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Nuts: source of energy and macronutrients

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On the basis of the high fat content of nuts, they are traditionally considered as foods that provide a high amount of energy. However, epidemiologic and clinical observations do not indicate an association between nut intake and increased BMI. There is a notorious variability in macronutrient composition among nuts, although they have some consistent patterns. Nuts contain all major macronutrients: protein, carbohydrate, and fat. The total protein content is relatively high, which makes them a good source of plant protein (especially for vegetarians). Although nuts contain low amounts of some essential amino acids, this is not a nutritional concern due to the complement of protein. In addition, nuts have a low lysine:arginine ratio, which is inversely associated with the risk of developing hypercholesterolemia and atherosclerosis. Carbohydrates are the second highest macronutrient in nuts in terms of total calories provided. The fat fraction is characterized by a high amount of unsaturated fatty acids and a low content of saturated fatty acids. In conclusion, the high content in unsaturated fatty acids, the low lysine:arginine ratio, and the presence of other bioactive molecules (such as fibre, phytosterols, vitamin and other antioxidants, and minerals) make the addition of nuts to healthy diets a useful tool for the prevention of cardiovascular heart diseases.

As we define them today, tree nuts (almonds, Brazil nuts, cashew, hazelnuts, macadamia nuts, pecans, pine nuts, pistachios and walnuts) originate from Anatolia. From there, the cultivation of tree nuts was introduced in Greece, then in Italy during the Roman Empire, and finally it was extended to all of Europe during the Middle Ages. The growing of tree nuts was introduced in America in the 16th century (Lemoine, 1998). Nuts are part of the Mediterranean diet, although their *per capita* consumption is relatively low (2–9 kg/year). Traditional Mediterranean nuts include almonds, hazelnuts, walnuts, peanuts and pistachios. Typically in Mediterranean diets, nuts are incorporated into many dishes, such as snacks (roasted and salted almonds, hazelnuts, and pistachios), sauces ('romesco' and 'pesto'), cold soups, such as 'ajoblanco' in Spain, cakes, pastries, and cookies ('turrón', 'nougat', walnut cakes, 'menjar blanc', 'amaretti'). Because of their high-energy content, nuts have been introduced into sports snacks and supplements.

With today's busy lifestyles, nuts are a convenient, tasty and easy snack that contributes to a healthy lifestyle. In addition to their tastiness, tree nuts and peanuts are both cholesterol-free and rich in important nutrients, including vegetable protein, fibre and unsaturated fatty acids. They also contain relevant micronutrients, such as folic acid, niacin and vitamins E and B_6, and minerals such as magnesium, copper, zinc, selenium, phosphorus and potassium.

Nuts are part of the US Food Guide Pyramid and Mediterranean Diet Pyramids. Experts recommend eating a variety of foods from the five food groups every day in order to obtain the nutrients you need. Nuts fall into the 'Meat, Poultry, Fish, Dry Beans, Eggs and Nut Group' and can be eaten every day. The recommended number of servings from this group is 2–3 per day. One-third of a cup of nuts or two tablespoons of peanut butter contain the same energy as a one-ounce serving of cooked lean meat.

Nuts also have a low water content, with water activity (a_w) between 0·6 and 0·7. While the low water content of nut helps to preserve them for long periods of time, the high unsaturated fat content increases their chances of becoming rancid, especially during roasting, and this leads to a loss of flavour during storage.

Since nuts are high in fat and therefore energy-dense, consumers regard them as fattening foods. However, while they are rich in energy they are also rich in many healthful nutrients such as unsaturated fatty acids, vitamins, minerals, and non-nutrients such as phytosterols and a host of phytochemicals that have health promoting benefits to humans.

Energy

Table 1 shows the total energy content of nuts. Brazil nuts, pecans, and macadamia nuts are richest in fat and energy, followed by almonds, walnuts, hazelnuts and pine nuts. Pistachios and cashews are the nuts with the lowest energy content.

