Nut Oils and their Dietetic and Cosmetic Significance: a Review

Monika Michalak¹, and Anna Kiełtyka-Dadasiewicz²*

¹ Department of Dermatology and Cosmetology, Institute of Medical Sciences, Faculty of Medicine and Health Sciences, Jan Kochanowski University in Kielce, IX Wieków Kielc 19, 25-317 Kielce, POLAND
² Department of Plant Production Technology and Commodity Science, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, POLAND

Abstract: Vegetable oils, which are a rich source of unsaturated fatty acids, phytosterols, vitamins and antioxidants, have a significant effect on the functioning and development of the body and contribute to health maintenance. They can be obtained from seeds, fruit stones, fruit, nuts or sprouts. This study discusses various species of plants that are sources of nut oils consumed in the daily diet and also used in the pharmaceutical and cosmetics industries.

Key words: nuts, plant oils, fatty acids, skin, health prophylaxis

1 INTRODUCTION

Tree nuts rank third, behind spices and fruits, in terms of content of bioactive constituents¹. Tree nuts, dry fruits with a single seed in which the ovary wall hardens at maturity, are a rich source of phytochemicals with multi-faceted effects², ³. Nuts have played an important role in the diet of many cultures, due to their wealth of nutrients, high energy value, and vast variety of flavours. Nuts are used as an ingredient in many dishes, such as snacks (roasted and salted almonds, hazelnuts and pistachios), sauces, cold soups, cakes, pastries and biscuits. They are also used as a component of dietary supplements. Nuts are considered a food with a high energy density⁴, ⁵, providing 23.4 to 26.8 kJ/g⁶. They contain fats (mainly unsaturated fatty acids), vegetable proteins, carbohydrates, and fibre, as well as a number of phytochemicals (Fig. 1).

The type and content of phytoneutrients in various nuts depends mainly on the species, as well as on agronomic,
seasonal, and environmental conditions\textsuperscript{2).} Nuts contain nutrients with antioxidant properties, such as flavonoids (luteolin, quercetin, myricetin and kaempferol), phenolic acids, isoflavonoids (formononetin, daidzein and genistein), hydrolysable tannins, proanthocyanidins (condensed tannins), tocopherols, carotenoids and phytosterols. Nuts are also a valuable source of minerals (e.g. calcium, magnesium and potassium) and vitamins (vitamins E and B, folic acid and niacin)\textsuperscript{3, 4, 6-10} (Table 1).

The synergistic effect of many bioactive compounds contained in nuts determines their beneficial effects on human physiology\textsuperscript{17}. As a natural source of antioxidants, nuts can potentially be used as ingredients in functional food\textsuperscript{10}. Research indicates the multi-faceted health benefits of nuts, including inflammatory, prebiotic, anti-microbial, chemopreventive, and hypocholesterolaemic effects\textsuperscript{2}. Research carried out by Estruch\textsuperscript{18} has shown that including nuts in the diet may reduce the plasma level of pro-inflammatory cytokines (particularly IL-6, ICAM-1 and VCAM-1)\textsuperscript{18}. Consumption of nuts as part of a balanced diet has been associated with a reduced risk of cardiovascular disease, as well as metabolic syndrome and diabetes\textsuperscript{19-21}. In addition, nuts improve mental health, reduce stress and the risk of depression, and help to preserve cognitive functions\textsuperscript{22-24}. Long-term consumption of nuts reduces total cholesterol and triglyceride levels and is associated with a reduced risk of weight gain and obesity\textsuperscript{25, 26}. Owing to their high content of protein and fibre, nuts provide a longer-lasting feeling of satiety. Although they contain high levels of fat, these are mainly poorly absorbed unsaturated fats, which induce energy expenditure by accelerating thermogenesis\textsuperscript{2}. Moreover, oils derived from nuts, owing to their content of bioactive compounds, such as phenolics, tocopherols, sterols, or phospholipids, impart health benefits or desirable physiological effects\textsuperscript{7}. For this reason, there has been an increase in interest in and nut oils and in their use in the food, pharmaceutical and cosmetics industries\textsuperscript{22}.

### 2 NUT OILS

Nut oils are obtained from various species of plants whose fruits are nuts. Sometimes, they are botanically drupes whose stones are called nuts. Nut oils are a natural source of fatty acids, including unsaturated fatty acids that play an important role in the proper functioning of the human body\textsuperscript{17}. (Table 2).

Nut oils are characterized by low content of saturated fatty acids (SFAs) and high content of unsaturated fatty acids, among which monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) dominate. Nut oils are well known for their high content of oleic acid (C18:1), which is a monounsaturated fatty acid.

### Table 1

| Nut       | Ca (mg) | Mg (mg) | Na (mg) | K (mg) | PS (mg CA) | TPC (mg GAE) | TFC (mg CA) | Tocopherol content (mg CA) | Antioxidant activity |
|-----------|---------|---------|---------|--------|------------|--------------|-------------|---------------------------|---------------------|
| Macadamia | 85      | 130     | 5       | 368    | 11         | 116          | 497.8       | 137.9                    | 0.54                |
| Walnut    | 98      | 158     | 2       | 441    | 98         | 72           | 1580.5      | 744.8                    | 0.70                |
| Hazelnut  | 114     | 163     | 0       | 680    | 113        | 96           | 314.8       | 113.7                    | 15.03               |
| Brazil nut | 160   | 376     | 3       | 659    | 22         | 47-148\textsuperscript{10} | 169.2       | 107.8                    | 5.73                |
| Cashew    | 37      | 292     | 12      | 660    | 25         | 158          | 316.4       | 63.7                     | 0.90                |

PS-plant sterols; TPC-total phenolic content expressed as gallic acid equivalent (GAE); TFC-total flavonoid content expressed as catechin equivalent (CA); AAE- ascorbic acid equivalent. Source:\textsuperscript{3, 11, 12} \textsuperscript{11}Inhibition of oxidation of LDL+VLDL-EC-\textsubscript{10}, DPPH inhibition percentage\textsuperscript{14-16}.

