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The nutritional and health benefits of almonds: a healthy food choice

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Abstract

Over the last decade, the research on the effects of almonds on reducing blood cholesterol levels and reduction of risk of heart disease has grown significantly. Emerging research on almonds also shows promising health benefits linked to body weight control and diabetes. Almonds naturally contain high levels of monounsaturated and polyunsaturated fatty acids, protein and dietary fibre, as well as a variety of essential nutrients including vitamin E and several trace elements. Almonds are very low in sodium and high in potassium, and they contain a range of phytoprotective constituents. The available evidence also indicates that weight gain may not be a concern when nuts are consumed in moderation, and that regular consumption of nuts can be recommended in the context of a healthy balanced diet.

Keywords: almonds, nutrient density, heart health, weight control

1. Introduction

Almonds (*Prunus dulcis*; Gradziel 2009) are a nutrient-dense food, and extensive research during the last decade on the potential health benefits of almonds has linked consumption patterns to reduced risk of chronic diseases such as coronary heart disease (CHD) and type 2 diabetes, as well as to weight maintenance and weight control. Tree nuts such as almonds have been part of mankind's diet since pre-agricultural times and their popularity has continued to grow in modern times, either as snacks or as part of a meal. Almonds can be eaten whole (fresh or roasted) and in spreads like almond butter or they can be used in a wide range of food products and recipes.

Almonds have complex food matrices containing diverse nutrients and other phytoprotective substances that favourably influence human physiology. All nuts are energy dense and contain high levels of fat, but much of this is unsaturated. However, there is still caution about overt recommendations for nut consumption and a lack of understanding and awareness of how nuts can fit into a balanced diet.

The present article highlights that almonds are a rich source of many essential nutrients including vitamin E and several trace elements, that there is compelling evidence that almonds have beneficial effects on the reduction of plasma cholesterol levels and other heart disease risk factors, and that evidence is emerging which suggests that almonds may have a positive role in healthy weight maintenance and weight loss.

2. The nutritional attributes of almonds

2.1 *Almonds as a source of energy and macronutrients*

Almonds typically contain around 575 kcal per 100 g and about 50% fat. However, the fatty acid composition of almonds is beneficial because monounsaturated fatty acids (MUFA) predominate and the saturated fat content (3.7 g per 100 g almonds) is the lowest of all nuts. Table 1 shows the nutrient composition of almonds. The total fat content is made up of 62% MUFA and 24% of polyunsaturated fatty acids (PUFA; Ros and Mataix 2006; Chen *et al*. 2006;

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Table 1. Nutrient composition of almonds[a]

Nutrient	Unit	Per 100 g	Per 30 g serving	RDA for labelling[c]	Amounts to meet criteria for nutrient content claims in EU[b]: 'Source' (15% RDA per 100 g)	'High' (30% RDA per 100 g)	Nutrition claim in EU[b]
Macronutrients							
Water	g	4.70	1.41				
Energy	kcal	575	172				
Protein	g	21.22	6.37				See footnote d
Total fat	g	49.42	14.83				
Total sugars	g	3.89	1.17				See footnote e
Dietary fibre	g	12.20	3.66				See footnote f
Minerals							
Calcium	mg	264	79	800	120.00	240.00	HIGH
Iron	mg	3.72	1.12	14	2.10	4.20	SOURCE
Magnesium	mg	268	80	375	56.25	112.50	HIGH
Phosphorus	mg	484	145	700	105.00	210.00	HIGH
Potassium	mg	705	211	2000	300.00	600.00	HIGH
Sodium	mg	1	0				See footnote g
Zinc	mg	3.08	0.92	10	1.50	3.00	HIGH
Copper	mg	1.00	0.30	1	0.15	0.30	HIGH
Manganese	mg	2.28	0.68	2	0.30	0.60	HIGH
Selenium	µg	2.50	0.75	55	8.25	16.5	—
Vitamins							
Thiamin	mg	0.21	0.06	1.1	0.17	0.33	SOURCE
Riboflavin	mg	1.01	0.30	1.4	0.21	0.42	HIGH
Niacin	mg	3.38	1.01	16	2.40	4.80	SOURCE
Pantothenic acid	mg	0.47	0.14	6	0.90	1.80	—
Vitamin B_6	mg	0.14	0.04	1.4	0.21	0.42	—
Folate	µg	50	15	200	30.00	60.00	SOURCE
Vitamin A (retinol equivalent)	µg	0	0	800	120	240	—
Vitamin E							
α-Tocopherol	mg	26.22	7.87	12.00	1.80	3.60	HIGH
β-Tocopherol	mg	0.29	0.09				
γ-Tocopherol	mg	0.65	0.19				
δ-Tocopherol	mg	0.05	0.01				
Lipids							
Saturated fats	g	3.73	1.12				
Monounsaturated fats	g	30.89	9.27				
18: 1	g	30.61	9.18				
Polyunsaturated fats	g	12.07	3.62				
18: 2	g	12.06	3.62				
Phytosterols	mg	172	52				
Stigmasterol	mg	4	1				
Campesterol	mg	5	1				
β-Sitosterol	mg	132	40				
Other phytosterols[h]	mg	31	10				
Amino acids							
Lysine	g	0.58	0.17				
Arginine	g	2.47	0.70				
Other							
β-Carotene	µg	1	0				
Total phenolics	mg[i]	418	125				
Total flavonoids[j]	mg[i]	23.89	7.17				

