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Special Article

Pistachio nuts: composition and potential health benefits

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The pistachio is a nutrient-dense nut with a heart-healthy fatty-acid profile as well as protein, dietary fiber, potassium, magnesium, vitamin K, γ-tocopherol, and a number of phytochemicals. The pistachio's unique green and purple kernel color is a result of its lutein and anthocyanin content. Among nuts, pistachios contain the highest levels of potassium, γ-tocopherol, vitamin K, phytosterols, and xanthophyll carotenoids. Five published randomized cardiovascular trials have shown that pistachios promote heart-healthy blood lipid profiles. Exploratory clinical studies suggest that pistachios help maintain healthy antioxidant and anti-inflammatory activity, glycemic control, and endothelial function. When consumed in moderation, pistachios may help control body weight because of their satiety and satiation effects and their reduced net metabolizable energy content. One study with subjects in a weight-loss program demonstrated lower body mass index and triglyceride levels in individuals who consumed pistachios compared with those who consumed an isocaloric pretzel snack. Emerging research suggests that the addition of pistachios to high-glycemic meals may lower the overall postprandial glycemic response. This review examines the nutrients and phytochemicals in pistachios as well as the potential health effects of these nuts.

INTRODUCTION

Pistachios have been part of the human diet since prehistoric times and have been consumed by past civilizations because of their nutritional and potential disease-management properties.[1] The pistachio (*Pistacia vera* L., Anacardiaceae family) is an ancient nut with a storied history.[2] Native to the Middle East, the pistachio tree is one of the oldest flowering nut trees. Archeological records of early human pistachio consumption in Turkey date back to as early as 7,000 B.C. Flourishing in hot climates, pistachio trees spread from the Middle East to the Mediterranean, with the nuts becoming a valued delicacy among royalty, travelers, and commoners alike. Legend has it that the Queen of Sheba decreed pistachios an exclusively royal food. In the first century A.D., pistachios were debuted as a prized nut in Rome. The pistachio has been used as a folk remedy for a variety of ailments, and its high nutritional value and long storage life also made it an important lightweight food item among early explorers and traders.[1]

In the 1880s, pistachios were first imported to America as a specialty nut by people of Middle Eastern descent. Pistachio trees were planted experimentally in California beginning in the early 1930s.[2] After a decade of careful research and selective breeding, one especially hearty Middle Eastern variety (Kerman) emerged to support commercial production. Pistachios grow in heavy grape-like clusters and, like almonds, are surrounded by a fleshy hull. Pistachios ripen in late summer or early autumn, their hulls becoming rosy and their inner shells splitting naturally along their sutures. The pistachio tree grows up to 10 meters (30 ft) tall. The pistachio tree is a desert plant tolerant of sun and saline soil. In the 1960s and 1970s, commercial cultivation of pistachios expanded across California's Central Valley, where the long, hot summers proved ideal for proper ripening of the fruit. The nut has a hard, whitish exterior shell, which

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Table 1 **Key nutrients and phytochemicals per 1.0 ounce (28.35 g) of pistachios, almonds, and walnuts.**

Nutrient	Pistachios (dry roasted/salted)	Almonds (raw, blanched, dry roasted/salted)	Walnuts (English)
Calories (kcal)	160	163–169	185
Total lipid content (g)	12.7	14.0–14.8	18.5
Monounsaturated fat (g)	6.7	8.8–9.2	2.5
Polyunsaturated fat (g)	3.8	3.4–3.7	13.4
Saturated fat (g)	1.5	1.1	1.7
Protein (g)	5.9	6.0	4.3
Dietary fiber (g)	2.8	3.1–3.5	1.9
Potassium (mg)	285	187–206	125
Magnesium (mg)	31–34	76–80	45
Vitamin K (μg)	3.7	0	0.8
Vitamin E (α-tocopherol) (mg)	0.7	6.8–7.4	0.2
Total phenols (mg)	470	120	440
γ-Tocopherol (mg)	6.7	0.2	5.9
Lutein + zeaxanthin (μg)	329	0	3.0
Total phytosterols (mg)	61–82	34–56	20–32

GAE, gastric acid equivalents.
Data from references[13,23,24,46,47]

constitutes about 50% of the pistachio weight. The seed has a thin skin and light green flesh with a distinctive flavor. Iran and California are the largest producers of pistachios worldwide, with each producing several hundred million pounds annually. Pistachio kernels are often eaten as snacks, roasted and salted or flavored, and incorporated into food products such ice cream, salads, or bakery products.

