004). Their results indicated that the fat content of hazelnuts, macadamias, peanuts, walnuts and almonds is slightly lower. On the other hand, they did not mention the moisture content. In addition, Nergiz and Dönmez (2004) reported that the amount of oil in pines was 44.9% on average and proposed that the low fat content varies due to differences in species and environmental factors. Nevertheless, our results confirm the earlier observations that nuts are sources of high energy due to their total fat content. Therefore, nuts have been treated with caution in most previous food pyramids (Fraser, 1999). However, this point of view has now been reconsidered and moderate nut consumption is recommended since their unsaturated fatty acids have been shown to be cardioprotective (Kris-Etherton et al., 2001; Fraser, 1999) – more than 75% of total fatty acids of nuts are unsaturated.

The mean value of unsaponifiable matter oscillated between 0.27 g/100 g extracted oil (hazelnuts) and 0.52 g (Brazil nuts). These results are in agreement with the hazelnut investigations of Savage et al. (1997). Nev-

Table 1
Fat and dry matter as well as unsaponifiable matter of the investigated nuts

	Dry matter (% dry weight)		Fat content (% dry weight)		Unsaponifiable matter (g/100 g extracted oil)	
	Mean	Range	Mean	Range	Mean	Range
Almonds[+,−a]	95.8	95.1–96.6	56.7	52.1–60.4	0.44	0.35–0.53
Brazil nuts[b]	97.3	96.9–97.7	68.3	66.2–69.5	0.52	0.44–0.66
Cashews[b]	96.0	95.7–96.1	47.1	44.8–49.1	0.39	0.25–0.53
Hazelnuts[b]	96.3	95.8–97.3	60.2	55.9–67.1	0.27	0.20–0.30
Macadamias[b]	98.1	97.8–98.6	76.2	73.9–77.6	0.31	0.30–0.33
Peanuts[+b]	93.9	93.6–94.1	51.6	49.4–53.8	0.43	0.35–0.59
Pecans[b]	96.6	96.1–97.3	71.8	70.2–73.6	0.38	0.30–0.45
Pines[b]	97.2	96.9–97.5	69.2	67.8–70.7	0.41	0.40–0.42
Pistachios[a]	97.2	96.0–98.3	52.8	44.7–58.9	0.39	0.29–0.45
Walnuts[b]	96.4	96.1–96.9	64.2	63.2–65.2	0.33	0.25–0.40

[a] Data are expressed as means and range ($n = 6$).
[b] Data are expressed as means and range ($n = 3$).
[−] Without skin.
[+] With skin.

ertheless, limited information regarding the unsaponifiable matter is available in the literature. However, knowledge of these components is important to explain the biological mechanisms that occur in a reduction of cardiovascular diseases (CHD).