[a]Nutrient data obtained from the USDA National Nutrient Database for Standard Reference, Release 21 (2008)

[b]Regulation (EC) No. 2006 of the European Parliament/2006 of the European Parliament and of the Council of 20th December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union* 18.1.2007, L 12/3

[c]Commission of the European Communities. 2008/100/EC. Commission Directive amending Council Directive 90/496/EC on nutrition labelling for foodstuffs as regards recommended daily allowances, energy conversion factors and definitions. *Official Journal of the European Union* L285/9. 29.10.2008

[d]Whole natural almonds contain 21.22 g protein per 100 g. On an energy basis, 21.22 × 4 kcal = 84.88 kcal protein calories are provided by 100 g almonds containing 575 kcal. Hence, 14.7% of the energy is derived from protein. Almonds can claim 'natural source of protein' under the new European legislation, which requires at least 12% of the energy value of a food to be provided by protein

[e]Whole natural almonds contain 3.89 g total sugars per 100 g. Almonds can claim 'naturally low in sugars' because they contain no more than 5 g sugars per 100 g

[f]Whole natural almonds contain 12.20 g dietary fibre per 100 g, sufficient to claim 'naturally high in fibre' under the new European regulation, which requires at least 6 g fibre per 100 g

[g]Whole natural, unsalted almonds contain 1 mg sodium per 100 g, which is within the claim criteria for sodium free or salt free, namely that the food should contain no more than 0.005 g sodium, or the equivalent value for salt, per 100 g

[h]Other phytosterols include δ 5-avenasterol, sitostanol, campestanol, and other minor phytosterols

[i]Expressed as gallic acid equivalents (Wu *et al.* 2004)

[j]Determined from Butte, Carmel, Fritz, Nonpareil, Mission, Monterey, Padre and Price varieties and adjusted for their market contribution.

Table 2. Phytosterol content of nuts in mg/100 g edible portion*

	β-Sitosterol		Campesterol		Stigmasterol		5-Avenasterol	Total phytosterols	
Almonds	132[a]	143[b]	5[a]	5[b]	4[a]	5[b]	20[b]	120	199
Brazil nuts	nd	66	nd	2	nd	6	14	nd	95
Cashews	nd	113	nd	9	nd	1	14	158	150
Hazelnuts	89	102	6	7	1	2	3	96	121
Macadamia nuts	108	144	8	10	0	nd	13	116	187
Peanuts, dry roasted	nd	77	nd	13	nd	12	18	nd	137
Pecans	89	117	5	6	3	3	15	102	157
Pine nuts	nd	132	nd	20	nd	1	40	141	236
Pistachios	198	210	10	10	5	2	26	214	279
Walnuts	64	89	7	5	1	nd	7	72	113

*Sources: adapted from Segura *et al.* (2006)
nd, not determined
[a]US Department of Agriculture National Nutrient Database for Standard Reference, Release 21
[b]Phillips *et al.* (2005).

