Prunus dulcis

Scientific Name

***Prunus dulcis* (Mill.) D.A.Webb**

Synonyms

Amygdalus amara Duhamel, *Amygdalus communis* L., *Amygdalus communis* var. *amara* (Duhamel) Candolle, *Amygdalus communis* var. *dulcis* (Miller) Candolle, *Amygdalus communis* var. *fragilis* (Borkhausen) Seringe, *Amygdalus dulcis* Mill., *Amygdalus fragilis* Borkhausen, *Amygdalus sativa* Miller, *Prunus amygdalus* (Linnaeus) Batsch, *Prunus amygdalus* var. *amara* (Duhamel) Focke, *Prunus amygdalus* var. *dulcis* (Miller) Koehne, *Prunus amygdalus* var. *fragilis* (Borkhausen) Focke, *Prunus amygdalus* var. *sativa* (Miller) Focke, *Prunus communis* (L.) Arcang., *Prunus communis* var. *dulcis* (Miller) Borkhausen, *Prunus communis* var. *fragilis* (Borkhausen) Focke, *Prunus communis* var. *sativa* (Miller) Focke, *Prunus dulcis* var. *amara* (Duhamel) H. L. Moore.

Family

Rosaceae

Common/English Names

Almond, Bitter Almond, Sweet Almond

Vernacular Names

Afrikaans: Amandel;
Albanian: Bajame, Bajamja;
Amharic: Lawz;
Arabic: Lawz, Lawzah, Luz;
Aramaic: Badam, Luz, Qataraq, Shegd, Shegda;
Azerbaijan: Badam;
Basque: Alemndra, Amanda;
Belarusian: Mihdaly, Mindai;
Brazil: Amêndoa-Amarga, Amêndoa-Doce, Amendoeira (Portuguese);
Breton: Alamandez, Alamandez Dous;
Bulgarian: Badem;
Catalan: Ametler;
Chinese: Hahng Yahn (Cantonese), Bian Tao, Ben Tao, Ba Tan Hsung, Xing Ren (Mandarin);
Coptic: Karia;
Croatian: Badem, Mendula;
Czech: Mandloň Obecná, Mandloň Obecná Hořká;
Danish: Bittermandel, Mandel;
Dutch: Amandel, Amandelboom;
Esperanto: Migdalo;
Eastonian: Harilik Mandlipuu;
Farsi: Badam;
Finnish: Manteli;
French: Amandier, Amandier Amer, Amandier Commun;
Frisian: Mangel;
Gaelic: Almon, Cno Ghreugach;
Garo: Badam Pol;
Georgian: Nushi;

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German: Bittermandelbaum, Knackmandel, Mandel, Mandelbaum, Süsser Mandelbaum;
Greek: Amigdalia, Amygdalia;
Hebrew: Shaqed;
Hungarian: (Édes Vagy Keserű) Mandula, Keserű Mandula;
Iceland: Mandla;
India: Badam (Assamese), Badam, Katbadam (Bengali), Bada Pol (Garo), Badam (Gujarati), Badam (Hindi), Badamu, Badaami, Baadaami (Kannada), Badam, Badam Kayu, Badamkotta (Malayalam), Baadaam (Marathi), Badam (Punjabi), Alabukhara, Vatadah, Vatamah (Sanskrit), Padam, Paruppu, Vatamkottai, Vaadumai, Vatumai (Tamil), Badamvittulu, Baadaamamu, Baadaamu, Badamupappu, Paarsibaadami (Telugu), Badam (Urdu);
Italian: Mandorlo;
Japanese: Amendo;
Kazakhstan: Badam, Badamgül, Ïtbadam;
Khais: Budam;
Korean: Amondu;
Latvian: Mandele;
Lithuanian: Migdolai:
Macedonia: Badem;
Malay: Badam;
Maltese: Lewż;
Mongolian: Büjls;
Norwegian: Mandel;
Persian: Baadaam;
Polish: Migdal, Migdałowiec Pospolity, Migdał Zwyczajny;
Portuguese: Amêndoa (Fruto), Amendoeira, Amendoeira-Amarga, Amendoeira-Doce;
Romanian: Migdală, Migdal;
Russian: Mindal' Obyknovennyj;
Serbian: Badem;
Slovašcina: Mandljevec;
Slovencina: Mandľa Obyčajná;
Spanish: Almendra, Almendro, Migdalujo;
Swahili: Lozi;
Swedish: Mandel;
Tajikstan: Bodom;
Thai: Alomon, Aelmon;
Turkish: Baadaam, Badem;
Ukrainian: Mygdal;
Uzbekistan: Bodom;
Vietnamese: Hạnh;
Welsh: Almon;
Yiddish: Mandl.

