



World Scientific News

An International Scientific Journal

WSN 135 (2019) 116-128

EISSN 2392-2192

Characterization of health-related properties of selected tree-nuts - a review

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ABSTRACT

As interest in the health effects of tree-nuts consumption has increased. Nuts are vary used in food industry, especially in confectionery industry, in milk products, chocolate products and ice cream. This nuts are also added to products dedicated for healthy breakfast like muesli, cereals, breads and salads. The consumption of nuts is frequently associated with reduction in risk factors for diabetes, cancer, cardiovascular diseases. Despite high fat and caloric content, several studies have reported beneficial effects after nut consumption, due to fatty acid profiles, sterols, proteins, fibers, vitamins, minerals, tocopherols, flavonoids and phenolic acid with potential antioxidant and anti-inflammatory properties. Daily intake up to 30-40 g per day of nuts are recommended. This review highlights the composition of eight nut varieties (walnuts, almonds, hazelnuts, cashews, pistachios, Brazilian nuts, pecan nuts, macadamia nuts) on the context of human health.

Keywords: nuts, tree nut, fatty acid composition, phenolic acid, flavonoids

1. INTRODUCTION

Nut consumption has increased in recent times following both the inclusion of this food group in guidelines for healthy eating and wide media coverage of recent evidence relating nut

intake to a wide range of health benefits. Tree nuts (hazelnuts, walnuts, pistachio, almond, cashew, Brazil nut, pecan and macadamia) are one of the most important crops in terms of commercial production and human consumption [1]. Nuts are also considered as a beneficial product to human health due to its high-antioxidant properties [2], high content of monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) and tocopherols [3]. Furthermore, nuts playing a significant role in prevention of cancer, cardiovascular diseases and diabetes. Studies also have shown anti-inflammatory properties and improved blood lipid profile [4, 5]. Another health-promoting nut ingredient is dietary fiber. A portion of 30 g of nuts can provide up to 12% of the daily recommended dietary fiber intake [6]. Several studies showed that, despite the high fat content, consumption of nuts does not result in the gain of weight [7], and consequently up to 30-40 g per day of nuts are recommended. Nuts could be also a source of plant sterols in the diet. According to four meta-analyses have shown significant reductions in LDL-C concentrations after consumption of foods enriched with plant sterol or stanol esters [8-11].

Many nuts are predominantly consumed roasted. The roasting process plays the main role in tree-nut processing. In industrial conditions, the roasting parameters vary between the temperature range of 100 to 180 °C and from 5 to 60 minutes [12]. This processing leads to an improvement in flavor, colour, appearance, crispiness and crunchiness. However, microstructural and lipid modifications might lead to an enhanced susceptibility to lipid oxidation of roasted nuts compared to raw nuts. The main purpose of roasting is to increase the palatability of the nuts. Also, most of the nuts are roasted to remove the pellicle. The seed coat after roasting leaves a bitter taste, which lowers its value [13]. However, in all nuts, most of the antioxidants are located in the pellicle or outer soft shell, and more than 50% of them are lost when the skin is removed [14, 15]. Walnuts are an exception, because they are almost always consumed as the raw product with skins. Studies have shown that almond [16], hazelnut and peanut [17] skins are very high in antioxidants. Therefore, the aim of this study was to summarize recent knowledge on the health-related properties of the tree nuts.

Characteristic of tree-nuts

Walnut (*Juglans regia* L.) (Fig. 1 A) belongs to the fruit tree species of the Juglandaceae family). One of the largest producers of this nuts is the United States, and world production is estimated at about 1 million tons per year. In Poland, the crop dates back several hundred years. Walnut in Poland is cultivated mainly amateur, and the number of orchards over 2 ha is small. Annually, domestic production is estimated at around 1000 t. Walnuts are a valuable element in the diet because of their high nutritional value. More than half of their composition is fat, which is why they are included in very calorie products (720 kcal in 100 g). Of all nuts, they have the largest unsaturated fatty acid content. They are recommended in the diet for the prevention of e.g. cancer, cardiovascular disease, Alzheimer's disease and osteoporosis. Consumption of walnuts in the amount of 30-40 g per day can improve the functioning of the human body [18, 19].