According to the energy density (ratio between energy content in kcal and weight), foods can be classified into four groups: a) very low energy density foods (<0·6 kcal/g); b) low energy density foods (0·6–1·5 kcal/g); c) medium energy density foods (1·5–4 kcal/g), and d) high energy density foods (>4 kcal/g). Nuts are high energy density foods and their consumption could contribute to a high energy intake and weight gain. The explanation for the excess consumption of fat could be the fact that sensory-specific satiety has been shown to be affected by the amount of food rather than the energy content (Rolls *et al.* 1999).

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Table 1. Energy content of nuts

	Raw		Roasted	
	Energy (kcal)	Energy (kJ)	Energy (kcal)	Energy (kJ)
Almonds	581	2·431	607	2·541
Brazil nuts	656	2·743	–	–
Cashew nuts	553	2·314	574	2·402
Hazelnuts	629	2·630	646	2·703
Macadamia nuts	718	3·004	718	3·005
Pecans	691	2·889	715	2·990
Peanuts	567	2·374	581	2·431
Pine nuts	629	2·632	–	–
Pistachios	557	2·332	568	2·376
Walnuts	618	2·584	–	–

Source: US Department of Agriculture Nutrient Data Base at http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl

Table 2. Carbohydrate (CHO), protein, and fat content of nuts (g/100 g of raw and roasted product)

	Raw			Roasted		
	CHO*	Protein	Fat	CHO*	Protein	Fat
Almonds	19·9	21·9	50·6	17·7	21·2	55·2
Brazil nuts	12·3	14·3	66·4	–	–	–
Cashews	30·2	18·2	46·4	29·9	16·8	47·8
Hazelnuts	17·0	13·7	60·8	17·6	15·0	62·4
Macadamia nuts	13·8	7·9	75·8	13·4	7·8	76·1
Pecans	13·9	9·2	72·0	13·0	9·2	75·2
Peanuts	16·1	25·8	49·2	18·9	26·4	49·3
Pine nuts	19·3	11·6	61·0	–	–	–
Pistachios	28·0	20·6	44·4	26·8	21·4	46·0
Walnuts	9·9	26·1	65·2	–	–	–

*By difference (total energy minus energy from fat and protein).
Source: US Department of Agriculture Nutrient Data Base at http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl

However, as discussed by Rajaram & Sabaté (2006) in this supplement, available data suggest that adding nuts to the habitual diets of free-living individuals does not induce weight gain and may even help lose weight. Garcia-Lorda *et al.* (2003) and Sabaté (2003) suggest several hypotheses which may explain this fact. First, the absorption of energy from nuts is incomplete, probably due to the structure of lipid-storing granules with incomplete release of fatty acids during digestion (Ellis *et al.* 2004), or to various fibre components. Second, it is suggested that nuts exert a satiating effect due to components such as fibre, whose role in energy intake has been discussed at length (Marlett *et al.* 2002). Third, nuts may increase resting energy expenditure and diet-induced thermogenesis because of their high-protein content and high polyunsaturated-to-saturated-fatty acid ratio (Jones *et al.* 1992), and this may result in less fat deposition.

When nuts are roasted with oil, there is an increase in their total energy content (Table 1). Because of oil absorption, total energy increases by an average of 30–40 kcal/100 g in oil-roasted nuts. The nutritional value of the final product is linked to the quality of the oil used and to the technological treatment employed. Both factors can modify the fatty acid profile of nuts.

Protein

The total protein content of some nuts is relatively high, making them a good source of plant protein (Table 2). Peanuts, walnuts, almonds, pistachios and cashews have the highest protein content, followed by Brazil nuts, hazelnuts and pine nuts. Pecans and macadamia nuts have the lowest protein content. The protein fraction decreases in roasted nuts due to the increase in the fat content.