Origin/Distribution

Almond and related species are indigenous to the Mediterranean climate region of the Middle East (Syria, Lebanon, Israel and Jordan and Turkey eastward to Pakistan). The almond and its close relative, the peach, probably evolved from the same ancestral species. Almonds were domesticated at least by 3000 BC, and perhaps much earlier since wild almonds have been unearthed in Greek archaeological sites dating to 8000 BC. Traditional regions of almond cultivation are located around the Mediterranean Sea and southwest Asia with extension to south western Russia and Ukraine, Caucasus, Middle Asia and Himalaya. Later introduced into North and South America, South Africa and Australia. California is the world leading almond producer. In 2002, there were over 500,000 acres of almonds in California, making it the most widely planted tree crop in the state.

Agroecology

Almond grows in the following climatic regimes ranging from Cool Temperate Moist to Wet through Subtropical Thorn to Moist Forest Life zones. It prefers areas with mild winters and long rain-less, hot summers with low humidity. It thrives in areas with 400–1,470 mm annual rainfall but requires supplemental irrigation in dry areas for good growth and yield of well-filled nuts. Although relatively cold hardy, it prefers frost free areas with annual temperature of 10.5–19.5°C. Critical temperatures below which damage occurs varies with the stage of flowering and fruit development: pink bud stage −4°C to −7°C, full bloom stage −1°C to −2°C and small nut stage 0.6°C. Almond has a low winter chilling requirement (or short rest period), and the relatively low amount of heat required to bring the trees into bloom, the almond is generally the earliest deciduous fruit or nut tree to flower, hence extremely subject to frost injury where moderately late-spring frosts prevail. Almond does well in the hot, dry interior valleys of California, where the nuts mature satisfactorily. The almond tree has been successfully grown on wide range of soils. Almond will tolerate poor soils but does best in deep, well-drained sandy loam soils with pH range of 5.3–8.3. Almond trees have high nitrogen and phosphorus requirements.

Edible Plant Parts and Uses

Almonds kernels are eaten raw, dried, cooked, roasted or dried and ground into a powder for use in bakery and confectionery. A standard one cup serving of almond flour contains 20 g of carbohydrates, of which 10 g is dietary fibre, for a net of 10 g of carbohydrate per cup. This makes almond flour very desirable for use in cake, pastries, cookies, candies and bread recipes by people on carbohydrate-restricted diets. Crushed almond pieces are often sprinkled over desserts, particularly sundaes and other ice cream based dishes, and used in cakes cookies and pastries. Almonds are used in desserts like baklava, nougat, macaroons and marzipan. In China, almonds are used in a popular dessert when they are mixed with milk and then served hot. In Indian cuisine, almonds are the base ingredient for *pasanda*-style curries. In Spain, almonds of the Marcona variety are traditionally served after being lightly fried in oil, and are also used by Spanish chefs to prepare a dessert called *turrón*. Almonds are also made into a spread called almond butter which is good for people with peanut allergy. Almond can be processed into almond milk for an analog to dairy, and soy-free choice and for lactose intolerant consumers and vegans. Almonds can be made into almond syrup – an emulsion of sweet and bitter almonds usually made with barley syrup or in a syrup of orange-flower water and sugar. *Oleum Amygdalae* or almond oil is used as a substitute for olive oil and is used as a flavouring agent in baked goods and also perfumery and medicines.

Botany

A small, deciduous tree, 3–8 m high with unarmed spreading horizontal branches and greyish brown bark and an open spreading crown. Leaves are alternate, medium green, lanceolate to elliptic lanceolate 3–9 cm by 1.2.5 cm, sparsely pilose when young becoming glabrescent with broadly cuneate to rounded base, shallowly densely serrate, margin and acute to shortly acuminate apex (Plates 1 and 2). Flowers are usually borne laterally on spurs or short lateral branchlets or laterally on long shoots. Flowers solitary, white to pink, actinomorphic, pentamerous, 2–5 cm across, on 3–4 mm pedicels, appearing before the foliage. Hypanthium cylindrical and glabrous

Plate 1 Dense almond foliage and branchlets

Plate 2 Almond leaves and immature fruit

Plate 3 Whole and halved almond fruit

Plate 4 Almond fruit showing the thick hull, the hard endocarp, testa and white kernel

Plate 5 Almond nuts (endocarp) with the kernel

Plate 6 Almond kernels with brown testa

outside. Sepals 5, broadly oblong to broadly lanceolate, margin pubescent, apex obtuse. Petals 5, white or pinkish, oblong to obovate-oblong, base tapering to a narrow claw, apex obtuse to emarginate. Stamens elongated, unequal in length. Ovary perigynous and densely tomentose. Style longer than stamens. Fruit an obliquely oblong to oblong-ovoid drupe 3–6 cm by 2–4 cm, pubescent, the tough mesocarp splitting at maturity to expose the endocarp (stone) (Plates 2, 3, 4, 5). Endocarp yellowish white to brown, ovoid, broadly ellipsoid, or shortly oblong, asymmetric on both sides, 2.5–4 cm, hard to fragile, ventral suture curved and acutely keeled, dorsal suture generally straight, surface smooth and pitted with or without shallow furrows (Plates 4 and 5) enclosing a flattened, long-ovoid, brown-coated seed containing a white kernel (endosperm) (Plates 3, 4, 6).