Ternus *et al.* 2009). The fatty acids from almonds are important contributors to the beneficial health effects of frequent nut consumption, namely reduced risk of cardiovascular disease and sudden cardiac death, lowering of blood cholesterol, preservation or enhancement of low density lipoprotein (LDL) resistance to oxidation and improvement of endothelial function (Ros and Mataix 2006; Griel and Kris-Etherton 2006). The total protein content of almonds is 21.2%, making them a good source of plant protein, and the proteins in almonds are high in arginine (Ahrens *et al.* 2005). Almonds also contain around 3.9 g total sugars per 100 g, and because they contain less than 5 g sugars per 100 g they can be described as 'naturally low in sugars' under the new European regulation on nutrition 1924/2006 on nutrition and health claims (European Parliament and Council 2007).

2.2 *Almonds are naturally high in fibre*

Whole natural almonds contain around 12 g dietary fibre per 100 g (Table 1), which is sufficient to claim 'naturally high in fibre' under the new European regulation. There is a general consensus based on epidemiological and human intervention studies that dietary fibre from the plant cell walls of foods such as whole grain cereals, vegetables, legumes, fruits and nuts is associated with a range of health benefits. These benefits include reduction in the risk of developing CHD and diabetes and positive effects on the digestive system, e.g. prebiotic effects. Plant cell walls are supramolecular networks of cellulose, hemicelluloses, pectic substances and non-carbohydrate components (e.g. phenolic compounds), and they are the major source of dietary fibre (Ellis *et al.* 2004). Different types of dietary fibre can attenuate the rise in postprandial glycaemia and lower plasma concentrations of cholesterol. Increasing the intake of dietary fibre can also increase satiety and reduce body weight gain over time. The addition of nuts such as almonds to low calorie diets for weight loss may increase satiation and result in incomplete intestinal absorption of fat. These latter two effects may be due largely to the high fibre and protein contents of nuts. Plant cell walls are known to influence the rate and extent of lipid release from plant food tissues during digestion, and the structural characteristics of almond cell walls (dietary fibre) play an important role (Ellis *et al.* 2004).

A typical serving of almonds (28–30 g) provides about 14% of the daily fibre requirement.

2.3 *Micronutrients*

Almonds are one of the most nutrient-rich forms of food available (Blomhoff *et al.* 2006). Table 1 shows the vitamin and mineral contents naturally present in whole almonds, along with the nutrition claims that meet the conditions laid down in the EU Regulation 1924/2006. Almonds are naturally high in vitamin E, riboflavin (vitamin B_2) and the minerals calcium, magnesium, phosphorus, potassium, zinc, copper and manganese.

2.4 *Sodium and potassium content*

From Table 1, it can be seen that almonds are essentially sodium free and high in potassium. On the basis of the EU nutrition claim criteria, almonds are naturally high in potassium, naturally sodium free and fit well into low sodium/high potassium diets.

2.5 *Phytosterols and antioxidants*

Tree nuts, including almonds, contain no dietary cholesterol but are rich in the chemically related phytosterols, a class of compounds that interfere with cholesterol absorption and thus help maintain healthy blood cholesterol levels. The most abundant phytosterols in plants are campesterol, β-sitosterol, 5-avenasterol and stigmasterol. The phytosterol content of nuts is shown in Table 2. The cholesterol-lowering efficacy of nuts in human studies has often been higher than predicted on the basis of fatty acid exchange and the high content of MUFAs (Griel and Kris-Etherton 2006). Phytosterols in nuts may be responsible in part for this effect.

As well as the antioxidant vitamin E, several nuts are among those dietary plants with the highest contents of total antioxidants (Blomhoff *et al.* 2006). Dietary flavonoids are hypothesised to play a significant role as antioxidants *in vivo*, thereby reducing risk of chronic disease. However, their role has been challenged because of the observations that only very low amounts of flavonoids are achieved in plasma after consumption of flavonoid-rich foods. In this area of emerging science, *in vitro* and animal studies have indicated that flavonoids from almond skins are bioavailable and act synergistically with vitamins C and E to enhance LDL cholesterol resistance to oxidation (Chen *et al.* 2005). The potential effects of almond consumption on DNA damage and oxidative stress among cigarette smokers has also been studied (Jia *et al.* 2005). Research is now focusing on the complete characterisation and quantification of almond polyphenolics and antioxidants, on the antioxidant activity of almond seed extracts, on flavonoids from almond skins, and on the effects of almond skin polyphenols and quercetin on human LDLs and biomarkers of lipid peroxidation.