### Table 2

| Nut       | Energy (kJ/100g) | Oil content (%) | Approximate fatty acid distributions (% of total fat) in nut oil C14:0 | C16:0 | C16:1 | C18:0 | C18:1 | C18:2 | C18:3 | C20:0 | C20:1 | C22:0 | C22:1 |
|-----------|------------------|-----------------|---------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Macadamia | 3004             | 69-78           | 1.28 9.65 26.74 2.13 148.43 3.40 0.18 1.67 2.00 0.49 0.16 |
| Walnut    | 2738             | 54-72           | 0.41 9.58 0.19 3.35 24.27 50.68 11.23 0.08 0.17 0.07 |
| Hazelnut  | 2629             | 60.4            | 0.13 5.82 0.29 2.74 79.30 10.39 0.46 0.16 0.21 0.12 0.34 |
| Brazil nut | 2743            | 67.4            | 0.06 13.50 0.33 11.77 29.09 42.80 0.20 0.54 0.21 0.12 0.34 |
| Cashew    | 2314             | 46.4            | 0.07 9.93 0.36 8.70 57.24 20.80 0.23 0.97 0.25 0.39 0.28 |

nd-not detected
Nut oils and their Dietetic and Cosmetic Significance: a Review

J. Oleo Sci. 68, (2) 111-120 (2019)

Fig. 2  Percentages of monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) of nut oils\textsuperscript{11, 29, 32, 33}.

Predominant fatty acids in most nuts (Fig. 2). Monounsaturated fatty acids of the omega-9 series (\(\omega-9\) or n-9), together with polyunsaturated fatty acids (PUFAs) of the omega-3 (\(\omega-3\) or n-3) and omega-6 (\(\omega-6\) or n-6) series, contribute about 91\% of the energy from fat\textsuperscript{30}.

Polyunsaturated fatty acids are not synthesized in the human body, so they must be supplied in the diet. Rich sources include vegetable oils, nuts, seeds and products made from vegetable oils. PUFAs are significantly accumulated in specific tissues based on selective need\textsuperscript{27, 31}. Polyunsaturated fatty acids can undergo enzymatic transformation consisting in the introduction of successive double bonds (involving \(\Delta_6, \Delta_5\) desaturases) and elongation of the carbon chain (mediated by elongase). Acids of the n-3 and n-6 series are metabolized in the human body by the same enzymes, indicating functional links between the metabolic pathways of both series. That is why the correct ratio of n-6 to n-3 acids in the human diet is so important\textsuperscript{27, 35}. N-3 and n-6 fatty acids are precursors of eicosanoids (prostaglandins (PG), prostacyclins (PGI), thromboxanes (TXA), leukotrienes (LT) and lipoxins (LX) – tissue hormones with a broad spectrum of activity (e.g. an anticoagulant effect, reduction in triacylglycerol concentration, and regulation of cardiovascular function, blood pressure or inflammatory processes)\textsuperscript{34, 36} (Fig. 3). Essential unsaturated fatty acids have an important role in health prophylaxis, especially prevention of cardiovascular, allergic or inflammatory diseases\textsuperscript{27, 34, 37}. Proper intake of PUFAs, including ALA (18:3 n-3), a metabolic precursor of EPA and DHA, provides the functional effects and health benefits of EPA and DHA\textsuperscript{38}.

Omega-3 acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), exert cardioprotective effects and reduce platelet aggregation and vasoconstriction\textsuperscript{19, 36}. Properties reducing the risk of cancer are ascribed to them as well\textsuperscript{31}.

Nut oils together with the mono- and polyunsaturated fatty acids contained in them are not only an important component of the daily diet, but are also used in the care of the skin and its appendages (Fig. 4). Of particular cosmetic significance are omega-3 and omega-6 fatty acids, including alpha-linolenic acid (ALA, 18:3, n-3), linoleic acid (LA, 18:2, n-6) and gamma-linolenic acid (GLA, 18:3, n-6), classified as essential fatty acids (EFA). The cosmetic effect of vegetable oils primarily involves softening, hydration and regeneration of the epidermis. Owing to unsaturated fatty acids, which alongside ceramides and cholesterol are a component of intercellular cement, the skin acts as an effective barrier to transepidermal water loss (TEWL), which ensures an appropriate level of epidermal hydration and protection against external factors\textsuperscript{31-41}.

Common edible tree nuts include walnut, hazelnut, almond, Brazil nut, cashew, macadamia, pecan, pine nut and pistachio\textsuperscript{1, 4}. The present study aims to draw attention to selected plant species that are sources of nut oils of importance in food, pharmaceuticals and cosmetics.

2.1 Macadamia nut oil

The macadamia (Macadamia integrifolia Maiden and Betche), of the Proteaceae family, is a tree found in Australia, South Africa, Brazil, Hawaii, Kenya and Costa Rica\textsuperscript{42}. Macadamia nuts are valued for their delicate taste, but also for their health benefits\textsuperscript{29, 41}. They are a rich source of nutrients and bioactive compounds. Depending on the variety, seed maturity, location, and growth conditions, macadamia nuts vary in their content of lipids (33-65\%), protein (8-20\%), crude fibre (6-30\%) and polyphenols (46-156 mg GAE/100 g)\textsuperscript{42, 44}. Other bioactive components of the oil are tocopherols, including \(\alpha\)-tocopherol (0.8-1.1 \(\mu\)g/g), \(\delta\)-tocopherol (3.5-4.8 \(\mu\)g/g) and \(\alpha\)-tocotrienol (17.2-48.4 \(\mu\)g/g); and sterols (1.117-1.549 \(\mu\)g/g), including sitosterol (901-
**Fig. 3** Biosynthetic pathways of unsaturated fatty acids in human body.\(^{27, 34, 35, 37}\) Abbreviations: MUFAs-monounsaturated fatty acids, PUFAs-polyunsaturated fatty acids, LA-linoleic acid, ALA-alpha-linolenic acid, GLA-gamma-linolenic acid, DGLA-dihomogamma-linolenic acid, AA-arachidonic acid, EPA-eicosapentaenoic acid, DPA-docosapentaenoic acid, DHA-docosahexaenoic acid, \(\Delta^6\)-delta-6 desaturases, \(\Delta^5\)-delta-5 desaturases, PG-prostaglandins, PGI-prostacyclins, TXA-tromboxanes, LT-leukotrienes.