Nutritive/Medicinal Properties

Proximate food value of almond nut (*Prunus dulcis*) per 100 g edible portion (60% shells as refuse) (USDA 2011) was reported as: water 4.70 g, energy 575 kcal (2,408 kJ), protein 21.22 g, total lipid (fat) 49.42 g, ash 2.99 g, carbohydrate 21.67 g, fibre (total dietary) 12.2 g, sugars (total) 3.89 g, sucrose 3.60 g, glucose (dextrose) 0.12 g, fructose 0.09 g, maltose 0.04 g, galactose 0.05 g, starch 0.74 g; calcium 264 mg, iron 3.72 mg, magnesium 268 mg, phosphorus 484 mg, potassium 705 mg, sodium 1 mg, zinc 3.08 mg, copper 0.996 mg, manganese 2.285 mg, selenium 2.5 µg; thiamine 0.211 mg, riboflavin 1.014 mg, niacin 3.385 mg, pantothenic acid 0.469 mg, vitamin B-6 0.143 mg, total folate 50 µg, choline (total) 52.1 mg, betaine 0.5 mg, vitamin A 1 IU, vitamin E (α-tocopherol) 26.22 mg, β-tocopherol 0.29 mg, γ-tocopherol 0.65 mg, δ-tocopherol 0.05 mg; total saturated fatty acids 3.731 g, 14:0 (myristic acid) 0.006 g, 16:0 (palmitic acid) 3.044 g, 17:0 (margaric acid) 0.007 g, 18:0 (stearic acid) 0.658 g, 20:0 (arachidic acid) 0.013 g, 22:0 (behenic acid) 0.002 g; total monounsaturated fatty acids 30.889 g, 16:1 undifferentiated (palmitoleic acid) 0.243 g, 16:1 c (palmitoleic acid cis) 0.231 g, 16:1 t (palmitoleic acid trans) 0.012 g, 17:1 (heptadecenoic acid) 0.025 g, 18:1 undifferentiated (oleic acid) 30.611 g, 18:1 c (oleic acid cis) 30.611 g, 20:1 (gadoleic acid) 0.010 g; total polyunsaturated fatty acids 12.070 g, 18:2 undifferentiated (linoleic acid) 12.061 g, 18:2 n-6 c,c (linoleic acid n-6, cic, cis) 12.055 g, 18:2 CLAs 0.001 g, 18:2 t (trans linoleic acid) not further defined 0.005 g, 18:3 undifferentiated (linolenic acid) 0.006 g, 18:3 n-3 c,c,c (α-linolenic acid) 0.006 g, 20:2 n-6 c,c (eicosadienoic acid) 0.004 g; total trans fatty acids 0.017 g, total trans-monoenoic fatty acids 0.012 g; stigmasterol 4 mg, campesterol 5 mg, β-sitosterol 132 mg β-carotene 1 μg, lutein + zeaxanthin 1 μg; amino acids: tryptophan 0.214 g, threonine 0.598 g, isoleucine 0.702 g, leucine 1.488 g, lysine 0.580 g, methionine 0.151 g, cystine 0.189 g, phenylalanine 1.120 g, tyrosine 0.452 g, valine 0.817 g, arginine 2.446 g, histidine 0.557 g, alanine 1.027 g, aspartic acid 2.911 g, glutamic acid 6.810 g, glycine 1.469 g, proline 1.032 g, serine 0.948 g, phytosterols (δ-5-avenasterol, sitostanol, campestanol, and other minor phytosterols) 31 mg.

Almonds are a rich source of vitamin E containing 26 mg/100 g, monounsaturated fats (31 g/100 g) – mainly palmitoleic acid and oleic acid that are responsible for lowering LDL cholesterol. They are also rich in energy, proteins, essential amino acids, dietary fibre, niacin, and minerals like Ca, K, P, Fe and Zn. They also contains selenium, thiamine, riboflavin, pantothenic acid, vitamin B6, folate, betaine and phytosterols.