In the 1980s, a major dietary recommendation to control chronic disease risk and weight was to lower dietary fat, which raised questions about the total fat content of nuts despite their traditional history as a natural, healthy, nutrient-dense food. During this period, the food industry, in response to healthy eating recommendations, promoted low-fat foods, and consumers turned to low-fat diets, often limiting nut intake. Today, it is recognized that, when consumed in moderation, nuts can fit into a heart-healthy diet by helping consumers reduce their intake of saturated fatty acids (SFA) and increase their intake of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA).[3–9] Recently, the US Food and Drug Administration (FDA) reported that consumers generally lack an understanding about the health effects of MUFA and PUFA and it recognized the need for better educational programs promoting awareness of these healthy dietary fats.[10]

According to the FDA's qualified health claim, pistachio producers are allowed to state the following: "Scientific evidence suggests but does not prove that eating 1.5 ounces per day of most nuts, such as pistachios, as part of a diet low in SFA and cholesterol may reduce the risk of heart disease."[11,12] The scientific support for the qualified health claim about pistachios was further enhanced by the report of the 2010 Dietary Guidelines Advisory Committee, which concluded that the body of scientific evidence was greatest for almonds, pistachios, and walnuts.[5]

Pistachios are characterized by the following components: unsaturated fatty acids (e.g., MUFA and PUFA), protein, dietary fiber, magnesium, potassium, vitamin K, and phytochemicals such as phytosterols, lutein (xanthophyll carotenoid), γ-tocopherol, and polyphenols.[13] These components may act synergistically to help promote cardiovascular health, glycemic control, and weight maintenance when consumed in moderation and in the context of an overall healthy diet.[3–9] Compared with almonds and walnuts, pistachios have lower fat and caloric levels (based on the Atwater system) and higher levels of potassium, phytosterols, γ-tocopherol, vitamin K, and xanthophyll carotenoids (Table 1).[13] This review examines the nutrients and phytochemicals in pistachios as well as the potential health effects of these nuts.

PISTACHIOS AND CARDIOVASCULAR HEALTH

Effects on blood lipids

There are currently five published randomized clinical trials on pistachio nuts and blood lipids (as a primary outcome), in which test subjects with normal to moderately elevated cholesterol levels consumed between 32 g and 126 g of pistachios per day as part of either free-living or controlled diets.[14–18] Four of the five studies found significant reductions in total cholesterol (TC),[14,15,17,18] and one reported a nonsignificant reduction.[16] Two of the studies reported significant reductions in low-density lipoprotein (LDL),[14,15] while the other three found nonsignificant reductions.[16–18] Two demonstrated a significant increase in high-density lipoprotein (HDL),[16,18] while the other three showed nonsignificant changes.[14,15,17] Two of the studies demonstrated significant reductions in triglycerides,[14,15] while the other three reported nonsignificant reductions.[16–18] All five studies reported significant reductions in the TC/HDL ratio or the LDL/HDL ratio.[14–18] One trial found that the inclusion of pistachios in a healthy diet resulted in a dose-response improvement in the ratios of TC/HDL, LDL/HDL, and non-HDL/HDL ($P < 0.05$).[15] These clinical studies are summarized in Table 2.[14–18]