Even though the total amount of protein in nuts is high, the biological value of nuts is not very high since they are limiting in some essential amino acids. The amino acid composition of walnuts and hazelnuts are compared to that of a whole egg in Figs. 1 and 2. In general, for all nuts, threonine is the limiting amino acid. Threonine is present in nuts in the range of 25–40 mg/g of protein compared to 44 mg/g of protein in a whole egg. Brazil nuts are poorest and cashews are richest in threonine. The tryptophan content of all nuts is quite similar and close to that of whole eggs, with the exception of macadamia nuts, which have less tryptophan (around 8 mg/g of protein) than other nuts. Nuts are low in isoleucine, with a content ranging between 32 and 40 mg/g of protein. This contrasts with the total isoleucine content of whole egg of 54 mg/g of protein. For this amino acid, almonds show the least amount (32 mg/g of protein) and cashews the most (43 mg/g of protein). The total amount of leucine is almost similar to that of whole eggs, around 86 mg/g of protein. Pistachios and pecans have the lowest content of leucine, around 65 mg/g of protein.

As shown in Table 3, the dibasic amino acid lysine, which is in deficit in many foods, is also poor in most nuts and considerably lower than in whole eggs (70 mg/g of protein). The sulphur amino acids, such as methionine and cysteine, are also found in low amounts in nut protein. The exception is Brazil nuts, which contain 96 mg/g of protein of total sulphur amino acids, an amount higher than in whole eggs (57 mg/g of protein). Other amino acids such as phenylalanine and tyrosine are present in significant amounts in the protein of all nuts. The content of valine is quite important. Quantitatively, cashew nuts provide 60 mg/g of protein, whereas whole eggs provide 68 mg/g of protein. Almonds provide the lowest total amount of valine, with a content of 38 mg/g of protein. Finally, the content of histidine is quite high for nuts overall, pistachios being the only nuts having a lower amount (21 mg/g of protein) than whole eggs (24 mg/g of protein).

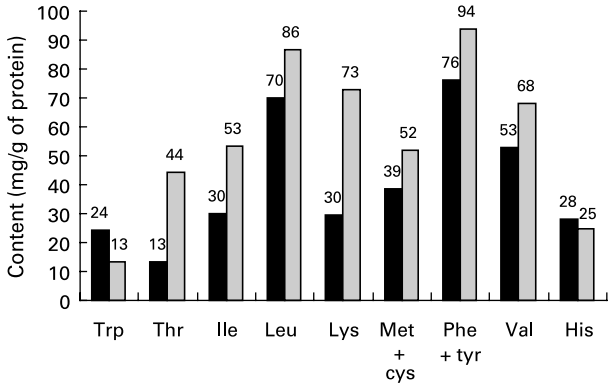

Fig. 1. Essential amino acids (mg/g protein) of walnut protein compared with egg protein. ■, Walnuts; ▨, Egg.

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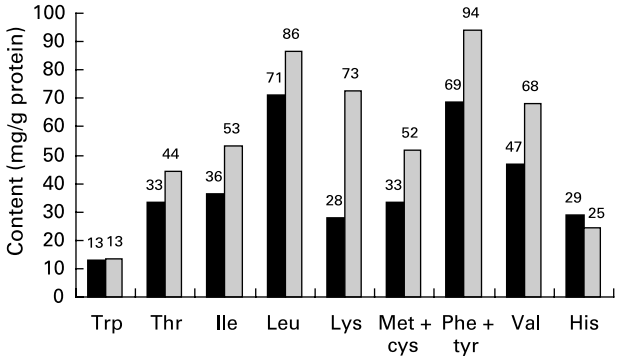

Fig. 2. Essential amino acids (mg/g protein) in hazelnut protein compared with egg protein. ■, Hazelnuts; ▨, Egg.

Looking at the amino acid composition of nuts, it can be said that their protein profile is suboptimal because one or more essential amino acids are present in small amounts. Therefore, for the body to make good use of proteins, nuts need to complement other food proteins. Strict vegetarian diets that are rich in nuts can be supplemented with pulses or other vegetables and with dairy products in order to provide a high protein value.