The food composition of three marketing varieties of almonds: Carmel, Mission, and Nonpareil were found to be as follows: moisture, lipids, protein, ash, sugars, and tannins ranges were 3.05–4.33%, 43.37–47.50%, 20.68–23.30%, 3.74–4.56%, 5.35–7.45%, and 0.12–0.18%, respectively (Ahrens et al. 2005). No detectable hemagglutinating and trypsin inhibitory activities were present in the three varieties of almonds tested. Amino acid analyses indicated the sulfur amino acids (methionine + cysteine), lysine, and threonine to be the first, second, and third limiting amino acids in almonds when compared to the recommended amino acid pattern for children 2–5-year old. However, compared to the recommended amino acid pattern for adults, sulfur amino acids were the only limiting amino acids in almonds tested. Analysis of fatty acid composition of soluble lipids of almonds grown in California indicated that palmitic (C16:0), oleic (C18:1), linoleic (C18:2), and α-linolenic (C18:3) acid, respectively, accounted for 5.07–6.78%, 57.54–73.94%, 19.32–35.18%, and 0.04–0.10%; of the total lipids (Sathe et al. 2008). Oleic and linoleic acid were inversely correlated ($R^2 = -0.99$) and together accounted for 91.16–94.29% of the total soluble lipids. In China, the major fatty acids in Taiyuan almond oil were found to be about 68% oleic acid (C18:1), 25% linoleic acid (C18:2), 4.6–4.8% palmitic acid (C16:0) and a little of palmitoleic acid (C16:1), stearic acid (C18:0) (Shi et al. 1999). A trace of arachidic acid (C20:0) was also found.

Almond fruit consists of four portions: kernel or meat (seed), middle shell (endocarp), outer green shell cover or almond hull and a thin leathery layer known as brown skin of meat or seedcoat (testa) (Esfahlan et al. 2010). The nutritional importance of almond fruit is attributable to its kernel. In the past decades, different phenolic compounds were characterised and identified in almond seed extract and its skin, shell and hull as almond by-products. Polyphenols are important micronutrients in the human diet, and evidence for their role in the prevention of degenerative diseases such as cancer and cardiovascular diseases is emerging. The health effects of polyphenols depend on the amount consumed and on their bioavailability. Esfahlan et al. (2010), had recently comprehensively reviewed the importance of almond and its by-products. They also reviewed the antioxidant properties and potential use as natural dietary antioxidant, as well as their other beneficial compounds and applications of various phenolic compounds present in almond and its by-products. Polyphenol metabolism may produce several classes of metabolites that could often be more biologically active than their dietary precursor and could also become a robust new biomarker of almond polyphenol intake. In a metabolomic study of human urinary metabolome modifications, ingestion of a dietary supplement of almond skin phenolic compounds (flavan-3-ols and flavonols) identified conjugates of hydroxyphenylvaleric, hydroxyphenylpropionic, and hydroxyphenylacetic acids in the human urinary samples (Llorach et al. 2010).

Total phenols ranged from 127 to 241 mg gallic acid equivalents/100 g of fresh weight of the major almond varieties in California (Milbury et al. 2006). The analyses produced a data set of 18 flavonoids and three phenolic acids in the skins and kernels. The predominant flavonoids were isorhamnetin-3-O-rutinoside and isorhamnetin-3-O-glucoside (in combination), catechin, kaempferol-3-O-rutinoside, epicatechin, quercetin-3-O-galactoside, and isorhamnetin-3-O-galactoside at 16.81, 1.93, 1.17, 0.85, 0.83, and 0.50 mg/100 g of fresh weight almonds, respectively Using the existing approach of calculating only the aglycone form of flavonoids for use in the U.S. Department of Agriculture nutrient database, whole almonds would provide the most prevalent aglycones of isorhamnetin at 11.70 (3.32), kaempferol at 0.60 (0.17), catechin at 1.93 (0.55), quercetin at 0.72 (0.20), and epicatechin at 0.85 (0.24) mg/100 g of fresh weight (mg/oz serving), respectively. These data can lead to a better understanding of the mechanisms of action underlying the relationship between almond consumption and health-related outcomes and provide values for whole and blanched almonds suitable for inclusion in nutrient databases. Four flavonol glycosides, isorhamnetin rutinoside, isorhamnetin glucoside, kaempferol rutinoside, and kaempferol glucoside, were detected and quantified in almond skin in analyses made in Canada (Frison and Sporns 2002). In all almond varieties, isorhamnetin rutinoside was the most abundant flavonol glycoside, and the total content ranged from 75 to 250 μg/g.