| Unsaturated Fatty Acids | MUFAs | PUFAs |
|------------------------|-------|-------|
| \(\omega-9\)           |       |       |
| Oleic ac. C18:1n-9     |       | \(\Delta^6\) |
| Octadecadienoic ac. C18:2n-9 | \(\Delta^6\) | |
| Eicosadienoic ac. C20:2n-9 | \(\Delta^5\) | |
| Eicosatrienoic ac. C20:3n-9 | \(\Delta^5\) | |
| Docosatrienoic ac. C22:3n-9 | \(\Delta^6\) | |
| \(\omega-6\)           |       |       |
| LA C18:2n-6            | \(\Delta^6\) | |
| GLA C18:3n-6           | \(\Delta^6\) | |
| DGLA C20:3n-6          | \(\Delta^5\) | |
| Eicosatetraenoic ac. C20:4n-3 | \(\Delta^5\) | |
| \(\omega-3\)           |       |       |
| ALA C18:3n-3           |       |       |
| Octadecatetraenoic ac. C18:4n-3 |       |       |
| DPA C22:5n-3           |       |       |
| DHA C22:6n-3           |       |       |

**Fig. 4** Importance of nut oils for the health, food and cosmetics industry.

*J. Oleo Sci.* **68**, (2) 111-120 (2019)
1.354 μg/g), campesterol (61-112 μg/g), and δ-5-avenasterol (82-207 μg/g). The kernel, the edible part of macadamia, contains more than 60% oil. The results of research carried out by Kajser et al. indicate varying oil content (69-78%) in different varieties of macadamia nut. Macadamia oil, in addition to saturated fatty acids (13.2-17.8%), contains polyunsaturated fatty acids (2.8-4.7%) and large amounts of monounsaturated fatty acids (80%), predominantly oleic and palmitoleic acid. The low content of polyunsaturated fatty acids makes the oil more stable and less susceptible to oxidation. Due to the high content of monounsaturated fatty acids, consumption of macadamia nuts maintains health and reduces serum levels of low-density lipoproteins (LDL) and cholesterol. These properties may be associated with high content of other bioactive compounds such as tocopherols, phytosterols and squalene. Literature data confirm the benefits of including macadamia nuts in the diet to reduce the risk of coronary disease. Macadamia oil is used in the food, pharmaceutical and cosmetics industries. It can be used to make gluten-free products, as ingredients for baked goods and beverages, or in the production of protein powder supplements. Macadamia oil capsules are used as a dietary supplement with nutritional and health-maintenance properties. In the production of cosmetics, oils with high content of essential fatty acids, which are the main component of the skin barrier, have the most important role. Macadamia oil quickly penetrates the skin, has a softening effect, and influences the condition and proper functioning of the skin. For this reason it is an important component of skin repair products, moisturizers, products preventing over-drying and irritation, and anti-ageing products. It can also be used in products intended for bleaching dark spots, regenerating the skin after excessive exposure to UV radiation, and reducing wrinkles. Macadamia oil is used in cosmetics for skin and hair care and other personal care products.

2.2 Walnut oil

The walnut (Juglans regia L.), of the Juglandaceae family, is the most common tree nut in the world. The walnut is a highly popular nut because of its good flavour. Due to its nutritional and therapeutic benefits, walnut has also been recognized as a functional food. Walnut seeds contain 54% to 72% oil (depending on the variety and cultivation conditions), 25% protein (including glutelin, prolamin, globulin and albumin) rich in essential amino acids, and 12-16% carbohydrates. In addition, it contains 1.5-2.0% cellulose; 1.7-2.0% minerals, e.g. sodium (0.30-0.41 mg/100 g), potassium (277-296 mg/100 g), calcium (68.15-75 mg/100 g), magnesium (71-94 mg/100 g), phosphorus (289-365 mg/100 g), iron (2.41-3.36 mg/100 g), zinc (1.92-3.02 mg/100 g), copper (0.65-1.11 mg/100 g) and manganese (2.21-2.43 mg/100 g); and polyphenols (1.558-1.625 mg GAE/100 g), including pedunculagin, ellagic acid, tellimagrandin I, casuaricin, tellimagranin II, casuarinin and gallic acid. Walnut oil contains saturated fatty acids, i.e. palmitic acid C16:0 (3.9-11.4%) and stearic acid C18:0 (1.1-5.2%), and unsaturated fatty acids – linoleic C18:2 (n-6, 46.9-68.6%), α-linolenic C18:3, n-3, 6.9-17.6%), and oleic 18:1 (n-9, 10.0-25.1%). The bioactive compounds in the oil include tocopherols (186.54 to 436.2 mg/kg), such as γ-tocopherol (81.58%), δ-tocopherol (6.19-15.79%), α-tocopherol (1.03-2.93%) and β-tocopherol (0.1-0.6%), carotenoids, mainly β-carotene (0.22-0.62 mg/kg), and phytosterols (144-1.679 mg/kg), including β-sitosterol (69.42-89.26%), campesterol (0.33-5.24%) and δ-5-avenasterol (0.1-7.34%). Due to its nutritional value, walnut oil has not only dietetic importance but health-promoting value as well. The mild-flavoured, yellowish oil of the walnut is recommended as an addition to foods prepared at low temperatures, such as salads or cold desserts. The polyphenols naturally occurring in walnut oil are responsible for the stability of the oil during storage. Moreover, polyphenolic compounds, including flavonoids, have a significant role in the treatment of a number of diseases due to their antioxidant and radical-scavenging abilities. Consumption of walnuts and walnut oil, which is rich in natural antioxidants, may offer protection against certain cancers and also reduce the risk of cardiovascular disease and diabetes. Research shows that walnuts improve the lipid profile and have a cardioprotective effect. In addition to polyunsaturated fatty acids, walnuts contain a number of compounds with neuroprotective effects. Research on a rat model has shown that walnut consumption significantly contributes to maintenance of protein homeostasis in the brain, which was associated with improved cognitive and motor function. Vadivel et al. also emphasize the anti-inflammatory and antioxidant properties of walnuts. Walnut oil has been shown to be capable of scavenging DPPH radicals, which is linked to the presence of polyphenolic compounds and tocopherols. Walnut oil can also be used in the cosmetics and pharmaceutical industries. The results of a study by Tsamouri et al. indicate that walnut oil can be used for encapsulation and delivery of drugs and active ingredients in cosmetics. Other studies have shown that walnut oil can be a valuable base for pharmaceutical or cosmetic emulsions. As a component of an oil/water (O/W) emulsion, possibly through a humectant mechanism, it helps to improve skin hydration. For this reason, it can be a valuable component of natural skin care products, including those recommended especially for dry skin, as well as medicinal products, e.g. for the treatment of atopic dermatitis or psoriasis.