Table 2 shows the tocopherol and carotinoid content of the 10 selected nuts. The α-tocopherol equivalents varied from non-detectable (macadamias) to 33.1 mg/100 g extracted oil (hazelnuts). The mean α-TEs in descending order was hazelnuts > almonds > peanuts > pistachios > pines > walnuts > Brazil nuts > pecans > cashews > macadamias. We calculated with the lower conversion factor for β- and γ-tocopherol to prevent an overestimation of α-TEs. α-Tocopherol content was highest in hazelnuts (mean value = 31.4 mg/100 g oil) and almonds (mean value = 24.2 mg/100 g oil). The α-tocopherol content of hazelnuts was similar to those reported previously (Açkurt, Özdemir, Biringen, & Löker, 1999; Alasalvar et al., 2003a, 2003b; Özdemir et al., 2001; Parcerisa et al., 1995; Parcerisa, Richardson, Rafecas, Codony, & Boatella, 1998). Maguire et al. (2004) mentioned that α-tocopherol was the most dominant tocopherol in almonds, peanuts, hazelnuts and macadamias. It ranged from 9.4 (peanuts) to 186.4 μg/g oil (almonds). In our investigations, small amounts of α-tocopherol (<7 mg/100 g oil) were also detected in Brazil nuts, peanuts and pines. However, not only α-tocopherol but also other tocopherol forms are recently considered to be of biological importance (Wagner, Kamal-Eldin, & Elmadfa, 2004). Both, β- and γ-tocopherol, were the most predominant tocopherols in 7 nut types and the mean amounts in descending order were pistachios > walnuts > pecans > Brazil nuts > pines ⩾ peanuts > cashews. Traces of δ-tocopherol (<4 mg/100 g extracted oil) were found in cashews, hazelnuts, peanuts, pecans, pines, pistachios and walnuts. No tocopherols were detected in macadamias. These results are comparable with data published by other workers. Kaijser et al. (2000) mentioned that the tocopherol contents are very low in macadamias (<1.1 μg/g lipids). Otherwise, they identified α-tocotrienol ranging from 12.5 to 48.4 μg/g lipids. In contrast with the latter, Maguire et al. (2004) reported that the α-tocopherol content in the macadamias was 122.3 μg/g oil. In reference to nutrition, low levels of vitamin E could be associated with a potentially higher risk of atherosclerosis or other degenerative diseases and increased intakes appear to be protective against these diseases. One of the most developed theory for the cardioprotective effect appears to be concerning tocopherol induced inhibition of LDL oxidation, which is proposed to be a key role in the atherogenic process (Elmadfa & Wagner, 2003). On the other hand, Miller et al. (2005) showed that high dosage (>400 IU/d) vitamin E supplements may increase all-cause mortality. However, low quantities which can be obtained from average nut consumption have been shown to be beneficial on CHD (Bramley et al., 2000). In addition, α-tocopherol is assumed to be the most active form in humans; however γ-tocopherol is the most prevalent form of vitamin E in plant seeds, especially in nuts (Jiang, Christen, Shigenaga, & Ames, 2001; Wagner et al., 2004). Therefore, nuts are good dietary sources of α-, β- and γ-tocopherol and can contribute to a balanced intake of vitamin E. Nevertheless, the average intake of nuts is very low in Austria (4 g/d) and should be increased in order to meet the recommendations of 30 g/d.

Table 2
Tocopherol and carotinoid content of oil extracted from different kinds of nuts

	α-Tocopherol		β- and γ-Tocopherol		δ-Tocopherol		α-TE		β-Carotene		Lutein	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Almonds[+,−a]	24.2	nd to 34.9	3.1	0.5–10.4	nd	nd	25.0	2.6–35.2	nd	nd	nd	nd
Brazil nuts[b]	1.0	nd to 2.2	13.2	8.2–17.9	nd	nd	4.3	2.1–6.7	nd	nd	nd	nd
Cashews[b]	nd	nd	5.1	4.8–5.3	0.3	0.3–0.4	1.3	1.2–1.3	nd	nd	nd	nd
Hazelnuts[b]	31.4	15.7–42.1	6.9	4.3–9.4	0.1	nd to 0.3	33.1	16.8–44.4	nd	nd	nd	nd
Macadamias[b]	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Peanuts[+b]	6.1	1.7–10.4	8.1	5.4–10.0	1.8	1.4–2.4	8.1	3.1–12.9	nd	nd	nd	nd
Pecans[b]	nd	nd	14.8	2.1–23.8	0.2	nd to 0.7	3.7	0.5–6.0	nd	nd	nd	nd
Pines[b]	4.1	2.2–6.0	8.1	6.4–9.8	0.3	nd to 0.7	6.1	3.8–8.5	nd	nd	nd	nd
Pistachios[a]	nd	nd	29.3	10.0–43.4	0.5	nd to 2.3	7.3	2.5–10.8	0.4	nd to 1.0	4.4	1.5–9.6
Walnuts[b]	nd	nd	21.9	12.4–32.8	3.8	2.3–5.4	5.5	3.1–8.2	nd	nd	nd	nd

Data are expressed as mg/100 g extracted oil.

nd, not detectable. Vitamin E activity in food is represented as α-tocopherol equivalents (α-TE). α-TEs were defined as α-tocopherol, mg × 1.0; β- and γ-tocopherol, mg × 0.25 (lower conversion factor); and δ-tocopherol, mg × 0.01.