The unique combination of MUFAs, phytosterols and antioxidants, together with the high nutrient density of almonds with respect to vitamin E, folate, calcium, magnesium and potassium combined with low sodium, may all contribute to the health benefits observed in epidemiological studies and human trials.

3. Bioaccessibility of protein, lipid and vitamin E from almonds

Compared with other tree nuts, almonds are unusual for the large amounts of protein and vitamin E (α-tocopherol) they contain. The main component of almonds is fat, and it has been observed in human volunteers that a significant proportion of lipid seems to be slowly digested and absorbed or remains completely undigested. The term 'bioaccessibility' is defined as the proportion of a nutrient that can be released from a complex food matrix and therefore becomes potentially available for absorption in the gastrointestinal tract (Ellis *et al.* 2004). The evaluation of the bioaccessibility of almond nutrients is an active area of research (Berry *et al.* 2008; Frecka *et al.* 2008; Mandalari *et al.* 2008a, 2008b; Cassady *et al.* 2009) because it may have implications for the management of overweight and obesity, as well as for reduced risk of cardiovascular disease. The effects of mastication on particle size directly affects the bioaccessibility of lipid, protein and vitamin E (Mandalari *et al.* 2008a), and early studies indicate that prolonged chewing increases the number of fractured plant cells, thereby increasing the bioavailability of vitamin E and lipid. This decrease in the absorption of the fat energy from almonds could reduce their theoretical contribution to energy intake by around 7% (Mattes 2008). Moreover, the rate and extent of lipid bioaccessibility of almonds, which is primarily regulated by the integrity of the plant cell walls (dietary fibre) that encapsulate the lipids, play an important role in determining postprandial lipaemia (Berry *et al.* 2008). Results of *in vitro* studies and ileostomy digestibility studies have also demonstrated that the dietary fibre, lipid and protein present in almond tissue after duodenal digestion are available for fermentation in the colon by the gut microbiota (Mandalari *et al.* 2008b). Further studies have investigated the potential prebiotic effect of almond seeds by using a full model of the gastrointestinal tract, which simulates *in vitro* gastric and duodenal digestion. The resultant residues are used as substrates for the colonic model to assess their influence on the composition and metabolic activity of gut bacteria populations. Finely ground almonds significantly increased the populations of *Bifidobacteria* and *Enterobacterium rectale*, resulting in a higher prebiotic index (4.43) than was found for the commercial prebiotic fructooligosaccharide (4.08) after a 24 h incubation. The increase in numbers of *E. rectale* during this *in vitro* fermentation correlated with increased butyrate production. These initial results indicate that almond seeds exhibit the potential to be used as a source of prebiotics, and that more detailed studies should be performed on human volunteers.

Data from epidemiological studies and human trials indicate that incorporating nuts such as almonds into the diet does not compromise body weight owing not only to strong satiety properties and effects on resting energy expenditure, but also because of limited lipid bioaccessibility. In human studies, a significant increase in faecal energy loss has been demonstrated that accounts for about 5–15% of the energy content of almonds (Cassady *et al.* 2009). It is hypothesised that by three routes, namely satiety, promotion of energy expenditure and inefficient energy utilisation, moderate nut consumption does not pose a threat for weight gain (Mattes 2008; see Section 5).

4. Almond consumption and reduced risk of cardiovascular disease

4.1 Observational studies

Epidemiological studies have been remarkably consistent in showing an association between nut consumption and a reduced risk of CHD (Sabaté and Ang 2009). The four major cohort studies (Fraser *et al.* 1992; Kushi *et al.*

1996; Hu *et al*. 1998; Albert *et al*. 2002) all show a clear dose-response gradient between nut consumption and reduced CHD risk. Taken together, these observational studies exhibited an average risk reduction of CHD mortality of 37% (relative risk (RR) = 0.63; 95% confidence interval (CI): 0.51, 0.83) or an average of 8.3% reduction in risk of CHD death for each weekly serving of nuts (Kelly and Sabaté 2006). The beneficial effects of nut consumption are similar for different clinical outcomes: non-fatal myocardial infarction, fatal CHD, and sudden cardiac death. Collectively, these epidemiological findings provide strong evidence of the cardioprotective benefits of nut consumption (Sabaté and Ang 2009).