Pistachios (*Pistachia vera* L.) (Fig. 1 E) are popular, usually eaten as a stand-alone snack because of their palatability and tenderness. Pistachios are also appreciated by consumers due to their health benefits. They regulate cholesterol levels and have a positive effect on cardiovascular diseases [20]. They are also characterized by the content of antioxidants [21], which have a positive effect on the human body. The key processes to obtain the best performance and good quality are the proper harvesting and post-harvest handling of nuts. The

stages of handling the collected raw material are dehulling, washing, drying or roasting, packaging and storage for several months. However, the treatment steps can affect the nutritional value and taste of the nuts [22].

Pecan nuts (*Carya illinoensis*) (Fig. 1 G) belong to the Juglandaceae family. The tree on which they grow naturally occurs in North America and Mexico. Pecan fruit is a drupe, which consists of a nut enclosed in a shell that grows from a flower. Pecans among Brazil nuts, pistachios and cashews have the highest ratio of unsaturated to saturated fatty acids. The total unsaturated fatty acid content of pecan nut oil reaches up to 93% [23]. Linoleic acid is the most abundant polyunsaturated acid in pecans. The highest amount of monounsaturated fatty acid is oleic acid [24]. According to other studies, oleic acid (52.52-7.09%) and linoleic acid (17.69-37.52%) are the main monounsaturated and polyunsaturated fatty acids in pecans [25]. They are a source of thiamine, folic acid, niacin, riboflavin and vitamin B6 as well as minerals: calcium, iron, magnesium, phosphorus and zinc. They also contain phytosterols: beta-sitosterol, campesterol and stigmasterol [23]. Pecan nuts are eaten as an independent snack, but are mainly used in the kitchen to bake cakes, cookies and snacks.

Macadamia nuts (*Macadamia Integrifolia*) (Fig. 1 H) belongs to the botanical family *Proteaceae*. They are grown in tropical and subtropical areas. Macadamia nuts come from and are grown mainly in Australia, while commercial production takes place mainly in Hawaii. In addition, macadamia trees are also grown in some Latin American, African and Asian countries, and in the United States (Florida, California). Due to their fatty acid profile, and in particular their high concentration of oleic acid, their consumption is beneficial for reducing coronary heart disease. Frequent consumption of these nuts reduces the risk of diabetes [26]. Lowering cholesterol and protecting coronary vessels can be caused by a high content of unsaturated fatty acids and bioactive ingredients: tocopherols, phytosterols, and squalene. Compared to other popular species such as almonds or cashews, macadamia nut oil contains a higher concentration of oil and fat and a low protein content. The content of macro and micronutrients is as follows: protein 9%, carbohydrates 9%, dietary fiber 2%, calcium, potassium, sodium, phosphorus, selenium, iron, thiamine, niacin, riboflavin [27]. Compared to walnuts, pistachios, pecans, peanuts with the skin and almonds with the skin, hazelnuts contain the lowest levels of antioxidants (polyphenols and tocopherols). Oils obtained from macadamia nuts have a higher ratio of unsaturated to saturated fatty acids, which makes them more susceptible to oxidation of unsaturated fatty acids, affecting their stability and quality [28]. Macadamia nuts are most often consumed as stand-alone snacks without additions, in cakes, cookies and sweets.