2.3 Hazelnut oil

The hazelnut (Corylus avellana L.) belongs to the Betulaceae family. Hazelnuts are often recommended as part of...
a healthy diet, but have also found application in cosmetics. They are a valuable source of vitamins (including vitamin E, with 22.4 mg/100 g), minerals (magnesium, potassium, calcium, manganese, iron, zinc, phosphorus and copper) and polyphenols (291-835 mg GAE/100 g)\(^2, 58\). They contain flavonoids (e.g., flavon-3-ols, catechin, epicatechin, myricetin-3-rhamnoside, and quercetin-3-rhamnoside)\(^{59, 60}\); phenolic acids (6.21-14.31 mg/100 g), including gallic, caffeic, ferulic, p-coumaric and sinapic acid; condensed tannin (941-3163 mg CE/100 g)\(^61, 62\); and stilbene (resveratrol)\(^9\). The seeds, containing from 54.6% to 63.2% oil, are an important source of saturated and unsaturated fatty acids, including oleic acid (39.5%), palmitoleic acid (37.0%), linoleic acid (6.9%), eicosaenoic acid (4.6%), docosenoic acid (3.4%), eicosanoic acid (2.3%), palmitic acid (2.3%), linolenic acid (1.1%), stearic acid (0.5%) and tetraecosanoic acid (0.3%)\(^63, 65\). Hazelnut oil has been found to contain 98.4% triacylglycerols and less than 0.2% phospholipids (phosphatidylcholine and phosphatidylinositol)\(^64\). It also contains tocopherols (462-508 mg/kg oil), predominantly α-tocopherol (382-472 mg/kg) and γ-tocopherol (61.2 mg/kg), and phytosterols (1.2-2.2 g/kg), including sitosterol (1416-1693 μg/g), campesterol (78-114 μg/g) and delta 5-avenasterol (110-170 μg/g)\(^63, 65\). Hazelnuts are used in the food, pharmaceutical and cosmetics industries. The nuts and the oil obtained from them are often recommended as part of a healthy diet due to their strong antioxidant properties, which is linked to their high content of polyphenols and tocopherols\(^2, 57\). Research results have shown that the inclusion of hazelnuts in the diet as a source of monounsaturated fatty acids is associated with favourable plasma lipid profiles and reduced risk of coronary heart disease (CHD)\(^66\). It has also been suggested that MUFA-rich nuts may moderately improve oxidative status\(^67\). Hazelnut oil is used in cosmetic products as well, such as face and body cleansing and care cosmetics (day and night cream), bath oil, shampoo, personal care products, shaving products, and tanning products. It is used as a moisturizing, occlusive and regenerating agent for skin conditioning. Studies on hazelnuts as a cosmetic ingredient have dealt with concentration of use; methods of extraction/manufacture and quality control (chemical analyses); and contaminants and methods of their extraction (especially pesticides and heavy metals). The scientific literature on the safety of oils from various hazelnut species shows that the available data on the use of hazelnut oil as an ingredient in cosmetics are insufficient. Experts point out the need for research on questions such as dermal irritation and sensitization, UV absorption (if absorption is significant, then a photosensitization study is needed), 28-day dermal toxicity, reproductive and developmental toxicity, and genotoxicity\(^56\).

### 2.4 Brazil nut oil

The Brazil nut tree (Bertholletia excelsa H.B.K.), of the Lecythidaceae family, grows throughout the Amazon Basin in South America. The Brazil nut, whose nutritional value is known all over the world, is one of the most important oleaginous seeds from the Amazon region\(^10, 12\). The total content of oil in the seeds is 60.8 g/100 g\(^2\). On an industrial scale, oil is extracted by hot or cold pressing\(^68\). The pale yellow oil, with a characteristic pleasant aroma and flavour, contains 15% saturated fatty acids (SFAs), including large quantities of palmitic acid (13.50%) and stearic acid (11.77%), 5% MUFAs, including large quantities oleic acid (41.40%), and 21% PUFAs, predominantly linoleic acid (33.20%)\(^11, 67, 68\). The oil also contains tocopherols, including α-tocopherol (82.9 μg/g oil) and γ-tocopherol (116.29 μg/g oil), as well as phytosterols, including β-sitosterol (1325.4 μg/g oil), campsterol (26.9 μg/g oil), stigmasterol (577.5 μg/g oil) and brassicasterol (1.50 mg/100 g)\(^13, 16\). Brazil nuts contain polyphenols (112-310 mg GAE/100 g), including flavonoids, as well as squalene\(^11, 67\). They also contain magnesium (325 mg/100 g), calcium (180 mg/100 g), selenium (11.48 g/g), copper (1.4 mg/100 g), iron (2.98 mg/100 g), potassium (675.0 mg/100 g), zinc (3.51 mg/100 g), phosphorus (610.0 mg/100 g), niacin, and vitamins E, B\(_1\) and B\(_2\)\(^69, 70\). Due to their content of bioactive components, including those with antioxidant properties, Brazil nuts help to reduce the incidence of cardiovascular disease and eliminate risk factors such as oxidative stress, inflammation, high cholesterol or diabetes\(^69\). Their rich micronutrient composition can help to prevent heart disease and cancer\(^13\). Selenium, as an essential micronutrient which is present in large quantities in Brazil nuts and has good bioavailability, supports physiological processes such as immune system modulation and thyroid hormone regulation. As an antioxidant, it protects the body against the harmful effects of free radicals and also prevents the accumulation of heavy metals\(^6, 60\). Due to their wealth of nutritional and functional compounds, Brazil nuts and the oil obtained from them can be used to produce pharmaceuticals, foods, and skin care products\(^70, 71\). The dietary and health-promoting properties of Brazil nut oil are linked to the presence of unsaturated fatty acids from the ω-3 (linoleic acid), ω-6 (linoleic acid) and ω-3 (linolenic acid) families\(^70\). Due to the high content of sitosterol in the oil, it can be used as a component of an anti-cholesterol diet. Owing to its favourable proportions of unsaturated fatty acids and the presence of sterols, tocopherols and tocotrienols, Brazil nut oil can be used in the health food industry and in some areas of medical science\(^70, 71\). It is also a natural material valued by the pharmaceutical and cosmetics industries\(^68\).