[a] Data are expressed as means and range ($n = 6$).

[b] Data are expressed as means and range ($n = 3$).

[−] Without skin.

[+] With skin.

The samples were also investigated on the carotenoids α- and β-carotene, zeaxanthin, lutein, cryptoxanthin and lycopene, but their total amount was marginal. Only traces of β-carotene and lutein (<5 mg/100 g oil) were present in pistachios. The results are comparable to those reported by Lavedrine, Ravel, Poupard, and Alary (1997). They mentioned that retinol and carotenes were not identified in walnuts. Otherwise, there is a paucity of information regarding the content of carotenes in the literature.

Table 3 shows results for total phenolics (TP). The mean value of total phenolics oscillated between 32 mg (pines) and 1625 (walnuts) GAE/100 g. In increasing amounts, the order was pines < macadamias < almonds without skin < Brazil nuts < cashews < almonds with skin < hazelnuts < peanuts with skin < pistachios < pecans < walnuts, which is in accordance with published data (Anderson et al., 2001; Wu et al., 2004). In addition, Wu et al. (2004) investigated the lipophilic and hydrophilic antioxidant capacities, the total antioxidant capacity (TAC) as well as total phenolics of common foods in the United States. The compositions of total phenolics reported in the study are comparable to our data. Their investigated mean value varied between 0.68 mg GAE/g (pines) and 20.16 mg GAE/g (pecans). They also found a high total antioxidant capacity in pecans (179 μmol TAC/g), pistachios (80 μmol TAC/g) and walnuts (135 μmol TAC/g). Pines showed the lowest level of total antioxidant capacity with only 7 μmol/g. Our investigations showed that almonds with skin have a higher content than almonds without hulls (239 vs. 47). The results confirm the earlier observation that almonds hulls contain high amounts of phenolics. For example, rhamnetin, quercetin, kaempherol aglycones, chlorogenic acid, cryptochlorogenic acid, neochlorogenic acid, 3-prenyl-4-*O*-β-glucopyranosyl-oxy-4-hydroxylbenzoic acid, catechin, protocatechuic acid, betulinic acid, olianolic acid and ursolic acid have been identified (Pinelo, Rubilar, Sineiro, & Núñez, 2004; Sang et al., 2002a, Sang, Lapsley, Rosen, & Ho, 2002b; Takeoka & Dao, 2003; Takeoka et al., 2000). Sang et al. (2002a, 2002b) determined nine phenolic compounds from almond skins (Punus amygdalus Batsch). The latter authors isolated 3′-*O*-methylquercetin3-*O*-β-D-glucopyranoside, 3′-*O*-methylquercetin3-*O*-β-D-galactopyranoside, 3′-*O*-methylquercetin3-*O*-α-L-rhamno-pyranosyl-(1-6)-β-D-glucopyranoside, kaempferol3-*O*-α-L-rhamnopyranosyl-(1-6)-β-D-glucopyranoside, naringenin7-*O*-β-D-gluco-pyranoside, catechin, protocatechuic acid, vanillic acid and *p*-hydroxybenzoic acid. Shobha, Krishnaswamy, and Ravindranath (1992) investigated the phenolic lipid composition (anacardic acids, cardols and cardanols) during development of cashews. Phenolic compounds in macadamias were identified by Quinn and Tang (1996). They identified only 4 from over 30 peaks, such as 2,6-dihydroxybenzoic acid, 2′-hydroxy-4′-methoxyacetophenone, 3′5′-dimethoxy-4′-hydroxy-acetophenone and 3,5-dimethoxy-4-hydroxycinnamic acid by gas chromatography. Furthermore, thin layer chromatography of oil extracted from macadamia nut kernels suggested the presence of catechol, phrogallol and 3,4,5,-trihydroxy phenolic compounds (Quinn & Tang, 1996). In our work, we analysed raw peanut kernels with hulls, because the skin is rich in phenolics and health promoting compounds. Yu, Ahmedna, and Goktepe (2005) reported that three classes of phenolics were found in peanut skin. 1. Phenolic acids including chlorogenic acid, caffeic acid, coumaric acid; 2. flavonoids including epigallocatechin, epicatechin, catechin gallate, epicatechin gallate and 3. stilbene (resveratrol). In addition, Talcott, Passeretti, Duncan, and Gorbet (2005) published recently the phenolic content in high oleic acid peanuts. Among nut species, peanuts have a major role in human nutrition. Peanuts provide an excellent source of antioxidant polyphenolics, such as *p*-coumaric acid (Talcott et al., 2005). The recent combined data suggest that nuts serve as a good source of total phenolics with a high antioxidative potential, especially walnuts, pistachios, pecans, almonds with hulls, hazelnuts and peanuts. Experimental investigations reported by Anderson et al. (2001) support this assumption. The latter authors have shown that walnut polyphenols are effective inhibitors of in vitro plasma and LDL oxidation. Nuts polyphenols have lipophilic and hydrophilic properties (Wu et al., 2004). Moreover, Durak et al. (1999) reported that supplementation of hazelnuts (1 g/day/kg body weight) to the habitual diet enhanced the antioxidant potential in plasma and lowered malondialdehyd, total cholesterol and LDL-cholesterol levels. Similar results were observed for dose-response effects of almonds. However, Jenkins et al. (2002) measured conjugated dienes in the LDL fraction as a marker of LDL.