The low incidence of CHD in Mediterranean countries has been partly ascribed to dietary habits, and recent findings from large European cohort studies (Trichopolou *et al*. 2003; Knoops *et al*. 2004, 2006) suggest that a high degree of adherence to the traditional Mediterranean diet is associated with a reduction in mortality (Trichopolou and Lagiou 1997). Tree nuts such as almonds, hazelnuts and walnuts, which are common in the Mediterranean diet, have favourable fatty acid profiles and are a rich source of nutrients and other bioactive compounds, which may account in part for the observed beneficial effects on reduced risk of CHD. Estruch *et al*. (2006) reported the results of a randomised trial in Spain. Participants were assigned to a low fat diet (n = 257) or to one of two Mediterranean diets. Those allocated to Mediterranean diets received nutrition education and either free virgin olive oil (1 L/week (n = 257)), or free nuts (15 g/day walnuts, 7.5 g/day hazelnuts and 7.5 g/day almonds, for 3 months (n = 258)). The completion rate was 99.6%. Compared with the low fat diet, the two Mediterranean diets supplemented with olive oil or nuts produced beneficial effects on cardiovascular risk factors, including blood glucose, systolic blood pressure and total cholesterol to high density lipoprotein (HDL) ratio (Estruch *et al*. 2006; Salas-Salvado *et al*. 2008a, 2008b). These authors concluded that a Mediterranean diet including nuts such as almonds could be a useful tool in managing individuals who are at high risk of cardiovascular disease. Similarly, a Mediterranean-style diet with a relatively higher intake of nuts and legumes and high in MUFA was found to improve glucose metabolism more than a typical Western diet (Due *et al*. 2008).

In conclusion, regular nut consumption reduces the risk of cardiovascular disease, an effect that has been observed in several populations and is independent of other lifestyle factors (Kris-Etherton 2001; Kelly and Sabaté 2006). Nut eaters typically eat less meat, have lower intakes of *trans* fatty acids and higher intakes of unsaturated fatty acids and fibre (Hu and Stampfer 1999; Ternus *et al*. 2009). These authors estimated that substituting 28 g of nuts for the equivalent energy from carbohydrate in an average diet was associated with a 30% reduction in CHD risk. They concluded that regular nut consumption can be recommended in the context of a healthy and balanced diet.

4.2 Human intervention studies

Human studies involving mixed nuts have been conducted in six countries: Australia, Canada, Israel, India, New Zealand and the United States. The results showed significant reductions in plasma total cholesterol (7–25%) and plasma LDL cholesterol (10–33%). These studies have been reviewed by Ternus *et al*. (2009). Further evidence for the cardioprotective effects of nuts is provided by single-nut trials, including several studies using almonds.

Spiller *et al*. (1992) first reported that consumption of 100 g/day of almonds decreased plasma total cholesterol by 9% and plasma LDL cholesterol by 12% in 26 hypercholesterolaemic patients. Hyson *et al*. (2002) extended this observation in a trial of 22 healthy subjects by achieving reductions in plasma total cholesterol of 4% and plasma LDL cholesterol of 6% by replacing half their fat intake with 35 g of almond oil and 66 g of whole almonds (containing 35 g of fat). Jenkins *et al*. (2002) demonstrated a dose-response relationship with the addition of 28 g and 56 g of almonds daily to an isoenergetic diet, lowering plasma total cholesterol and plasma LDL cholesterol by 4.7 and 9.9%, respectively. These authors calculated that for each 7 g/day of almond intake, plasma LDL cholesterol is reduced by 1%. These results on almonds are consistent with those from mixed nut studies (Ternus *et al*. 2009). Recently, Phung *et al*. (2009) evaluated the influence of almonds on serum lipid profiles. On the basis of a meta-analysis, almond consumption ranging from 25 to 168 g/day significantly lowered plasma total cholesterol and showed a strong trend toward reducing plasma LDL cholesterol. No significant effects on plasma HDL cholesterol, triglycerides or LDL: HDL ratios were found.