### 2.5 Cashew nut oil

Cashew (Anacardium occidentale L.) belongs to the family Anacardiaceae. It is generally grown in coastal
regions, especially Brazil, and has spread to some tropical regions. *A. occidentale* was used for centuries for medicinal purposes, to treat headache and topical diseases such as dermatitis, and for its anti-diarrheal properties. Today, cashew nuts, with their desirable flavour and significant content of proteins (20%), carbohydrates (23%), and fats (45%), are an important component of the human diet all over the world. Cashew nut consumption has been shown to have cardioprotective, anti-obesity, anticancer and antioxidant effects. Cashew nuts not only reduce the risk of cardiovascular disease, particularly stroke, but also lower the risk of metabolic syndrome. Attention has also been drawn to the nutritional and health benefits of cashew nut oil. As a chemically stable oil rich in phytosterols, cashew nut oil can be consumed directly (served fresh, e.g. in salads) or for frying. Its high content of alkyl-phenols and naphthoquinones, which have antibacterial and antioxidant properties, helps to preserve the oil against oxidation. Cashew nut oil is recommended as part of a healthy diet due to its antioxidant properties, which are linked to its content of polyphenols (346.52 mg/kg oil), including quercetin (3.18 mg/100 g), kaempferol (4.24 mg/100 g),isorhamnetin (2.62 mg/100 g), naringenin (1.64 mg/100 g), resveratrol (1.41 mg/100 g), gentisic acid (104.04 mg/kg), benzoic acid (31.77 mg/kg), abscisic acid (22.71 mg/kg), ferulic acid (21.91 mg/kg), p-hydroxybenzoic acid (21.94 mg/kg) and naphthylacetic acid (10.38 mg/kg), as well as tocopherols (171.48 mg/100 g oil), including β-tocopherol (31.77 mg/100 g), γ-tocopherol (33.72 mg/100 g) and δ-tocopherol (0.63 mg/100 g). The anacardic acids present in cashew nuts have been shown to exhibit greater antioxidant activity than well-known antioxidants such as 1-((+)-acetoxy pinoresinol, hydroxytyrosol, tyrosol, salicylic acid and caffieic acid. Scientific research demonstrates that tocopherols, as natural antioxidants present in vegetable fats, display stronger properties in combination with other antioxidants. Tocopherols are known to have numerous beneficial properties. They exhibit anti-inflammatory and anti proliferative properties, and also play a protective role against lipid peroxidation of membrane lipids and lipoproteins. The monounsaturated (oleic) and polyunsaturated (linoleic, linolenic) fatty acids in cashew nut oil reduce the level of low-density lipoprotein cholesterol and the risk of coronary heart disease. Phytosterols are used in the food industry (as anti-cholesterol additives in functional foods), pharmaceutical industry (in production of therapeutic steroids) and cosmetics industry (in creams and lipsticks). The presence of potentially bioactive compounds in cashew nuts may be interesting for many branches of industry, where they can be used as a natural source of antioxidants.

5 CONCLUSION

Nuts are complex plant foods, which, apart from vegetable protein, fibre, micronutrients, plant sterols and antioxidants, are a rich source of oil. Due to their favourable fatty acid profile, nut oils are an important element of the diet, contributing to health maintenance and playing an important role in the prevention of many diseases. Numerous scientific studies have also confirmed the beneficial effect of vegetable oils in maintaining proper skin structure and function. For this reason, they are increasingly used as cosmetics or potential ingredients in cosmetic products.

References

1. Pérez-Jiménez, J.; Neveu, V.; Vos, F.; Scalbert, A. Identification of the 100 richest dietary sources of polyphenols: an application of the Phenol-Explorer database. *Eur. J. Clin. Nutr.* 64, 112-120 (2010).
2. Chang, S.K.; Alasalvar, C.; Bolling, B.W.; Shahidi, F. Nuts and their co-products: The impact of processing (roasting) on phenolics, bioavailability, and health benefits-A comprehensive review. *J. Funct. Food* 6, 88-122 (2016).
3. Ros, E. Health benefits of nut consumption. *Nutrients* 2, 652-682 (2010).
4. Brufau, G.; Boatella, J.; Rafecas, M. Nuts: source of energy and macronutrients. *Brit. J. Nutr.* 96, 24-28 (2006).
5. Delgado-Zamarreño, M.M.; Fernández-Prieto, C.; Bustamante-Rangel, M. Determination of tocopherols and sitosterols in seeds and nuts by QuEChERS-liquid chromatography. *Food Chem.* 192, 825-839 (2016).
6. Cardoso, B.R.; Duarte, G.B.S.; Reis, B.Z.; Cozzolino, S.M.F. Brazilian nuts: Nutritional composition, health benefits and safety aspects. *Food Res. Int.* 100, 9-18 (2017).
7. Hidalgo, F.J.; Zamora, R. Peptides and proteins in edible oils: Stability, allergenicity, and new processing trends. *Trends Food Sci. Tech.* 17, 56-63 (2006).
8. Vadiel, V.; Kunyanga, C.N.; Biesalski, H.K. Health benefits of nut consumption with special reference to body weight control. *Nutrition* 28, 1089-1097 (2012).
9. Thompson, L.U.; Boucher, B.A.; Liu, Z.; Cotterchio, M.; Kreiger, N. Phytoestrogen content of foods consumed in Canada, including isoflavones, lignans, and coume stan. *Nutr. Cancer* 54, 184-201 (2006).
10. John, J.A.; Shahidi, F. Phenolic compounds and antioxidant activity of Brazil nut (*Bertholletia excelsa*). *J. Funct. Foods* 2, 196-209 (2010).
11. Yang, J.; Liu, R.H.; Halim, L. Antioxidant and antiproliferative activities of common edible nut seeds. *LWT-Food Sci. Technol.* 42, 1-8 (2009).
12. López-Uriarte, P.; Bulló, M.; Casas-Agustench, P.; Ba...
bio, N.; Salas-Salvadó, J. Nuts and oxidation: a systematic review. *Nutr. Rev.* 67, 497-508 (2009).