Table 3
Content of total phenolics in nuts expressed as gallic acid equivalents (GAE)

	mg of GAE/100 g fresh weight	
	Mean	Range
Almonds[−a]	47	45–49
Almonds[+a]	239	130–456
Brazil nuts[a]	112	100–133
Cashews[a]	137	131–142
Hazelnuts[a]	291	101–433
Macadamias[a]	46	45–46
Peanuts[+a]	420	326–552
Pecans[a]	1284	1022–1444
Pines[a]	32	30–34
Pistachios[b]	867	492–1442
Walnuts[a]	1625	1020–2052

[a] Data are expressed as means and range ($n = 3$).
[b] Data are expressed as means range ($n = 6$).
[−] Without skin.
[+] With skin.

Their data indicate that almonds reduce oxidized LDL, which plays a key role in the development of CHD.

4. Conclusion

Nuts contain a diverse array of compounds that enhance the nutritional value of the human diet. Knowledge of these components is important to elucidate the protective mechanisms. There is much evidence that antioxidants from fruits and vegetables, such as tocopherols and polyphenols play an important role in the prevention of cancer, inflammatory activities and cardiovascular disease. In addition, proofs have suggested that it may be whole fruits or vegetables, rather than certain individual compounds they contain, that may prevent various diseases that have been observed by epidemiological studies. Regarding the antioxidant potential, nuts are an excellent source of tocopherols and polyphenols.

In this investigation, walnuts, pistachios and pecans contained the highest total phenol and total tocopherol content among all types of nuts, followed by peanuts with skin, hazelnuts and almonds with skin. The antioxidants were lower in cashews and pines. Macadamias contained the lowest level of antioxidative constituents (polyphenols, tocopherols). Finally, it is important to emphasise that, in addition to the tocopherols and polyphenols mentioned in this work, many other nutrients and components that nuts contain have the potential to reduce the risk of CHD.

References

Abbey, M., Noakes, M., Belling, G. B., & Nestel, P. J. (1994). Partial replacement of saturated fatty acids with almonds or walnuts lowers total plasma cholesterol and low-density-lipoprotein cholesterol. *American Journal of Clinical Nutrition, 59*(5), 995–999.

Açkurt, F., Özdemir, M., Biringen, G., & Löker, M. (1999). Effects of geographical origin and variety on vitamin and mineral composition of hazelnut (*Corylus avellana* L.) varieties cultivated in Turkey. *Food Chemistry, 65*, 309–313.