Antioxidant Activity

Portuguese regional and commercial almond cultivars exhibited dirreferential degrees of antioxidant activity as assayed by different biochemical models: DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity, reducing power, inhibition of β-carotene bleaching, inhibition of oxidative hemolysis in erythrocytes, induced by 2,2′-azobis(2-amidinopropane) dihydrochloride (AAPH), and inhibition of thiobarbituric acid reactive substances (TBARS) formation in brain cells (Barreira et al. 2008) Bioactive compounds such as phenols and flavonoids were also obtained and correlated to antioxidant activity. The results obtained were quite heterogeneous, revealing significant differences among the cultivars assayed. Duro Italiano cv. revealed better antioxidant properties, presenting lower EC_{50} values in all assays, and the highest antioxidants contents. The protective effect of this cultivar on erythrocyte biomembrane hemolysis was maintained during 4 hours.

Almond skin is a rich a source of bioactive polyphenols. Nine phenolic compounds were isolated from the ethyl acetate and n-butanol fractions of almond skins (Sang et al. 2002). These compounds were identified as 3′-O-methylquercetin 3-O-β-D-glucopyranoside (1); 3′-O-methylquercetin 3-O-β-D-galactopyranoside (2); 3′-O-methylquercetin 3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside (3); kaempferol 3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside (4); naringenin 7-O-β-D-glucopyranoside (5); catechin (6); protocatechuic acid (7); vanillic acid (8); and p-hydroxybenzoic acid (9). Compounds 6 and 7 showed very strong DPPH radical scavenging activity. Compounds 1–3, 5, 8, and 9 showed strong activity, whereas compound 4 exhibited very weak activity. Garrido et al. (2008) reported a total of 31 phenolic compounds corresponding to flavan-3-ols (33–56% of the total of phenolic compounds identified), flavonol glycosides (9–36%), hydroxybenzoic acids and aldehydes (6–26%), flavonol aglycones (1.7–18%), flavanone glycosides (3–7.7%), flavanone aglycones (0.69–5.4%), hydroxycinnamic acids (0.65–2.6%), and dihydroflavonol aglycones (0–2.8%) in the skins from three different varieties of almonds. The total contents of phenolic compounds identified were significantly higher (around two-fold) in the roasted samples than in the blanched, freeze-dried almonds. Industrial oven drying of the blanched almond skins produced a two-fold increase in the contents of phenolic compounds. The antioxidant activity (ORAC values) was higher for the roasted samples (0.803–1.08 mmol Trolox/g), followed by the samples subjected to blanching + drying (0.398–0.575 mmol Trolox/g) and then the blanched freeze-dried samples (0.331–0.451 mmol Trolox/g). Roasting was the most suitable type of industrial processing of almonds to obtain almond skin extracts with the greatest antioxidant capacity. Proanthocyanidins, including a series of A- and B-type procyanidins and propelargonidins up to heptamers, and A- and B-type prodelphinidins up to hexamers were also found in almond skins (Monagas et al. 2007). Flavanols and flavonol glycosides were the most abundant phenolic compounds in almond skins, constituting 38–57% and 14–35% of the total quantified phenolics, respectively.

Studies showed that almond skin flavonoids (ASF) possessed antioxidant capacity in-vitro, were bioavailable and acted in synergy with vitamins C and E to protect LDL against oxidation in hamsters (Chen et al. 2005). ASF from 0.18 to 1.44 μmol gallic acid equivalent (GAE)/L increased the lag time to LDL oxidation in a dose-dependent manner. Combining ASF with vitamin E or ascorbic acid extended the lag time >200% of the expected additive value. In subsequent studies, Chen et al. (2007) demonstrated the almonds skin polyphenolics (ASP) and quercetin reduced the oxidative modification of apo B-100 and stabilize LDL conformation in a dose-dependent manner, acting in an additive or synergistic fashion with vitamin C and E. The scientists also showed that ASP acted as antioxidants and induced quinine reductase activity, but these actions were dependent upon their dose, method of extraction, and interaction with antioxidant vitamins C and E (Chen and Blumberg 2008). Almond green husks (Cvs. Duro Italiano, Ferraduel, Ferranhês, Ferrastar and Orelha de Mula) were found to have good antioxidant properties, with very low EC_{50} values (<380 μg/mL), particularly for lipid peroxidation inhibition (<140 μg/mL) (Barreira et al. 2010). Correlation between total phenol – flavonoid contents and DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity, reducing power, inhibition of β-carotene bleaching and inhibition of lipid peroxidation in pig brain tissue through formation of thiobarbituric acid reactive substances, were also obtained.