13) Vinson, J.A.; Cai Y., Nuts, especially walnuts, have both antioxidant quantity and efficacy and exhibit significant potential health benefits. *Food Funct.* 3, 134-140 (2012).

14) Slatnar, A.; Mikulic-Petkovsek, M.; Stampar, F.; Veberic, R.; Solar, A. Identification and quantification of phenolic compounds in kernels, oil and bagasse pellets of common Walnut (*Juglans regia L.*). *Food Res. Int.* 67, 255-263 (2015).

15) Locatelli, M.; Coisson, J.D.; Travaglia, F.; Bordiga, M.; Arlorio, M. Impact of roasting on identification of hazelnut (*Corylus avellana L.*) origin: a chemometric approach. *J. Agric. Food Chem.* 63, 7294-7303 (2015).

16) da Costa, P.A.; Balhus, C.A.; Teixeira-Filho, J.; Godoy, H.T. Phytosterols and tocopherols content of pulps and nuts of Brazilian fruits. *Food Res. Int.* 43, 1603-1606 (2010).

17) Liu, R.H. Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. *Am. J. Clin. Nutr.* 78, 517-520 (2003).

18) Estruch, R. Anti-inflammatory effects of the Mediterranean diet: the experience of the PREMIDEX study. *Proc. Nutr. Soc.* 69, 333-340 (2010).

19) Kris-Etherton, P.M.; Hu, F.B.; Ros, E.; Sabate, J. The role of tree nuts and peanuts in the prevention of coronary heart disease: multiple potential mechanisms. *J. Nutr.* 138, 1746-1751 (2008).

20) Fernández-Montero, A.; Bes-Rastrollo, M.; Beunza, J.J.; Barrio-Lopez, M.T.; de la Fuente-Arrillaga, C.; Moreno-Galarraga L. et al. Nut consumption and incidence of metabolic syndrome after 6-year follow-up: the SUN (Seguimiento Universidad de Navarra, University of Navarra Follow-up) cohort. *Public Health Nutr.* 16, 2064-2072 (2013).

21) Kendall, C.W.C.; Esfahani, A.; Josse, A.R.; Augustin, L.S.A.; Vidgen, E.; Jenkins, D.J.A. The glycemic effect of nut-enriched meals in healthy and diabetic subjects. *Nutr. Metab. Cardiovasc. Dis.* 21, 34-99 (2011).

22) Nemeth, M.; Millei, E.; Wagner, K.H.; Wallner, B. Effects of diets high in unsaturated fatty acids on socially induced stress responses in guinea pigs. *PLOS ONE* 9, 0116292 (2014).

23) Carey, A.N.; Poulse, S.M.; Shukitt-Hale, B. The beneficial effects of tree nuts on the aging brain. *Nutr. Aging* 1, 55-67 (2012).

24) Sanhueza, C.; Ryan, L.; Foxcroft, D.R. Diet and the risk of unipolar depression in adults: systemic review of cohort studies. *J. Hum. Nutr. Diet.* 26, 56-70 (2013).

25) Bes-Rastrollo, M.; Wedick, N.M.; Martinez-Gonzalez, M.A.; Li, T.Y.; Sampson, L.; Hu, F.B. Prospective study of nut consumption, long-term weight change and obesity risk in women. *Am. J. Clin. Nutr.* 89, 1913-1919 (2009).

26) Grosso, G.; Estruch, R. Nut consumption and age-related disease. *Maturitas* 84, 11-16 (2016).

27) Saini, R.K.; Keum, Y.S. Omega-3 and omega-6 polyunsaturated fatty acids: Dietary sources, metabolism, and significance-A review. *Life Sci.* 203, 255-267 (2018).

28) Kris-Etherton, P.M.; Yu-Poth, S.; Sabate, J.; Ratcliffe, H.E.; Zhao, G.; Etherton, T.D. Nuts and their bioactive constituents: effects on serum lipids and other factors that affect disease risk. *Am. J. Clin. Nutr.* 70, 504-511 (1999).

29) Kajser, A.; Dutta, P.; Savage, G. Oxidative stability and lipid composition of macadamia nuts grown in New Zealand. *Food Chem.* 71, 67-70 (2000).

30) Gharibzahedi, S.M.T.; Mousavi, S.M.; Hamed, M.; Khodaiyan, F. Determination and characterization of kernel biochemical composition and functional compounds of Persian walnut oil. *J. Food Sci. Technol.* 51, 34-42 (2014).

31) Miraliakbari, H.; Shahihi F. Lipid class compositions, tocopherols and sterols of tree nut oils extracted with different solvents. *J. Food Lipids* 15, 81-96 (2008).

32) Ryan, E.; Galvin, K.; O’Connor, T.P.; Maguire, A.R.; O’Brien, N.M. Fatty acid profile, tocopherol, squalene and phytosterol content of brazil, pecan, pine, pistachio and cashew nuts. *Int. J. Food Sci. Nutr.* 57, 219-228 (2006).

33) Arranz, S.; Cert, R.; Pérez-Jiménez, J.; Cert, A.; Saura-Calixto, F. Comparison between free radical scavenging capacity and oxidative stability of nut oils. *Food Chem.* 110, 985-990 (2008).

34) Innes, J.K.; Calder, P.C. Omega-6 fatty acids and inflammation. *Prostaglandins Leukot. Essent. Fatty Acids* 132, 41-48 (2018).

35) Messamore, E.; Almeida, D.M.; Jandacek, R.J.; McNamara, R.K. Polyunsaturated fatty acids and recurrent mood disorders: Phenomenology, mechanisms, and clinical application. *Prog. Lipid Res.* 66, 1-13 (2017).