In conclusion, the consumption of around 28–30 g of natural (or roasted) almonds a day, roughly a handful, as part of a healthy diet low in saturated fat lowers plasma total cholesterol, thereby promoting heart health. This cholesterol-lowering effect is similar to that of other heart-healthy foods such as oats and soya. Furthermore, the combination of almonds with other cholesterol-lowering foods has been incorporated into the ‘Portfolio Eating Plan’ (Jenkins *et al*. 2003, 2005, 2006), with plasma LDL cholesterol reduction of 25–30%. In more recent research, a study was designed to answer the question of what happens when people follow the Portfolio Eating Plan in a real-world setting for 1 year (Jenkins *et al*. 2006). The diet included almonds, plant sterols, soy protein and viscous fibre along with lean meats and fish. After 1 year, male and female participants with elevated cholesterol levels experienced a statin-like effect, lowering their cholesterol by 20% or more. For those participants who followed the plan less strictly, their plasma LDL cholesterol level decreased by 15%. Berry *et al.* (2008) investigated the effects of lipid bioaccessibility on postprandial lipaemia. An elevated and prolonged postprandial lipaemic response is associated with an increased risk of CHD. In a randomised, crossover trial (n = 20 men), the researchers manipulated lipid bioaccessibility using test meals containing structurally intact almond seed or extracted almond oil plus defatted almond seed flour, thus producing meals with a predicted low- and high-lipid bioaccessibility, respectively. As predicted, the low-lipid bioaccessibility meal resulted in a significantly attenuated lipaemic response compared with the high-lipid bioaccessibility meals. The author concluded that manipulation of lipid bioaccessibility of almond seeds significantly reduced the postprandial increase in plasma triacylglycerol.

5. Almonds, satiety, weight maintenance and type 2 diabetes

Epidemiological studies suggest that those who eat nuts frequently (five times a week) tend to have lower body mass indices (Garcia-Lorda *et al.* 2003; Bes-Rastrollo *et al.* 2007; Ternus *et al.* 2009). These observations led to research on almonds to understand potential mechanisms of weight loss and weight maintenance. Almonds are high in fibre and protein and have a low glycaemic index, all of which are dietary factors shown to increase satiety and suppress appetite (Holt *et al.* 1995).

In 2008, the energetics of nut consumption was reviewed by Mattes, and three potential mechanisms were proposed. The first focuses on the satiety value of nuts, and it is hypothesised that inclusion of nuts in the diet results in a spontaneous reduction of energy intake at other times of the day to offset a high proportion of the energy provided by the nuts. Second, it is postulated that nut consumption may increase energy expenditure and thereby dissipate a portion of the energy they provide. Third, it is suggested that the absorption of the energy from nuts is attenuated, thereby reducing their theoretical contribution to energy intake (as described in Section 3). Using almonds as a model, Hollis and Mattes (2007) attempted to quantify the energetics of nut consumption in a randomised crossover trial that included 20 healthy adult female subjects with a mean body mass index (BMI) of 25.9 ± 3.1 kg/m^2. Two 10 week test periods were separated by a three week washout period. During one arm of the study, 1440 kJ/day of almonds were provided with no dietary advice except that the day's allotment of almonds had to be consumed. A second arm differed only in that nuts were disallowed.

The results revealed the strong satiating effects of almonds, with 74% of the energy from almonds offset by reduced energy intake from other sources. There was a significant increase in faecal energy loss, accounting for about 7% of the energy of almonds and a non-significant increase in daily energy expenditure that would account from about 14% of the energy of almonds. Accordingly, the findings showed minimal impact of almond consumption on body weight. These mechanisms help explain the results of epidemiological and clinical studies which suggest that moderate nut consumption does not pose a threat for weight gain. For example, a southern Californian study showed that adding a modest quantity of almonds (65 g) to the diet for six months resulted in no significant changes in body weight and an increase in the proportion of unsaturated fat in the diet for 81 subjects (Fraser *et al.* 2002). The authors reported that food displacement occurred after almond supplementation, and over 54–78% of extra calories from almonds were displaced by a decrease in intake of other less healthy foods in the habitual diet (Jaceldo-Siegl *et al.* 2004). In another almond study, which followed 65 overweight and obese individuals, Wien *et al.* (2003) showed that a moderate fat diet with almonds resulted in more weight loss than a low fat diet, even though the total number of calories in the six-month study period was the same for both groups. In addition, the almond group had a 50% greater reduction in waist circumference and a 62% greater reduction in fat mass than the low fat diet group.