Recently, two studies that included secondary blood lipid measures provided additional support for the LDL-lowering effect of pistachios after 3 weeks.[19,20] Collectively, these trials suggest an overall beneficial effect of pistachio consumption on blood lipid profiles when pistachios replace other calories in habitual or low-fat controlled-energy diets.[14–20] The beneficial blood lipid effects of pistachio consumption result from the following components (Table 1).[13]

Unsaturated fatty acids. A one-ounce (28.35 g; 49 kernels) serving of pistachios contains 12.7 g of total fat consisting of 1.5 g of SFA, 3.8 g of PUFA, and 6.7 g of MUFA, with oleic and linoleic acids accounting for about 88% of the total lipids.[13] The pistachio's unsaturated fatty acid content and its relatively low amount of SFA appear to be the primary nutritional factors that promote heart-healthy blood lipids, with a number of other components possibly playing secondary roles.[5,21,22]

Phytosterols. Among the tree nuts, pistachios have the highest phytosterol content, with 61–82 mg of phytosterols per ounce.[13,23,24] Phytosterols, structurally similar to cholesterol, interfere with dietary and endogenous cholesterol absorption, and foods naturally containing 76–449 mg of phytosterols have the ability to reduce cholesterol absorption in a dose-response manner.[25–36] Although 500 mg of phytosterols per serving is needed to support the FDA health claim, the levels of phytosterols in pistachios may be sufficient to play a synergistic role with the unsaturated fatty acids and the low SFA levels in helping to maintain normal cholesterol levels.[37]

Dietary fiber. Pistachios are a good source of dietary fiber, providing 2.8 g of fiber per ounce, with 80% of the fiber being insoluble.[13,38] In a prospective study, an inverse relationship between both soluble and insoluble fiber and risk of cardiovascular disease (CVD) was observed.[39] The blood-lipid-lowering mechanism of insoluble fiber is attributed to its ability to increase fecal bulk and decrease transit time in the intestine, interfering with cholesterol and bile absorption.[38]

Protein. Pistachios contain 5.9 g of protein per ounce, making them a good source of protein.[13] Clinical studies have shown that partial replacement of carbohydrates by plant-based protein may help lower serum LDL levels.[40,41]

Magnesium. Pistachios contain 31–34 mg of magnesium per ounce (8% of the daily value).[13,23] Preliminary evidence suggests that magnesium has potentially beneficial effects on reducing the risk of CVD.[42,43] In the Health Professionals Follow-up Study, the results suggested that the intake of magnesium had a modest inverse association with risk of CHD in men.[44] One clinical study reported that magnesium inhibits fat absorption by promoting insoluble complexes with SFA to reduce postprandial absorption in healthy subjects.[45]

Antioxidant and anti-inflammatory effects

Emerging research suggests that pistachios help improve antioxidant status and anti-inflammatory balance, which may support cardiovascular health. Among the tree nuts, pistachios are one of the richest and most diverse sources of water- and fat-soluble antioxidants.[46,47] Three clinical studies have shown pistachios to have significant antioxidant effects.[14,18,48] Two of these studies report that pistachios, at 20% of the daily energy intake, significantly enhanced endothelium-dependent vasodilation and superoxide dismutase levels and decreased serum interleukin-6 and lipid hydroperoxide levels, whereas there was no significant change in C-reactive protein or tumor necrosis factor-α levels.[14] Moreover, at the same level of intake, pistachios significantly enhanced antioxidant potential and reduced malondialdehyde in the plasma.[18] The third trial found that pistachio-containing diets significantly increased plasma lutein levels and lowered serum oxidized LDL concentrations compared with the control diets without pistachios.[48]

The key phytochemicals in pistachios that may provide antioxidant and anti-inflammatory support for cardiovascular health are reviewed below (Table 1).