36) Hanna, V.S.; Hafez, E.A.A. Synopsis of arachidonic acid metabolism: A review. *J. Adv. Res.* 11, 23-32 (2018).

37) Yates, C.M.; Calder, P.C.; Rainger, G.E. Pharmacology and therapeutics of omega-3 polyunsaturated fatty acids in chronic inflammatory disease. *Pharmacol. Ther.* 141, 272-282 (2014).

38) Baker, E.J.; Miles, E.A.; Burdge, G.C.; Yaqoob, P.; Calder, P.C. Metabolism and functional effects of plant-derived omega-3 fatty acids in humans. *Prog. Lipid Res.* 64, 30-56 (2016).

39) Michalak, M.; Glinka, R. Plant oils in cosmetology and dermatology. *Pol. J. Cosmetol.* 21, 2-9 (2018).

40) Feingold, K.R.; Elias, P.M. Role of lipids in the forma-
Nut Oils and their Dietetic and Cosmetic Significance: a Review

J. Oleo Sci. 68, (2) 111-120 (2019)

41. Correa, M.C.; Mao, G.; Saad, P.; Flach, C.R.; Mendelsohn, R.; Walters, R.M. Molecular interactions of plant oil components with stratum corneum lipids correlate with clinical measures of skin barrier function. *Exp. Dermatol.* 23, 39-44 (2014).

42. Trueman, S.J. The reproductive biology of macadamia. *Sci. Hortic.* 150, 354-359 (2013).

43. Wall, M.M.; Gentry, T.S. Carbohydrate composition and color development during drying and roasting of macadamia nuts (*Macadamia integrifolia*). *LWT-Food Sci. Technol.* 40, 587-593 (2007).

44. Navarro, S.L.B.; Rodrigues, C.E.C. Macadamia oil extraction methods and uses for the defatted meal by-product. *Trends Food Sci. Tech.* 54, 148-154 (2016).

45. Wall, M.M. Functional lipid characteristics, oxidative stability, and antioxidant activity of macadamia nut (*Macadamia integrifolia*) cultivars. *Food Chem.* 121, 1103-1108 (2010).

46. Somerset, S.M.; Graham, L.; Markwell, K. Isoenergetic replacement of dietary saturated with monounsaturated fat via macadamia nuts enhances endothelial function in overweight subjects. *e-SPEN J.* 8, 113-119 (2013).

47. Martínez, M.L.; Labuckas, D.O.; Lamarcque, A.L.; Mestri, D.M. Walnut (*Juglans regia* L.): Genetic resources, chemistry, by-products. *J. Sci. Food Agric.* 90, 1959-1967 (2010).

48. Fu, M.; Qu, Q.; Yang, X.; Zhang, X. Effect of intermittent oven drying on lipid oxidation, fatty acids composition and antioxidant activities of walnut. *LWT-Food Sci. Technol.* 65, 1126-1132 (2016).

49. Poggetti, L.; Ferfua, C.; Chiabà, C.; Testolin, R.; Baldini, M. Kernel oil content and oil composition in walnut (*Juglans regia* L.) accessions from north-eastern Italy. *J. Sci. Food Agric.* 98, 955-962 (2018).

50. Mao, X.; Hua, Y.; Chen, G. Amino acid composition, molecular weight distribution and gel electrophoresis of walnut (*Juglans regia* L.) proteins and protein fractions. *Int. J. Mol. Sci.* 15, 2003-2014 (2014).

51. Abdallah, I.B.; Tilli, N.; Martínez-Force, E.; Rubio, A.G.P.; Perez-Camino, M.C.; Albouchi, A.; Boukhchina, S. Content of carotenoids, tocopherols, sterols, triterpenic and aliphatic alcohols, and volatile compounds in six walnuts (*Juglans regia* L.) varieties. *Food Chem.* 173, 972-978 (2015).

52. Tsoukas, M.A.; Ko, B.J.; Witte, T.R.; Dincer, F.; Hardman, W.E.; Mantzoros, C.S. Dietary walnut suppression of colorectal cancer in mice: Mediation by miRNAPat terns and fatty acid incorporation. *J. Nutr. Biochem.* 26, 776-783 (2015).

53. Poulose, S.M.; Bielinski, D.F.; Shukitt-Hale, B. Walnut diet reduces accumulation of polyubiquitinated proteins and inflammation in the brain of aged rats. *J. Nutr. Biochem.* 25, 912-919 (2013).

54. Tsimouris, G.; Hatziantoniou, S.; Demetzos, C. Lipid analysis of Greek walnut oil (*Juglans regia* L.). *Z. Naturforsch. C* 57, 51-56 (2002).

55. Kowalska, M.; Mendrycka, M.; Zbikowska, A.; Kowalska, D. Assessment of a stable cosmetic preparation based on enzmtatic interesterified fat, proposed in the prevention of atopic dermatitis. *Acta Pol. Pharm.* 74, 465-476 (2017).

56. Madhavan, N. Final report on the safety assessment of *Corylus avellana* (Hazel) seed oil, *Corylus americana* (Hazel) seed oil, *Corylus avellana* (Hazel) seed extract, *Corylus americana* (Hazel) seed extract, *Corylus avellana* (Hazel) leaf extract, *Corylus americana* (Hazel) leaf extract, and *Corylus rostrata* (Hazel) leaf extract. *Int. J. Toxicol.* 20, 15-20 (2001).

57. Kornsteiner, M.; Wagner, K.H.; Elmadfa, I. Analytical, nutritional and clinical methods. Tocopherols and total phenolics in 10 different nut types. *Food Chem.* 98, 381-387 (2006).

58. Deon, V.; Bo, C.D.; Guaraldi, F.; Abello, F.; Belviso, S.; Porrini, M.; Riso, P.; Guardamagna, O. Effect of hazelnut on serum lipid profile and fatty acid composition of erythrocyte phospholipids in children and adolescents with primary hyperlipidemia: A randomized controlled trial. *Clin. Nutr.* 37, 1193-1201 (2018).

59. Gorji, N.; Moëini, R.; Memariani, Z. Almond, hazelnut and walnut, three nuts for neuroprotection in Alzheimer’s disease: A neuropharmacological review of their bioactive constituents. *Pharmacol. Res.* 129, 115-127 (2018).