Substituting almonds for other foods in the diet that are not as satiating is a potential strategy for weight loss and for weight maintenance. Almonds can replace less nutrient-dense foods in the diet, and eating more nutrient-dense foods involves fewer calories to achieve nutrient requirements. Data concerning the long-term association between nut consumption and weight changes in a free-living population are sparse. Bes-Rastrollo *et al.* (2009) carried out a prospective study of nut consumption, long-term weight change and obesity risk in women. Higher nut consumption was not associated with greater body weight gain during 8 years of follow-up in healthy middle aged women. Instead, it was associated with a slightly lower risk of weight gain and obesity. The authors concluded that the incorporation of nuts into habitual diets does not lead to greater weight gain and may contribute to weight control. With the steady increase in the incidence of obesity, it is becoming more important for scientists and health professionals to understand the role of nuts in body weight regulation and the related chronic diseases. Review of the available data suggests that adding nuts to habitual diets of free-living individuals does not cause weight gain. In fact, the evidence so far indicates that nuts have a tendency to lower body weight and fat mass (Rajaram and Sabaté 2006).

Evidence from epidemiological and human intervention studies is pointing towards a protective role for nuts, and almonds in particular, in improvements in glycaemic control, insulin sensitivity and reducing risk factors for diabetes (Rajaram and Sabaté 2006; Ternus *et al.* 2009). Although there is some evidence to suggest that almonds, and perhaps other nuts, may have a favourable effect on insulin sensitivity, more studies are needed to understand the possible mechanisms. Several studies have shown that risk of type 2 diabetes is lowered with higher intakes of dietary fibre and lower glycaemic loads. Jenkins and colleagues recently evaluated the ability of either mixed nuts or almonds to modulate glucose spikes that occur after consuming carbohydrate-rich foods that commonly raise blood sugar levels (Jenkins *et al.* 2006). The results showed that in healthy men and women, eating nuts with a carbohydrate-rich meal blunted the glycaemic and insulin response of the body to a significant degree (Jenkins *et al.* 2006, 2007; Ternus *et al.* 2009). In conclusion, the research findings look sufficiently promising to be able to continue to promote the inclusion of nuts and almonds as part of a healthy diet.

6. Food allergy: potential risks of nuts and tree nuts

Consumption of nuts and tree nuts including almonds has been proven to be a healthy dietary habit. However, they can also induce IgE-mediated adverse allergic reactions in susceptible individuals (Chen *et al.* 2006). Food allergy is estimated to affect around 1–2% of individuals over the first decade of life, and nuts can cause anaphylactic reactions and fatalities. Allergy to almonds resembles that for other tree nuts. Methods have been developed for the identification and detection of amandin, the major almond storage protein (Sathe *et al.* 2002). The IgE-binding activity of almond proteins is reduced with typical heat processing treatments applied to almonds, such as blanching and roasting (Venkatachalam *et al.* 2002).

Clear allergen labelling of food products containing nuts and other potentially allergenic foods is required under European food labelling legislation, and increasing efforts are being made to help educate people living with these allergies and their families on how to recognise early symptoms of an allergic reaction and how to treat anaphylaxis promptly.

7. Almonds in the diet

Owing to the increasing evidence of beneficial health effects, nuts such as almonds are now intrinsic to dietary guidelines in several countries. However, there are very few data on their intake profiles and the qualitative and quantitative differences in their consumption patterns within and between populations and geographic regions. The data from European Prospective Investigation into Cancer and Nutrition (EPIC), a cohort study of 520 000 subjects from 23 centres in ten countries of western Europe, provides information on consumption patterns and typical portion sizes (Jenab *et al.* 2006; Frecka *et al.* 2008). The most commonly consumed nuts were walnuts, almonds and hazelnuts and there was a clear northern to southern gradient of intake. In Sweden, mean intake was 0.15 g/day, with an average portion size of 15.1 g/day, whereas in Spain mean intake was 2.99 g/day, with an average portion size of 34.7 g/day. Average daily portion size for almonds was typically around 20 g. Clearly, cultural trends in southern Europe resemble the Mediterranean-style diet, and the intake patterns are only a 24 h snapshot of nut intake. Interestingly, in the United Kingdom there was a health-conscious sub-section of the population that had higher intakes of nuts. The average portion size of almonds in this health-conscious cohort was 26.1 g/day compared with 10.2 g/day in the general population.