Alasalvar, C., Shahidi, F., Liyanapathirana, C. M., & Ohshima, T. (2003a). Turkish tombul hazelnut (*Corylus avellana* L.). 1. Compositional characteristics. *Journal of Agricultural and Food Chemistry, 51*(13), 3790–3796.

Alasalvar, C., Shahidi, F., Ohshima, T., Wanasundara, U., Yurttas, H. C., Liyanapathirana, C. M., et al. (2003b). Turkish tombul hazelnut (*Corylus avellana* L.). 2. Lipid characteristics and oxidative stability. *Journal of Agricultural and Food Chemistry, 51*(13), 3797–3805.

Amaral, J. S., Casal, S., Pereira, J. A., Seabra, R. M., & Oliveira, B. P. P. (2003). Determination of sterol and fatty acid compositions, oxidative stability, and nutritional value of six walnut (*Juglans regia* L.) cultivars grown in Portugal. *Journal of Agricultural and Food Chemistry, 51*, 7698–7702.

Anderson, K. J., Teuber, S. S., Gobeille, A., Cremin, P., Waterhouse, A. L., & Steinberg, F. M. (2001). Walnut polyphenolics inhibit in vitro human plasma and LDL oxidation. *Journal of Nutrition, 131*(11), 2837–2842.

Bramley, P. M., Elmadfa, I., Kafatos, A., Kelly, F. J., Manios, Y., Roxboroug, H. E., et al. (2000). Review. Vitamin E. *Journal of the Science of Food and Agriculture, 80*, 913–938.

Dreher, M. L., & Maher, C. V. (1996). The traditional and emerging role of nuts in healthful diets. *Nutrition Reviews, 54*(8), 241–245.

Durak, İ., Köksal, İ., Kaçmaz, M., Büyükkoçak, S., Çimen, B. M. Y., & Öztürk, S. H. (1999). Hazelnut supplementation enhances plasma antioxidant potential and lowers plasma cholesterol levels. *Clinica Chimica Acta, 284*(1), 113–115.

Edwards, K., Kwaw, I., Matud, J., & Kurtz, I. (1999). Effect of pistachio nuts on serum lipid levels in patients with moderate hypercholesterolemia. *Journal of the American College of Nutrition, 18*(3), 229–232.

Elmadfa, I., & Wagner, K.-H. (1997). Vitamin E and stability of plant oils. *Fett–Lipid, 99*, 234–238.

Elmadfa, I., & Wagner, K.-H. (2003). Non-nutritive bioactive food constituents of plants: tocopherols (vitamin E). *International Journal for Vitamin and Nutrition Research, 73*(2), 89–94.

Fraser, G. E. (1999). Nut consumption, lipids, and risk of a coronary event. *Clinical Cardiology, 22*(Suppl. 7), III-11–III-15.

Grosso, N. R., Nepoto, V., & Guzmán, C. A. (2000). Chemical composition of some wild peanut species (Arachis L.) seeds. *Journal of Agricultural and Food Chemistry, 48*(3), 806–809.

Jakob, E., & Elmadfa, I. (1995). Rapid HPLC-Assay for the assessment of vitamin K1, A, E, and β-carotene status in children (7–19) years. *International Journal for Vitamin and Nutrition Research, 65*(1), 31–35.

Jenkins, D. J. A., Kendall, C. W. C., Marchie, A., Parker, T. L., Connelly, P. W., Qian, W., et al. (2002). Dose–response of almonds on coronary heart disease risk factors: blood lipids, oxidized low-density lipoproteins, lipoprotein(a), homocysteine, and pulmonary nitric oxide: a randomized, controlled, crossover trial. *Circulation, 106*(11), 1327–1332.

Jiang, Q., Christen, S., Shigenaga, M. K., & Ames, B. N. (2001). γ-Tocopherol, the major form of vitamin E in the US diet, deserves more attention. *American Journal of Clinical Nutrition, 74*(6), 714–722.