The protein and amino acid content of nuts also varies depending on the different cultivars. Savage (2001) found some differences in the total protein content of walnuts from various New Zealand cultivars. Another example of the differential protein content of walnuts is that the European commercial cultivar G139 shows the highest protein content (16·8 g/100 g), while the US Tehana cultivar shows the lowest protein content (13·6 g/100 g).

Intake of plant protein has been associated with a low cardiovascular risk compared to that of animal protein. Part of the explanation for this association may be the lysine to arginine ratio of plant protein (Kritchevsky, 1990). In general, vegetable proteins such as those in nuts are rich in arginine and poor in lysine, whereas the opposite occurs in meat and dairy products. The risk of developing hypercholesterolaemia and atherosclerosis is higher with foods that have a high lysine:arginine ratio (Carroll & Hamilton, 1975; Kritchevsky *et al.* 1982; Sugano *et al.* 1984; Kritchevsky, 1990).

Arginine is the precursor of nitric oxide (NO), an endogenous vasodilator and an important mediator of homeostatic processes and host defense mechanisms (Moncada & Higgs, 1993; Faxon *et al.* 2004). Arginine is required by the constitutive enzyme endothelial NO synthase to produce NO. Administration of this amino acid improves endothelial function in animal models and in humans with hypercholesterolemia and atherosclerosis (Gornik & Creager, 2004). It has been hypothesized that the decreased coronary heart disease risk observed in association with frequent nut intake in epidemiological studies, reviewed by Kelly & Sabaté (2006) in this supplement, may be due in part to the high arginine content of nuts leading to enhanced synthesis of NO (Cooke *et al.* 1993; Feldman, 2002). The lysine:arginine ratio of nuts is quite low. Hazelnuts, pine nuts and walnuts have the lowest ratios (0·19–0·20); pecans, Brazil nuts and almonds have ratios of 0·23–0·24, and the highest ratios are found in pistachios and cashews (≈0·5) (Souci *et al.* 2000). Such ratios are much lower than those present in animal proteins such as casein (1·9) and whole milk (2·4), and even in soy protein (0·58–1·0) (Kritchevsy *et al.* 1982). Thus, nut protein has a lysine:arginine ratio that is potentially more beneficial than that of soy protein.

The insulin:glucagon ratio has been used as an early metabolic index of the effect of dietary proteins on serum cholesterol levels, a risk factor for cardiovascular diseases (Sanchez & Hubbard, 1991). Therefore, taking into account that plant proteins (such as those contained in soy and nuts) are richer in arginine and glycine than animal proteins (such as casein), and that the postprandial insulin:glucagon ratio is affected by postprandial plasma amino acids (Sanchez *et al.* 1988; Calbet & MacLean, 2002), it is suggested that foods rich in protein (such as nuts), with a high content in arginine and glycine, may reduce the risk of chronic degenerative diseases by their influence on insulin and glucagon levels (Hubbard *et al.* 1989; Krajcovicova-Kudlackova *et al.* 2005).

Table 3. Arginine and lysine content (g/100 g of protein) and their ratio in nuts

	Arginine	Lysine	Lys:Arg ratio
Almonds	116·0	28·3	0·24
Brazil nuts	150·0	35·4	0·23
Cashews	116·5	50·9	0·44
Hazelnuts	147·9	28·1	0·19
Macadamia nuts	177·2	22·8	0·13
Pecans	128·4	31·3	0·24
Peanuts	119·6	35·9	0·30
Pine nuts	194·6	37·5	0·19
Pistachios	82·4	46·8	0·57
Walnuts	150·4	29·6	0·20

Source: US Department of Agriculture Nutrient Data Base at http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl

Carbohydrate

The total carbohydrate content of nuts is provided in Table 2. The lowest amounts are found in walnuts, and progressively increasing amounts occur in Brazil nuts, pecans and Macadamia nuts, almonds and pine nuts, pistachios and, finally, cashews. Different composition tables, however, may show different amounts of carbohydrate for specific nuts depending on whether the carbohydrate content has been actually determined or calculated.