Carotenoids. The colorful pistachio is the only nut with significant xanthophyll carotenoid content. The primary pistachio carotenoid is lutein, present at 329 µg/ounce.[13,46,47] Lutein, a xanthophyll carotenoid, is more polar than β-carotene, with a much lower propensity for pro-oxidant activity.[49] Lutein has been reported to help reduce small-particle-size LDL oxidation, which may be associated with lutein being primarily transported within the HDL complex, known for LDL targeted antioxidant activity.[50,51] A randomized crossover controlled-feeding study demonstrated the potential antioxidant effects of lutein from pistachios.[48] When participants consumed the pistachio-enriched diets, they had higher plasma lutein

Table 2 **Published clinical trials on effects of pistachios on blood lipids, as a primary outcome.**

Study	Characteristics of subjects	Number and age of subjects	Study type	Intervention	Duration	Outcome measures	Study results
Edwards et al. (1999)[17]	High blood cholesterol (median TC of 243 mg/dL [range 214–336 mg/dL]) Median weight 67 kg (range 50–102 kg)	10 (4 men aged 41–53 years and 6 women aged 28–64 years)	Randomized crossover trial w/ dietary counseling	20% caloric intake from pistachio nuts (median intake of 67 g/day)	3 weeks	Primary: blood lipids Secondary: body weight and blood pressur	Decreased TC ($P < 0.04$), increase in HDL ($P < 0.09$), decreased TC/HDL ratio ($P < 0.01$) and LDL/HDL ratio ($P < 0.02$) Nonsignificant decrease in TG and LDL levels Nonsignificant changes in body weight and BP
Kocyigit et al. (2006)[18]	Healthy men and women; mean TC of 159 mg/dL (range 134–173 mg/dL) Mean weight 64 kg (range 55–87 kg)	44; (control group $n = 22$; 33 ± 6.7 years of age, and pistachio group $n = 22$; 33 ± 7.2 years of age)	Randomized parallel trial w/ dietary counseling	Regular diet and pistachio diet in which pistachio nuts were substituted for 20% of the daily caloric intake (65–75 g of pistachios were consumed per day depending of subject's energy intake)	3 weeks	Primary: blood lipids, MDA, and AOP Secondary: body weight	Decreased mean plasma TC, MDA levels, and TC/HDL; LDL/HDL ratios were significantly decreased ($P < 0.05$, $P < 0.05$, $P < 0.001$, and $P < 0.01$, respectively) TG and LDL levels also decreased, but not significantly ($P > 0.05$) HDL, AOP, and AOP/MDA ratios were significantly increased ($P < 0.001$, $P < 0.05$, and $P < 0.01$, respectively) Nonsignificant changes in body weight
Sheridan (2007)[16]	High blood cholesterol (mean TC of 246 ± 6 mg/dL) BMI 28 ± 0.9	15; 11 men and 4 women, average age 60 ± 3 years (range 36–75 years)	Randomized crossover trial w/ dietary counseling	Dietary modification with 15% caloric intake from pistachio nuts (56–84 g/day)	4 weeks	Primary: blood lipids and apolipoproteins A-1 and B-100. Secondary: BMI and BP	Reductions for TC/HDL ($P = 0.001$), LDL/HDL ($P = 0.004$), and B-100/A-1 ($P = 0.009$) Increases for HDL ($P = 0.02$) Nonsignificant reductions for TC, TG, LDL, VLDL, and A-1 or B-100 Nonsignificant changes observed in BMI or BP
Gebauer et al. (2008)[15]	Elevated LDL: mean 137 mg/dL (range 90–191 mg/dL) BMI 26.8 ± 0.7	28; 10 men and 18 women, average age 48 ± 1.5 years	Randomized crossover controlled feeding trial	3 isoenergetic diets: Control diet: low-fat diet with no nuts (25% total fat energy) Diet with 10% of energy from pistachios (32–63 g/day; 30% total fat energy) Diet with 20% of energy from pistachios (63–126 g/day; 34% total fat energy)	4 weeks	Primary: blood lipids and apolipoproteins Secondary: CETP, insulin, glucose, plasma fatty acids, and body weight	Reductions in TC, LDL, and non-HDL with both the 10% and 20% energy diets ($P < 0.05$) Reductions in TG ($P < 0.01$) and in TC/HDL and LDL/HDL ($P < 0.001$) for 20% energy diets Differences between the 10% and 20% energy diets for the ratios of TC/HDL, LDL/HDL, and non-HDL/HDL ($P < 0.05$), which indicated a dose-dependent effect Nonsignificant differences in HDL, CEPT, and body weight between any of the diets ($P > 0.05$)
Sari et al. (2010)[14]	Healthy young men with TC of 200 ± 42 mg/dL Body weight 69.3 ± 4.9 kg	32; mean age 22 years (range 21–24 years)	Randomized controlled feeding trial	A Mediterranean diet was administered to subjects. After 4 weeks, participants continued to receive the Mediterranean diet, but pistachios were added for 4 weeks by replacing 20% (60–100 g) of daily caloric intake	4 weeks	Primary: blood lipids, and endothelial function Secondary: body weight, BP, oxidative/inflammatory stress, and blood glucose	Reduction for glucose ($P < 0.001$, 8.8 ± 8.5%), LDL ($P < 0.001$), TC ($P < 0.001$), and TG ($P = 0.008$) Nonsignificant change in HDL ($P = 0.069$). There were significant reductions in Apo AI and Apo B levels and in ratios of TC/HDL and LDL/HDL ($P < 0.001$ for all) Improved endothelium-dependent vasodilation ($P = 0.002$); decreased serum interleukin-6, total oxidant status, lipid hydroperoxide, and MDA; and increased superoxide dismutase ($P < 0.001$) Reductions in blood glucose ($P < 0.001$) Nonsignificant changes in C-reactive protein and tumor necrosis factor-α levels, body weight, and BP ($P > 0.10$ for all)