Kaijser, A., Dutta, P., & Savage, G. (2000). Oxidative stability and lipid composition of macadamia nuts grown in New Zealand. *Food Chemistry, 71*, 67–70.

Kris-Etherton, P. M., Yu-Poth, S., Sabaté, J., Ratcliffe, H. E., Zhao, G., & Etherton, T. D. (1999). Nuts and their bioactive constituents: effects on serum lipids and other factors that affect disease risk. *American Journal of Clinical Nutrition, 70*(Suppl. 3), 504S–511S.

Kris-Etherton, P. M., Zhao, G., Binkoski, A. E., Coval, S. M., & Etherton, T. D. (2001). The effects of nuts on coronary heart disease risk. *Nutrition Reviews, 59*(4), 103–111.

Lavedrine, F., Ravel, A., Poupard, A., & Alary, J. (1997). Effect of geographic origin, variety and storage on tocopherol concentrations in walnuts by HPLC. *Food Chemistry, 58*(1–2), 135–140.

Lavedrine, F., Ravel, A., Villet, A., Ducros, V., & Alary, J. (2000). Mineral composition of two walnut cultivars originating in France and California. *Food Chemistry, 68*, 347–351.

Linkens, H. F., & Jackson, J. F. (1988). *Wine analysis. Modern methods of plant analysis. Chapter: Wine phenols* (Vol. 6). Springer Verlag.

Maguire, L. S., O'Sullivan, S. M., Galvin, K., O'Connor, T. P., & O'Brien, N. M. (2004). Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. *International Journal of Food Sciences and Nutrition, 55*(3), 171–178.

Miller, E. R., 3rd, Pastor-Barriuso, R., Dalal, D., Riemersma, R. A., Appel, L. J., & Gullar, E. (2005). Meta-analysis: high-dosage vitamin E supplementation may increase all-cause mortality. *Annals of Internal Medicine, 142*, 37–46.

Nergiz, C., & Dönmez, İ. (2004). Chemical composition and nutritive value of *Pinus pinea* L. seeds. *Food Chemistry, 86*, 365–368.

Özdemir, M., Açkurt, F., Kaplan, M., Yildiz, M., Löker, M., Gürcan, T., et al. (2001). Evaluation of new Turkish hybrid hazelnut (*Corylus avellana* L.) varieties: fatty acid composition, α-tocopherol content, mineral composition and stability. *Food Chemistry, 73*, 411–415.

Parcerisa, J., Rafecas, M., Castellote, A. I., Codony, R., Farràn, A., Garcia, J., et al. (1995). Influence of variety and geographical origin on the lipid fraction of hazelnuts (*Corylus avellana* L.) from Spain: (III) oil stability, tocopherol content and some mineral contents (Mn, Fe, Cu). *Food Chemistry, 53*, 71–74.

Parcerisa, J., Richardson, D. G., Rafecas, M., Codony, R., & Boatella, J. (1998). Fatty acid, tocopherol and sterol content of some hazelnut varieties (*Corylus avellana* L.) harvested in Oregon (USA). *Journal of Chromatography A, 805*, 259–268.

Pinelo, M., Rubilar, M., Sineiro, J., & Núñez, M. J. (2004). Extraction of antioxidant phenolics from almond hulls (*Prunus amygdalus*) and pine sawdust (*Pinus pinaster*). *Food Chemistry, 85*, 267–273.

Quinn, L. A., & Tang, H. H. (1996). Antioxidant properties of phenolic compounds in macadamia nuts. *Journal of the American Oil Chemist's Society, 73*(11), 1585–1588.

Rajaram, S., Burke, K., Connell, B., Myint, T., & Sabaté, J. (2001). A monounsaturated fatty acid-rich pecan-enriched diet favorably alters the serum lipid profile of healthy men and women. *Journal of Nutrition, 131*(9), 2275–2279.

Sang, S., Lapsley, K., Jeong, W-S., Lachance, P. A., Ho, C.-T., & Rosen, R. T. (2002a). Antioxidative phenolic compounds isolated from almond skin (*Prunus amygdalus* Batsch). *Journal of Agricultural and Food Chemistry, 50*, 2459–2463.