Phenols levels in roasted peanut and hazelnut skins were higher than that of almond skins, but their flavan-3-ol profiles, differed considerably. Peanut skins were low in monomeric flavan-3-ols (19%) in comparison to hazelnut (90%) and almond (89%) skins (Monagas et al. 2009). In contrast, polymeric flavan-3-ols in peanut and almond skins occurred as both A- and B-type proanthocyanidins, but in peanuts the A forms (oligomers up to DP (degree of polymerization) 12) were predominant, whereas in almonds, the B forms (up to DP8) were more abundant. In contrast, hazelnuts were mainly constituted by B-type proanthocyanidins (up to DP9). The antioxidant capacity as determined by various methods (i.e., total antioxidant capacity, ORAC, DPPH test, and reducing power) was higher for whole extracts from roasted hazelnut and peanut skins than for almond skins; however, the antioxidant capacities of the high molecular weight fractions of the three types of nut skins were equivalent despite their different compositions and degrees of polymerization.

The methanol extract of almond hulls (Nonpareil variety) was found to contain 5-O-caffeoylquinic acid (chlorogenic acid), 4-O-caffeoylquinic acid (cryptochlorogenic acid), and 3-O-caffeoylquinic acid (neochlorogenic acid) in the ratio 79.5:14.8:5.7 (Takeoka and Dao 2003). The chlorogenic acid concentration of almond hulls was 42.52 mg/100 g of fresh weight. At an equivalent concentration (10 μg/1 g of methyl linoleate) almond hull extracts had higher antioxidant activity than α-tocopherol. At higher concentrations (50 μg/1 g of methyl linoleate) almond hull extracts showed increased antioxidant activity that was similar to chlorogenic acid and morin [2-(2,4-dihydroxyphenyl)-3,5,7-trihydroxy-4H-1-benzopyran-4-one] standards (at the same concentrations).

The data indicated almond hulls to be a potential source of these dietary antioxidants. The sterols (3β,22E)-stigmasta-5,22-dien-3-ol (stigmasterol) and (3β)-stigmast-5-en-3-ol (β-sitosterol) (18.9 mg and 16.0 mg/100 g) of almond hull, respectively.

Studies showed that almond had antioxidant property and retarded the aging process (Wang et al. 2004). D-gal-induced aging rats fed with almond at 65 g/kg feedstuff, 97.5 g/kg feedstuff after 30 days had their levels of malonaldehyde (MDA) significantly reduced, but the lowest dose group 32.5 g was not significantly different. At the same time, the activities of SOD (superoxide dismutase), GSH-Px (glutathione peroxidise) and the liquid fluidity of erythrocyte membrane increased significantly.

The total phenolic contents of ethanolic extracts of brown skin and green shell cover of almond were ten and nine times higher than that of the whole seed, respectively (Wijeratne et al. 2006). Brown skin extract at 50 ppm effectively inhibited copper-induced oxidation of human LDL cholesterol compared to whole seed and green shell cover extracts, which reached the same level of efficacy at 200 ppm. Green shell cover extract at 50 ppm level completely arrested peroxyl radical-induced DNA scission, whereas 100 ppm of brown skin and whole seed extracts was required for similar efficiencies. All three almond extracts exhibited excellent metal ion chelation efficacies. Tall the extract were found to contain quercetin, isorhamnetin, quercitrin, kaempferol 3-O-rutinoside, isorhamnetin 3-O-glucoside, and morin as the major flavonoids.

In a pilot study, almond consumption was found to have preventive effects on oxidative stress and DNA damage caused by smoking (Jia et al. 2006). After the almond intervention in a randomized, crossover clinical trial with 60 healthy male soldiers (18–25 years) who were habitual smokers (5–20 cigarettes/daily) (Li et al. 2007), serum α-tocopherol, plasma superoxide dismutase (SOD), glutathione peroxidase (GPX) increased significantly in smokers by 10%, 35%, and 16%, respectively and urinary 8-hydroxydeoxyguanosine (8-OHdG) and malondialdehyde (MDA) and peripheral lymphocyte DNA strand breaks decreased significantly by 28%, 34%, and 23%. In smokers, after almond supplementation, the concentration of 8-OHdG remained significantly greater than in nonsmokers by 98%. These results suggested almond intake could enhance antioxidant defences and diminish biomarkers of oxidative stress in smokers.

Anticancer Activity

Among the main components of almond hulls – oleanolic, ursolic, and betulinic acids, the 2-hydroxy analogues alphitolic, corosolic, maslinic acids, as well as the related aldehydes, namely, betulinic, oleanolic, and ursolic, and from a more polar fraction, the β-sitosterol 3-O-glucoside (Amico et al. 2006). Betulinic acid showed potent antiproliferative activity toward MCF-7 human breast cancer cells (GI_{50} = 0.27 μM), higher than the anticancer drug 5-fluorouracil. *Prunus dulcis* also contained the antitumour compound dihydroquercetin, taxifolin.