Hazelnuts (Fig. 1 C), which belong to the Betulaceae family, are fruits of a hazel tree and they are grown worldwide. Around 80% of all European nuts are produced by Turkey. The global area of hazelnut planting is over 900 thousands ha, which more than $\frac{3}{4}$ is located in Turkey. Turkish hazelnut planting is focused on varieties characterized by small size of nuts. However, Upper Midwest part of America is an producing region of hazelnuts crosses between American variety (*Corylus Americana*) and European variety to get bigger nuts resistant to diseases (*Corylus avellana*) [29,30]. Polish varieties of hazelnuts have large sizes fruits. Climatic conditions in Poland characterized by lower average temperature per year what determines improve nutritional and biological value of polish hazelnuts [31]. Hazelnuts are vary used in food industry, especially in bakery products, milk products, chocolate products and ice creams. This nuts are added to products dedicated for healthy breakfasts and dishes like muesli, cereals, breads and salads. They are widely recommended due to their high acceptable sensory properties and high nutritional value.

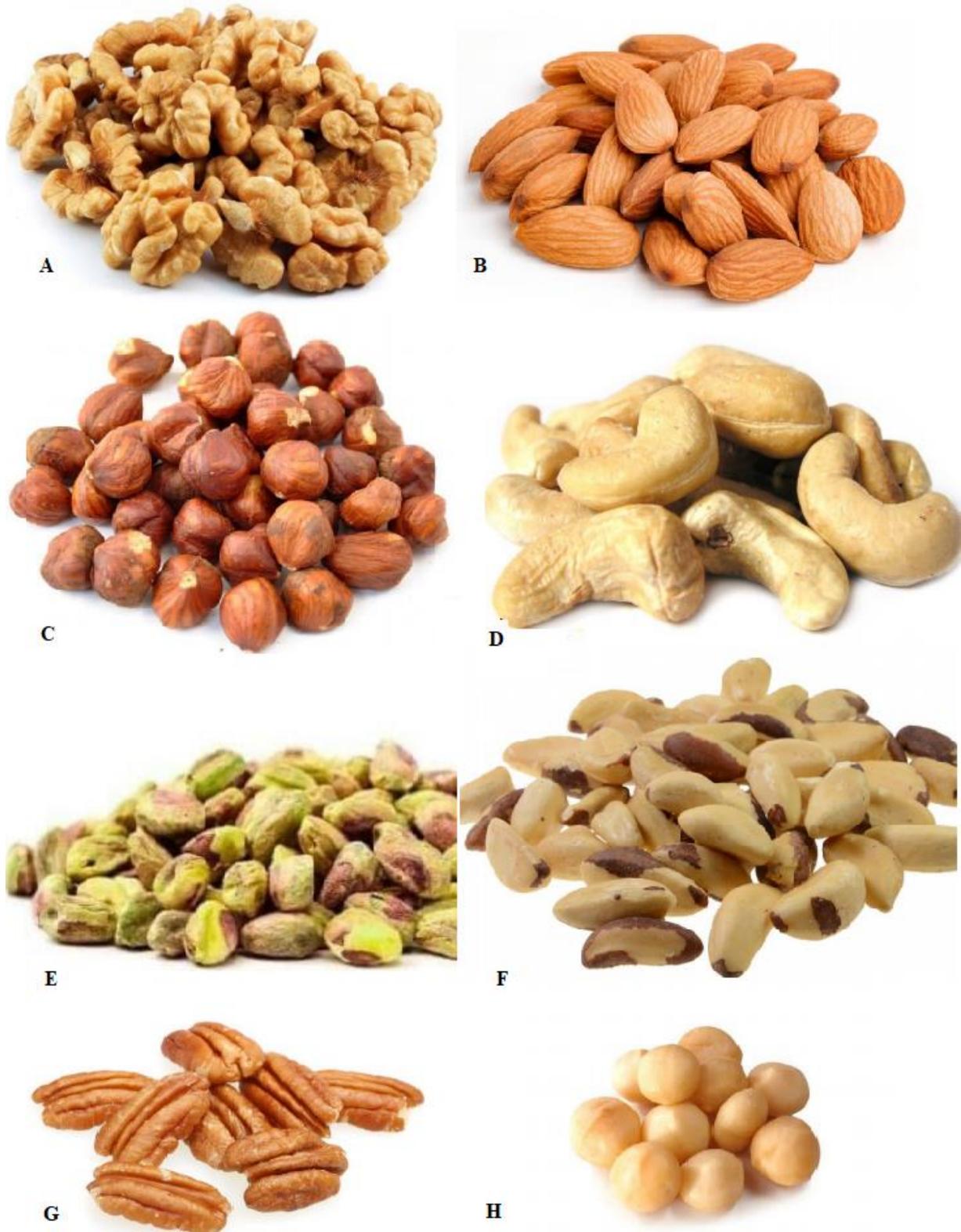


Figure 1. Graphics of selected tree-nuts.
A – walnuts, B – almonds, C – hazelnuts, D – cashews, E – pistachios,
F – Brazilian nut, G – pecan nut, H – macadamia nut.

Hazelnuts contain up to 70% of fat (what depends on specification of planting area's climate), mainly unsaturated fatty acids (up to 90%). Oleic acid is found in hazelnuts for the most part (75-84%) which is higher amount than pistachios, cashew nuts, chest nuts and almonds [32, 33]. Antioxidants are next nutritionally important compounds in hazelnuts which are there in high content. One of them is flavonoid which was found in the highest content (12-34 mg/100 g) reporting in systematic reviews among nuts group (pecans, pistachios and almonds). Furthermore, US Department of Agriculture (USDA) reported in hazelnuts appreciable content of total phenols (835 mg GDA/100 mg), what is in most part than almonds, brazil nuts, cashews, macadamias and pine nuts [34].