60. Schnitzius, V.; Slatnar, A.; Veberic, R.; Stampar, F.; Solar, A. Roasting affects phenolic composition and antioxidative activity of hazelnuts (*Corylus avellana* L.). *J. Food. Sci.* 76, 14-19 (2011).

61. Pelvan, E.; Alasalvar, C.; Uzman, S. Effects of roasting on the antioxidative status and phenolic profiles of commercial Turkish hazelnut varieties (*Corylus avellana* L.). *J. Agric. Food Chem.* 60, 1218-1223 (2012).

62. Shahidi, F.; Alasalvar, C.; Liyana-Pathirana, C.M. Anti-oxidant phytochemicals in hazelnut kernel (*Corylus avellana* L.) and hazelnut byproduct. *J. Agric. Food. Chem.* 55, 1212-1220 (2007).

63. Savage, G.P.; McNeil, D.L.; Dutta, P.C. Lipid composition and oxidative stability of oils in hazelnuts (*Corylus avellana* L.) grown in New Zealand. *J. Am. Oil. Chem. Soc.* 74, 755-759 (1997).

64. Parcerisa, J.; Richardson, D.G.; Rafecas, M.; Codony, R.; Boatella, J. Fatty acid distribution in polar and nonpolar lipid classes of hazelnut oil (*Corylus avellana* L.). *J. Agric. Food Chem.* 45, 3887-3890 (1997).

65. Maguire, L.S.; O’Sullivan, M.; Galvin, K.; O’Connor, T.P.; O’Brien, N.M. Fatty acid profile, tocopherol, squalene
and phytosterol content of walnuts, peanuts, hazelnuts and the macadamia nut. Int. J. Food Sci. Nutr. 55, 171-178 (2004).

66) Mercanlilig, S.M.; Arslan, P.; Alasalvar, C.; Okut, E.; Akgul, E.; Pinar A. et al. Effects of hazelnut-enriched diet on plasma cholesterol and lipoprotein profiles in hypercholesterolemic adult men. Eur. J. Clin. Nutr. 61, 212-220 (2007).

67) Santos, O.V.; Corrêa, N.C.F.; Soares, F.A.S.M.; Gioielli, L.A.; Costa, C.E.F.; Lanne, S.C.S. Chemical evaluation and thermal behavior of Brazil nut oil obtained by different extraction processes. Food Res. Int. 47, 253-258 (2012).

68) Muniz, M.M.P.; dos Santos, M.N.F.; da Costa, C.E.; Morais, L.; Lamarão, M.L.; Ribeiro-Costa, R.M.; Silva, J. O.C. Physicochemical characterization, fatty acid composition, and thermal analysis of Bertholletia excelsa HBK oil. Pharmacogn. Mag. 11, 147-151 (2015).

69) Martens, I.B.G.; Cardoso, B.R.; Hare, D.J.; Niedzwiecki, M.M.; Lajolo, F.M.; Martens A. et al. Selenium status in preschool children receiving a Brazil nut-enriched diet. Nutrition 31, 1339-1343 (2015).

70) Santos, O.V.; Corrêa, N.C.F.; Carvalho Jr., R.N.; Costa, C.E.F.; França, L.F.F.; Lannes, S.C.S. Comparative parameters of the nutritional contribution and functional claims of Brazil nut kernels, oil and defatted cake. Food Res. Int. 51, 841-847 (2013).

71) Chunthieng, T.; Hafidi, A.; Pioch, D.; Brochier, J.; Montet, D. Detailed study of Brazil nut (Bertholletia excelsa) oil micro-compounds: Phospholipids, tocopherols and sterols. J. Braz. Chem. Soc. 19, 1374-1380 (2008).

72) Gómez-Caravaca, A.M.; Verardo, V.; Caboni, M.F. Chromatographic techniques for the determination of alkylphenols, tocopherols and other minor polar compounds in raw and roasted cold pressed cashew nut oils. J. Chromatogr. A. 1217, 7411-7417 (2010).

73) Uslu, N.; Ozcan, M.M. Effect of microwave heating on phenolic compounds and fatty acid composition of cashew (Anacardium occidentale) nut and oil. J. Saudi Society of Agricultural Sciences (2017) in press (https://doi.org/10.1016/j.jssas.2017.10.001).

74) Rico, R.; Bulló, M.; Salas-Salvadó, J. Nutritional composition of raw fresh cashew (Anacardium occidentale L.) kernels from different origin. Food Sci. Nutr. 4, 329-338 (2016).

75) de Carvalho, J.M.; de Figueiredo, R.W.; de Sousa, P.H.M.; de Luna, F.M.T.; Maia, G.A. Cashew nut oil: effect of kernel grade and a microwave preheating extraction step on chemical composition, oxidative stability and bioactivity. Int. J. Food Sci. Tech. 53, 930-937 (2018).

76) Trevisan, M.T.S.; Pfundstein, B.; Haubner, R.; Wurtele, G.; Spiegelhalder, B.; Bartsch, H.; Owen, R.W. Characterization of alkyl phenols in cashew (Anacardium occidentale) products and assay of their antioxidant capacity. Food Chem. Toxicol. 44, 188-197 (2006).

77) Judde, A.; Villeneuve, P.; Rossignol-Castera, A.; le Guilou, A. Antioxidant effect of soy lecithins on vegetable oil stability and their synergism with tocopherols. J. Am. Oil Chem. Soc. 80, 1209-1215 (2003).

78) Biesalski, H.K.; Dragsted, L.O.; Elmadfa, I.; Grossklaus, R.; Müller, M.; Schrenk D. et al. Bioactive compounds: safety and efficacy. Nutrition 25, 1206-1211 (2009).

79) Fernandes, P.; Cabral, J.M. Phytosterols: applications and recovery methods. Bioresour. Technol. 98, 2335-2350 (2007).

80) Trox, J.; Vadivel, V.; Vetter, W.; Stuetz, W.; Kammerer, D.R.; Carle, R. et al. Catechin and epicatechin in testa and their association with bioactive compounds in kernels of cashew nut (Anacardium occidentale L.). Food Chem. 128, 1094-1099 (2011).