Abbreviations: AOP, antioxidant potential; BMI, body mass index; BP, blood pressure; CETP, cholesterol ester transfer protein; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MDA, malondialdehyde; TC, total cholesterol; TG, triglycerides; VLDL, very-low-density lipoprotein.

($P \leq 0.0001$) concentrations than after the baseline diet. After both periods in which diets were enriched with pistachios, either 1.5 ounces or 3.0 ounces, subjects had lower serum oxidized-LDL concentrations than after the control diet period ($P \leq 0.05$). However, after controlling for the change in serum LDL as a covariate, serum lutein levels in subjects consuming 3 ounces of pistachios were modestly associated with reduced oxidized-LDL ($P = 0.06$). The effect of pistachio lutein on cardiovascular health needs further investigation.

γ-Tocopherol. Pistachios contain 6.7 mg of γ-tocopherol per ounce.[13] As an antioxidant, γ-tocopherol uniquely scavenges reactive nitrogen species and has anti-inflammatory properties mediated through inhibition of cyclooxygenase-2.[52] In addition, preliminary studies suggest that γ-tocopherol may work synergistically with aspirin to produce a stronger anti-inflammatory effect without causing stomach injury.[53] CHD patients tend to have lower serum γ-tocopherol levels than CHD-free, healthy subjects.[52] Although pistachio consumption increases serum γ-tocopherol levels,[54] the effect of γ-tocopherol on cardiovascular health needs further investigation.

Phenolic compounds. The total content of phenolic compounds, including anthocyanins, flavonoids, lignans, phenolic acids, proanthocyanidins, stilbenes, and hydrolyzable tannins, varies widely among nuts, with pecans, pistachios, and walnuts being the richest sources.[46,47] Pistachios have a total phenol content of about 470 mg per ounce.[46] Phenolic compounds may have antioxidant and anti-inflammatory properties, which may help improve endothelial function and decrease oxidized LDL.[55–59] Phenolic antioxidants may be more effective in MUFA-rich nuts like pistachios than in PUFA-rich nuts.[47,59]

Effects on blood pressure

Of the nuts, pistachios have the highest level of potassium, containing 285 mg per ounce (8% daily value) (Table 1).[13,23,24] Potassium is the major intracellular cation in the body and is required for normal cellular function and vascular tone (blood pressure).[60–62] Observational and clinical studies suggest that increased potassium intake may help control blood pressure in normal and hypertensive people.[63–65]