There are many social, demographic, economic and lifestyle changes that determine our nutritional status, and for a variety of reasons many people are not achieving the recommended daily amount (RDA) or even the lower reference nutrient intake (LNRI) for specific, essential micronutrients (SACN 2008). As such, there is a gap between the ideal balanced diet and the reality of what people actually eat on a daily basis. For individuals at all stages of life where food selections may compromise optimal nutrition, encouragement to eat a healthier diet could easily incorporate the greater use of nuts like almonds. For example, in the United Kingdom, populations at risk include women of childbearing age, children aged 18 and under, the elderly, people trying to lose weight, those on restricted diets, socio-economically underprivileged groups, alcoholics and smokers (SACN 2008). Health professionals and policy makers currently focus on the fat, sugar and sodium contents of the diet. Much more attention needs to be paid to the nutrient density of the whole diet and to the special needs of vulnerable groups in society.

8. Conclusions and recommendations

Almonds provide a nutrient-dense source of vitamin E, riboflavin, manganese, magnesium, calcium, phosphorus, potassium, copper, iron and zinc as well as protein, dietary fibre and MUFA. Almonds also provide an excellent source of bioavailable α-tocopherol (vitamin E), and increasing their intake enhances the resistance of LDL cholesterol to oxidation (Chen *et al.* 2006). In addition, the polyphenolic constituents of whole almonds have been characterised and found to possess antioxidant action (Amarowicz *et al.* 2005; Chen *et al.* 2005, 2007; Chen and Blumberg 2008).

Nuts such as almonds are considered to be an important component of a healthy diet, and increased consumption has the potential to improve public health, especially if they replace foods that are high in saturated fatty acids, sugars and salt, or those lacking in vitamins, minerals and phytoprotective constituents.

It is clear from this review that almonds bring significant benefits regarding the lowering of blood cholesterol and the health of the cardiovascular system, particularly when eaten as part of a diet low in saturated fat. Researchers have found an increasing effect on cholesterol levels as almond consumption increases (Sabaté *et al.* 2003), and it has been shown that almonds can be part of an effective cholesterol-lowering diet (Jenkins *et al.* 2006). The strong body of evidence on the benefits of consuming almonds was a factor in the approval of the nut qualified health claim by the US Food and Drug Administration (2003), which states, "Scientific evidence suggests but does not prove that eating 1.5 ounces per day of most nuts, such as almonds, as part of a diet low in saturated fat may reduce the risk of heart disease".

As interest in incorporating almonds into the habitual diet grows, it is important that consumers understand how to include them in a healthy diet without promoting weight gain. Nuts, as a food category, are high-fat, energy-dense foods and can therefore contribute to positive energy balance. However, evidence is accumulating from epidemiological studies, which indicates that nut consumption is not associated with higher body weight and that habitual nut consumers have a lower body mass index than non-consumers. Similarly, human intervention trials indicate that the inclusion of nuts in the diet leads to little or no weight gain (Mattes *et al*. 2007).

A key area of research is the identification of foods and food constituents that can help contribute to healthy weight maintenance or weight loss using foods such as almonds that have a low glycaemic index, high-protein and high-fibre contents and that require mastication. Almonds appear to possess three properties that could be exploited to facilitate weight control and weight loss, namely enhancement of satiety, decreased efficiency of energy absorption and augmentation of energy expenditure (Mattes 2009). Chewing of almonds may also play a more complex role in the digestion process, impacting on nutrient absorption and endocrine responses influencing satiety. Further research is also required to gain better understanding of the role that bioavailability and bioaccessibility of almond constituents, and the synergy between them, play in their associated health outcomes. The importance of mastication in the context of weight management and suppression of hunger also needs further investigation.

Very few data exist on profiles of nut intake and the qualitative and quantitative differences in their consumption patterns within and between populations and geographic regions. More research is needed into the intake of nuts and disease risk to underpin development of food policies and intake recommendations for this important food group.

From a public health point of view, this review has shown that nuts such as almonds, in the context of a healthy, balanced diet can help reduce the risk of CHD, help to mitigate weight gain and help avoid the risk of overweight and development of obesity. It is important to stress that nutrition messages aimed at the general population should clearly indicate that nuts should replace the consumption of other foods and snacks that are energy-dense, high in saturated fats, sugars and salt, and low in essential nutrients. Consumers should also be made aware of the need to maintain overall energy balance.

In a nutshell, almonds offer a nutritious contribution to the habitual diet, with potentially beneficial effects on cardiovascular health without weight gain, making them a natural healthy food choice.

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