Recent data (Luscombe *et al.* 2002, 2003; Layman *et al.* 2003) suggest that some undesirable effects of low-carbohydrate diet may be counteracted by a higher protein intake, as high protein diets have been shown to induce favourable effects of feelings on satiety and hunger, help preserve lean body mass, effectively reduce fat mass and beneficially impact on insulin sensitivity and the blood lipid status. Therefore, the nutritional composition of nuts, rich in protein and low in CHO, make them a suitable food for incorporating into diets intended for weight loss and weight control (Adam-Perrot *et al.* 2006).

Fat

Total fat is the main fraction in nuts. As shown in Table 2, the total fat content per 100 g ranges from 44·4 g in pistachios to 75·8 g in macadamia nuts. Again, the geographic origin of

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different tree nut cultivars can result in variations of fat content. Parcerisa *et al.* (1993) studied Spanish hazelnut varieties, such as 'Pauetet', 'Gironell' and 'Negret', and reported that the geographic origin and the climatic conditions modified the fat content. For instance, for the 'Negret' variety, the authors showed a difference of 8 % in fat content depending on location, even within the same geographical area (Reus or Falset in Tarragona, Spain). This variability affects fatty acid composition as well, especially the proportions of oleic and linoleic acids. Triacylglycerol content, especially triolein, and vitamin E and mineral content are also affected by variety and geography. This variability may cause changes in the stability of nuts, especially during storage. On the other hand, the technological treatment applied to nuts can also modify the lipid content and the fatty acid composition. As discussed, oil roasting increases the fat content by approximately 4 %, due to dehydration occurring during the procedure and both adsorption and absorption of oil used for roasting. This is important because it may change the nutritional value of the lipid fraction of nuts, and special attention must be paid to the quality of the oil used in the roasting and frying processes.

The favourable fatty acid composition of nuts is discussed in detail by Ros & Mataix (2006) in this supplement. Nuts are characterized by a high content of MUFA and PUFA, and proportionally, less SFA. The predominant type of unsaturated fatty acid in most nuts is MUFA, contributing on average 62 % of the energy from fat. Together, MUFA and PUFA contibute around 91 % of the energy from fat (Kris-Etherton *et al.* 1999). Parcerisa *et al.* (1998) studied different varieties of hazelnuts from Oregon, and found relevant difference in fatty acid composition. For instance, the content of PUFA in that study ranged from 8·7 % in the Italian variety 'Tonda Romana' to 18 % for the Turkish variety 'Tomboul'.

A large number of studies (Sabaté 1993, 1999; de Lorgeril *et al.* 1999, 2001) suggest that nuts may play an important role in reducing the risk for cardiovascular diseases. In one study (Albert *et al.* 2002), researchers found that, although the benefits were greatest for frequent nut eaters, those who ate nuts even twice a week had a 47 % lower risk of sudden cardiac death and a 30 % lower risk of total coronary heart disease than those who rarely or never consumed nuts. Nuts, particularly walnuts, contain n-3 fatty acids, which have been shown to elicit cardioprotective effects due in part to reduced platelet aggregation and vasoconstriction (Kaminski *et al.* 1993) and favourable effects on blood coagulation via fibrinolysis (Barcelli *et al.* 1985) and blood clot formation (Shahar *et al.* 1993).

In the summer of 2004, the FDA accepted a qualified health claim for nuts and nut-containing products because of the link of nut consumption with a reduced risk of heart disease. The nut products which meet the FDA's criteria may be labelled as follows: 'Scientific evidence suggests but does not prove that eating 1·5 ounces per day of most nuts as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease'.

In addition to the distinctive fatty acid profile of nuts, they are good sources of several other important nutrients. Nuts are a source of phytosterols and other phytochemicals, including ellagic acid, flavonoids, phenolic compounds, luteolin and tocotrienols. Other micronutrients present in notable quantities in most nuts include thiamine, niacin, riboflavin, selenium, potassium and iron. Therefore, the constituents of nuts may contribute to their beneficial health effects through several mechanisms.

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