GLYCEMIC CONTROL AND TYPE 2 DIABETES

The worldwide prevalence of type 2 diabetes is on the rise, with an increase of 50% projected by the year 2030.[66] The presence of type 2 diabetes increases the risk of CVD two- to fivefold, especially for women.[67–73] The effects of diabetes on global health and the economy is enormous.[66] Diabetes is associated with a multitude of other health complications that include hypertension and stroke, cancer, limb amputation, blindness, and renal disease.[74–76]

The inclusion of nuts in the diets of people with or at risk of developing type 2 diabetes may be beneficial in moderating glycemic control.[77–81] Pistachio nuts have a very low glycemic index that ranges from 4 to 9.[82] A recent clinical study reported that the addition of pistachios to foods with a high glycemic index, like parboiled rice, pasta, and mashed potatoes, can reduce the total postprandial glycemic response by 20–30%.[82] This suggests potential blood glucose control benefits of incorporating pistachios into meals or snacks with a high glycemic index.

WEIGHT CONTROL

The growing prevalence of overweight and obesity worldwide is a critical public health concern, as excess body fat increases the risk of many chronic diseases.[83–94] In the United States, the obesity rate doubled and the net average daily per capita caloric intake increased by about 600 calories between 1970 and 2008.[4] Although a common recommendation for weight loss or maintenance has been the restriction of high-fat, energy-dense foods such as nuts, epidemiologic and clinical studies suggest that moderate consumption of nuts may help provide people an enjoyable way to control their weight.[84–89]

When consumed as portion-controlled snacks, pistachios may support a healthier weight compared with refined carbohydrate snacks for individuals on a calorie-restricted diet.[90] A randomized, parallel, isocaloric reduced-calorie weight-loss study compared the effect of pistachios with that of pretzels. The study involved 70 overweight and obese subjects consuming about 230 calories of pistachios or pretzels as an afternoon snack for 12 weeks. As expected, both groups lost weight ($P \leq 0.001$), but there was a trend for the pistachio group to lose more weight than the pretzel group ($P = 0.09$). Additionally, there was a significantly greater reduction in body mass index (BMI) in the pistachio group (4.3% of BMI) than in the pretzel group (2% of BMI) ($P < 0.05$) and a significantly lower level of triglycerides in the pistachio group compared with the pretzel group ($P < 0.01$).

The key weight-control mechanisms of pistachios are likely increased satiation and satiety signals[85,91–93] and lower metabolizable energy.[20,94] Two studies suggest a unique effect of in-shell pistachios on reducing caloric intake as a result of the following: 1) the visual cues of the empty pistachio shells accumulating on the table help people to be mindful of their intake, leading to the consumption of fewer calories,[92] and 2) the extra time needed to shell the nuts and the extra volume perceived when consuming in-shell pistachios resulted in subjects consuming about 40% fewer calories compared with consuming pistachio kernels, with the same fullness and satisfaction ratings.[93]

CONCLUSION

Pistachio nuts have been part of the human diet since prehistoric times and have been consumed by past civilizations in part for their nutritional and health-management properties. Pistachios are nutrient-dense nuts that contain a heart-healthy fatty-acid profile, protein, dietary fiber, potassium, magnesium, vitamin K, γ-tocopherol, and a number of phytochemicals, including phytosterols, phenolic acids, and xanthophyll carotenoids. Among nuts, pistachios contain the highest levels of potassium, phytosterols, vitamin K, γ-tocopherol, and lutein. A growing number of clinical studies suggest potential health benefits of pistachio nuts. Five published randomized clinical studies have shown that pistachios have a beneficial effect on blood lipid profiles. Furthermore, emerging clinical evidence suggests that pistachios may help reduce oxidative and inflammatory stress and promote vascular health, glycemic control, appetite management, and weight control.

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