Almonds (*Prunus dulcis*) (Fig. 1 B) are produced worldwide also but in California's areas mainly. California dominates in almonds production covering about 80% world's production. This nuts are in the top of products exported to foreign countries. According to US Food Drug Administration (FDA) almonds are considered as a good source of vitamin E, manganese, copper, magnesium and especially of fiber (due to recommended ratio of insoluble and soluble at 4:1). FDA claims that almonds contain phytosterols (120 mg/100 g) and monounsaturated fatty acids (32 g/100 g) in major. Lipids ratio in almonds is found as favorable for prevention of cardiovascular disease, obesity and diabetes [35, 34]. Unfortunately, recent Americans researchers found that almonds planting has higher water footprint per nuts weight (depending on climate condition of planting area), what is not suitable to sustainable production [36].

Other variety of tree nuts are cashew nuts (*Anacardium occidentale* L.) (Fig. 1 D). They are cultivated in tropical climate country, like South and Central America, South-east Asia, Australia, India and Central Africa. Cashew nut kernel grown in "apple" cashew fruits which in Asian and Indian country is used to produce jams, oils, vinegar, jelly, pectin and beverages [37]. Cashew nuts shell is used also for produce pharmaceuticals and oil paints. For African countries production of raw and processed cashew nuts is strong developing area [38]. It is considered that cashews are one of the lowest fatty nuts in tree nuts group. They are widely consumed as a snack and as addition to chocolate products or pastry. Presently, cashews are found as strong allergenic products [39]. Kernels, as well as "apple" cashew nuts contain antioxidants, but it is not stand out among other tree nuts. However, due to combination of major components, fats and carbohydrates cashews are very sweet in taste [34, 40, 41].

Brazil nuts (*Bertholletia excelsa*) (Fig. 1 G) are included in Lecythidaceae family and in tree nuts group as well. They originally come from Amazonian area. Brazil nuts production do not need chemicals additives. This nuts are resistant to pests and weeds and in effect they are found like organic raw materials. There are not as much common nuts as walnuts, hazelnuts or almonds but they are spread worldwide as a food rich of selenium (Se) [42, 43]. Selenium takes part in thyroid hormones reactions and it give antioxidant and anti-inflammatory effects protect human health. It reduces oxidative stress which is important to anticancer protection and endothelial dysfunction in patients with hypertension and hypercholesterolemia [42, 44].