Sang, S., Lapsley, K., Rosen, R. T., & Ho, C-T. (2002b). New prenylated benzoic acid and other constituents from almonds hulls (*Prunus amygdalus* Batsch). *Journal of Agricultural and Food Chemistry, 50*, 607–609.

Savage, G. P. (2001). Chemical composition of walnuts (*Juglans regia* L.) grown in New Zealand. *Plant Foods for Human Nutrition, 56*(1), 75–82.

Savage, G. P., McNeil, D. L., & Dutta, P. C. (1997). Lipid composition and oxidative stability of oils in hazelnuts (*Corylus avellana* L.) grown in New Zealand. *Journal of the American Oil Chemist's Society, 74*(6), 755–759.

Scalbert, A., & Williamson, G. (2000). Dietary intake and bioavailability of polyphenols. *Journal of Nutrition, 130*(Suppl. 8S), 2073S–2085S.

Shobha, S. V., Krishnaswamy, P. R., & Ravindranath, B. (1992). Phenolic lipid composition during development of cashew. *Phytochemistry, 31*(7), 2295–2297.

Simopoulos, A. P. (2001). The Mediterranean diets: what is so special about the diet of Greece? The scientific evidence. *Journal of Nutrition, 131*(Suppl. 11), 3065S–3073S.

Singanusong, R., Mason, R. L., D'Arcy, B. R, & Nottingham, S. M. (2003). Compositional changes of Australia-grown Western Schley pecans [*Carya illinoinensis* (Wangenh.) K. Koch] during maturation. *Journal of Agricultural and Food Chemistry, 51*(2), 406–412.

Spiller, G. A., Jenkins, D. A. J., Bosello, O., Gates, J. E., Cragen, L. N., & Bruce, B. (1998). Nuts and plasma lipids: an almond-based diet lowers LDL-C while preserving HDL-C. *Journal of American College of Nutrition, 17*(3), 285–290.

Takeoka, G. R., & Dao, L. T. (2003). Antioxidant constituents of almonds [*Prunus dulcis* (Mill.) D.A. Webb] hulls. *Journal of Agricultural and Food Chemistry, 51*, 496–501.

Takeoka, G., Dao, L., Teranishi, R., Wong, R., Flessa, S., Harden, L., et al. (2000). Identification of three triterpenoids in almond hulls. *Journal of Agricultural and Food Chemistry, 48*, 3437–3439.

Talcott, S. T., Passeretti, S., Duncan, C. E., & Gorbet, D. W. (2005). Polyphenolic content and sensory properties of normal and high oleic acid peanuts. *Food Chemistry, 90*, 379–388.

Wagner, K. H., Kamal-Eldin, A., & Elmadfa, I. (2004). γ-Tocopherol – an underestimated vitamin? *Annals of Nutrition and Metabolism, 48*(3), 169–188.

Wakeling, L. T., Mason, R. L., D'Arcy, R. B., & Caffin, N. A. (2001). Composition of pecan cultivars Wichita and Werstern Schley [*Carya illinoinensis* (Wangenh.) K. Koch] grown in Australia. *Journal of Agricultural and Food Chemistry, 49*(3), 1277–1281.

Wu, X., Beecher, G. R., Holden, J. M., Haytowitz, D. B., Gebhardt, S. E., & Prior, R. L. (2004). Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. *Journal of Agricultural and Food Chemistry, 52*(12), 4026–4037.

Yu, J., Ahmedna, M., & Goktepe, I. (2005). Effects of processing methods and extraction solvents on concentration and antioxidant activity of peanut skin phenolics. *Food Chemistry, 90*, 199–206.

Zambón, D., Sabaté, J., Muñoz, S., Campero, B., Casals, E., Merlos, M., et al. (2000). Substituting walnuts for monounsaturated fat improves the serum lipid profile of hypercholesterolemic men and women. A randomized crossover trial. *Annals of Internal Medicine, 132*(7), 538–546.