Almond kernel also contains amygdalin which is a major constituent in laetrile the abbreviated name for laevomandelonitrile. Amygdalin is often confounded with laetrile. Laetrile, has been erroneously dubbed as vitamin B17 and to have a positive effect in the treatment of cancer. Laetrile does not meet the requirements of a vitamin and its cancer curing claim is doubtful and bogus as reported by numerous studies. One study involving 178 cancer patients treated with amygdalin (Laetrile) plus a "metabolic therapy" program consisting of diet, enzymes, and vitamins generated no substantive benefits in terms of cure, improvement or stabilization of cancer, improvement of symptoms related to cancer, or extension of life span (Moertel et al. 1982). The hazards of amygdalin therapy were evidenced in several patients by symptoms of cyanide toxicity or by blood cyanide levels approaching the lethal range. This study confirmed amygdalin (Laetrile) to be a toxic drug not effective as a cancer treatment. Laetrile has not been approved for this use by the United States' Food and Drug Administration.

Antihyperlipidemic Activity

Almonds are known to have a number of nutritional benefits, including cholesterol-lowering effects and protection against diabetes. They are also a good source of minerals and vitamin E, associated with promoting health and reducing the risk for chronic disease. In one study, almonds used as snacks in the diets of hyperlipidemic subjects was found to significantly reduce coronary heart disease risk factors, probably in part because of the non-fat (protein and fibre) and monounsaturated fatty acid components of the nut (Jenkins et al. 2002). The full-dose almonds produced the greatest reduction in levels of blood lipids. Significant reductions from baseline were seen on both half- and full-dose almonds for LDL cholesterol (4.4% and 9.4% respectively) and LDL:HDL cholesterol (7.8% and 12.0% respectively) and on full-dose almonds alone for lipoprotein(a) (7.8%) and oxidized LDL concentrations (14.0%), with no significant reductions on the control diet.

In a randomised crossover study comparing the effects of whole almonds, taken as snacks, with the effects of low saturated fat (<5% energy) whole-wheat muffins (control) in the therapeutic diets of hyperlipidemic subjects, Mean body weights differed ≤300 g between treatments, although the weight loss on the half-dose almond treatment was greater than on the control (Jenkins et al. 2008a). At 4 weeks, the full-dose almonds reduced serum concentrations of malondialdehyde (MDA) and creatinine-adjusted urinary isoprostane output compared with the control. Serum concentrations of α-tocopherol or γ-tocopherol were not affected by the treatments. Almond antioxidant activity was demonstrated by their effect on 2 biomarkers of lipid peroxidation, serum MDA and urinary isoprostanes. Antioxidant activity provided an additional possible mechanism, in addition to lowering cholesterol, that may account for the reduction in CHD (coronary heart disease) risk with nut consumption. In another randomized crossover study, 27 hyperlipidemic men and women were provided 3 isoenergetic (mean, 423 kcal/day) supplements each for 1 month comprising 22.2% of energy and consisted of full-dose almonds (73 ± 3 g/day), half-dose almonds plus half-dose muffins, and full-dose muffins (Jenkins et al. 2008b). At the end of 4 weeks mean body weights differed by less than 300 g between treatments. No differences were seen in baseline or treatment values for fasting glucose, insulin, C-peptide, or insulin resistance as measured by homeostasis model assessment of insulin resistance. However, 24-hour urinary C-peptide output as a marker of 24-hour insulin secretion was significantly reduced on the half-and full-dose almonds by comparison to the control after adjustment for urinary creatinine output. The reductions in 24-hour insulin secretion appeared to be a further metabolic advantage of nuts that in the longer term may help to explain the association of nut consumption with reduced CHD risk.

Antidiabetic Activity

A separate study reported that almond-enriched diets do not alter insulin sensitivity in healthy adults or glycemia in patients with diabetes (Lovejoy et al. 2002). Almond consumption did not change insulin sensitivity significantly, although body weight increased and total and LDL cholesterol decreased by 21% and 29%, respectively in study 1. In study 2, total cholesterol was lowest with the HFA (high fat, high almond) diet (4.46, 4.52, 4.63, and 4.63 mmol/L with the HFA, HFC (High fat control), LFA (low fat high almond), and LFC (low fat control) diets, respectively). HDL cholesterol was significantly lower with the almond diets; however, no significant effect of fat source on LDL:HDL was observed. Glycemia was unaffected. Almonds had beneficial effects on serum lipids in healthy adults and produced changes similar to high monounsaturated fat oils in diabetic patients.

Consumption of almonds was found to lower postprandial glucose excursions and to decrease the risk of oxidative damage to proteins (Jenkins et al. 2006). Glycemic indices for the rice (38) and almond meals (55) were less than for the potato meal (94), as were the postprandial areas under the insulin concentration time curve.