2. RESULTS

Although nuts may seem like a fairly homogeneous group for consumers, the results of the studies show that nutrients content can vary between types of nuts (Table 1). According to comparison [5] the most calorific are Macadamia nuts (717.9 kcal/100 g), with the highest fat content at the level of 75.7%. Cashew nuts caloric content is the lowest (546.4 kcal/100g), but

Pistachio contains the least fat at level of 44.3%. The fat content of nuts is very important because on the one hand it affects their energy but on the other hand it is associated with a positive effect on health by special fatty acid composition. It is most beneficial to limit saturated fatty acids (SFA) intake in favor of a higher unsaturated fatty acids intake. Nuts can be a very good source of these health-promoting substances, especially for consumers from our latitude. The highest levels of MUFA are found in macadamia (58.9 g/100 g), hazelnuts and pecan tree-nuts. The highest levels of PUFA are observed in walnuts (47.1 g/100g), pecan and brazil nuts. At the same time the smallest share of MUFA is in walnuts (8.9 g/100 g), pistachio and brazil nuts. The smallest share of PUFA are found in macadamia (1.4 g/100 g), cashew and hazelnut. It is therefore difficult to indicate nuts that would be exceptionally rich in both MUFA and PUFA, because each type of nut has a specific composition of fatty acids. Among fatty acids, alfa-linoleic acid (ALA) and linoleic acid (LA) can have a very positive effect on health. The LA content of nuts ranges from 1.4-38.2 g/100g. Walnuts contain both the highest levels of LA (38.2 g/100g) and ALA (8.9 g/100g) acids. ALA are the most abundant acids in tree nut. From the examined group of nuts, this acid was detected only in walnut, pecan (0.7 g/100 g) and pistachio (0.4 g/100 g) nuts. Nuts are not the best source of protein in the diet, but they contain it in quite significant amounts, what could be very important especially for a vegan or vegetarian diet. Almonds contain the most protein (21.1%) and macadamia contain the least protein (7.9%). Nuts are also recommended for daily consumption as a fiber source. The highest levels of fiber are found in hazelnuts (10.4%), pistachio (8.9%), almond (8.6%) and brazil nuts (8.6%). However, it should be remembered that the content of fiber will be greatly affected by the presence of nut peel. Tree- nuts can also be a source of healthy plant sterols. The highest levels of plant sterols are found in pistachio (213.9 mg/100 g), cashew (157.9 mg/100 g) and almond (120.0 mg/100 g). Therefore, including these nuts in the diet should be especially recommended for people with blood cholesterol problems.

Table 1. Energy and fat content and average fatty acid composition per 100 g of nuts.

	Almond	Brazil nut	Cashew	Hazelnut	Macadamia	Pecan	Pistachio	Walnut
Energy (kcal)	578.5	653.5	546.4	628.6	717.9	689.3	557.1	653.6
Fat (g)	50.7	66.4	46.4	60.7	75.7	72.5	44.3	65.4
SFA (g)	3.9	15.0	9.3	4.6	12.1	6.1	5.4	6.1
MUFA (g)	32.1	24.6	27.1	45.7	58.9	40.7	23.2	8.9
PUFA (g)	12.1	20.7	7.9	7.9	1.4	21.4	13.6	47.1
LA (g)	12.1	20.4	7.9	7.9	1.4	20.7	13.2	38.2
ALA (g)	0.0	0.0	0.0	0.0	0.0	0.7	0.4	8.9
Protein (g)	21.1	14.3	17.9	15.0	7.9	8.9	20.4	15.0
Fiber (g)	8.6	8.6	5.7	10.4	6.1	8.2	8.9	6.4
PS (mg)	120,0	NR*	157,9	95,7	116,1	101,8	213,9	72,1