No postmeal treatment differences were seen in total antioxidant capacity. However, the serum protein thiol concentration increased following the almond meal (15 mmol/L), indicating less oxidative protein damage. Therefore, lowering postprandial glucose excursions may decrease the risk of oxidative damage to proteins. Almonds were postulated to lower this risk by decreasing the glycemic excursion and by providing antioxidants. These actions may relate to mechanisms by which nuts are associated with a decreased risk of coronary heart disease.

Tocopherol Improvement Activity

Almonds in the diet was found to simultaneously improve plasma α-tocopherol concentrations and reduce plasma lipids in healthy adults in a randomized, crossover feeding trial (Jambazian et al. 2005). Incorporating almonds into the diet helped meet the revised Recommended Dietary Allowance of 15 mg/day α-tocopherol and increased lipid-adjusted plasma and red blood cell α-tocopherol concentrations. A significant dose-response effect was observed between percent energy in the diet from almonds and plasma ratio of α-tocopherol to total cholesterol.

Prebiotic Activity

Almond also has prebiotic activity. Addition of finely ground almond altered the composition of gut bacteria by stimulating the growth of *Bifidobacteria* and *Eubacterium rectale* resulting in a higher prebiotic index (4.43) than was found for the commercial prebiotic fructo-oligosaccharides (4.08) at 24 hours of incubation (Mandalari et al. 2008). No significant differences in the proportions of gut bacteria groups were detected in response to deffated finely ground almonds.

Almond Allergy and Other Effects

Almond proteins can cause severe anaphylactic reactions in susceptible individuals. Two IgE-binding almond proteins were N-terminally sequenced and identified as almond 2S albumin and conglutin γ (Poltronieri et al. 2002).

Raw and roasted almonds were found to contain advanced glycation endproducts (AGEs) (Zhang et al. 2011). Carboxymethyl-lysine (CML) and carboxyethyl-lysine (CEL) were found in both raw and roasted almonds. Pyralline (Pyr) was identified for the first time in roasted almonds and accounted for 64.4% of free plus bound measured AGEs. Argpyrimidine (Arg-p), and pentosidine (Pento-s) were below the limit of detection in all almond samples tested. Free AGEs accounted for 1.3–26.8% of free plus bound measured AGEs, indicating that protein-bound forms predominated. The roasting process significantly increased CML, CEL, and Pyr formation in almonds. AGEs had been reported to play a role as proinflammatory mediators in gestational diabetes (Pertyńska-Marczewska et al. 2009) and also had been implicated in the progression of age related diseases such as diabetes and atheroscelrosis (Tan et al. 2006).

Traditional Medicinal Uses

Almond kernel and almond oil have been used in traditional folk medicine for cancer (especially bladder, breast, mouth, spleen, and uterus), carcinomata, condylomata, corns, indurations, kidney stones, gallstones and tumours. Almond is also used as folk remedy for asthma, constipation, cold, corns, cough, dyspnea, eruptions, gingivitis, heartburn, itch, lungs, prurigo, skin, sores, spasms, stomatitis, and peptic ulcers. It is reported to be alterative, astringent, carminative, cyanogenetic, demulcent, discutient, diuretic, emollient, laxative, pectoral, lithontryptic, nervine, sedative, stimulant and tonic. Almond oil is emollient and applied to dry skins and is also often used as a carrier oil in aromatherapy. The leaves have been used in the treatment of diabetes.

Other Uses

The seed contains amygdallin, under the influence of water and in the presence of emulsion it can be hydrolysed to produce benzaldehyde (the almond aroma, formula C6H5 CHO) and prussic acid. Almond oil extracted from the kernels is an excellent lubricant for watches. Sweet almond oil is widely used for cosmetic creams, perfumes, sopas and lotions because it has a softening and moisturising effect on the skin. Bitter almond oil in a crisis, might conceivably be used as an energy source. The burnt hulls is rich in potassium, it is used in soap making and a valuable absorbent for coal gas. After the almonds are harvested, the nuts are passed through a machine which removes the hulls. The hulls can be used in cattle and sheep rations. They have been mixed 1:1 with barley and fed together with alfalfa hay with excellent results. Varieties with soft hulls are superior to varieties with hard hulls. Other parts of fruit such as shells and hulls were burned as fuel. A green dye can be obtained from the leaves and fruits. A yellow dye is obtained from the roots and leaves. The gum exuded from the tree has been used as an adhesive and substitute for tragacanth.

Comments

The world's leading producer of almonds is the United States; other major producers include Greece, Iran, Italy, Morocco, Portugal, Spain, Syria and Turkey. In the United States, production is concentrated in California, with almonds being California's sixth leading agricultural product and its top agricultural export.

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