SFA – saturated fatty acids, MUFA – monounsaturated fatty acid, PUFA – polyunsaturated fatty acid, LA – linoleic acid, ALA – alfa-linolenic acid, PS – plant sterols, *NR – not researched
Source: Ros et al. 2010

The tree-nuts can also be a source of many very essential minerals in daily diet. In Poland, milk is considered to be the main source of Ca, while nuts such as almond, brazil nuts, hazelnuts and pistachio could contain similar or higher amounts of calcium. The content of macronutrients such as calcium ranges from 37 mg/100 g (cashew) to 248 mg/100 g (almond). The tree-nuts also contain high amounts of potassium, magnesium and sodium. The potassium content of nuts ranges from 368 mg/100 g (macadamia nuts) to 1025 mg/100 g (pistachio nuts). The highest level of magnesium are found in brazil nuts (376 mg/100 g), cashew (292 mg/100 g) and almond (275 mg/100 g).

Table 2. Calcium, magnesium, sodium and potassium content of nuts in mg/100 g.

	Calcium	Magnesium	Sodium	Potassium
Almond	248	275	1	728
Brazil nut	160	376	3	659
Cashew	37	292	12	660
Hazelnut	114	163	0	680
Macadamia	85	130	5	368
Pecan	70	121	0	410
Pistachio	107	121	1	1025
Walnut	98	158	2	441

Source: Ros et al. 2010

Table 3. Content of α -, β -, γ -, δ -tocopherols (mg/100g oil) and total phenolic compounds (TPC) (mg GAE/100 g FW) in selected tree-nuts.

	Tocopherols			Total tocopherols	TPC
	α	β and γ	δ		
Almond	24.2	3.1	ND	27.3	240
Brazil nut	1.0	13.2	ND	14.2	112

Cashew	ND	5.1	0.3	5.4	137
Hazelnut	31.4	6.9	3.8	42.1	291
Macadamia	ND	8.3	2.1	10.4	46
Pecan	ND	14.8	0.2	15.0	1650
Pistachio	ND	29.3	0.5	29.8	867
Walnut	ND	21.9	3.8	25.7	1625

*ND – not detected

Source: Ciemniowska-Żytkiewicz 2014; USDA 2019

The tree-nuts contain a variety of other phenolic compounds which may influence on their bioactivity. The dietary sources and intake of polyphenols is of interest because of their positive effect on health and the reduction of risk of chronic disease. The Folin-Ciocalteu reaction has been widely used to estimate of the content of total phenols in plant foods including nuts. The phenolic content of nuts ranges from 46 – 1650 mg Gallic Acid Equivalents (GAE)/100 g, while pecan nut and walnut has the highest TPC values. These values are much higher than the TPC content in many vegetables that are groups considered to be a source of phenolics [47].

The classes of polyphenols identified in tree nuts include flavan-3-ols flavanones, flavonols, anthocyanins, isoflavones. The profiles and content of polyphenols are affected not only by the type of nut and its cultivar but also the harvest year orchard location processing steps. Roasting condition and storage condition and time. The pecans have the highest TPC among investigated tree nuts at 34 mg/100 g, consisting mostly of flavan-3-ols (15.99 mg/100g) and anthocyanins (18.02 mg/100 g). The lowest TPC was observed in cashew and walnut 1.99 mg/100 g and 2.74 mg/100 g, respectively. The flavan3-ols and anthocyanins were the most abundant flavonoids in tree nut while the flavonones and flavonols were detected only in almond and pistachio respectively. The pistachios have the highest isoflavone content of nuts at 3.63 mg/100 g, more than 100-fold greater than levels of other nuts.

Table 4. Content of flavonoids in selected tree nuts (mg/100 g fw).

	Flavan-3-ols	Flavanones	Flavonols	Anthocyanins	Isoflavone	Σ
Almond	4.47	0.38	7.93	2.46	0.01	15.25
Brazil nut	ND	ND	ND	ND	ND	ND
Cashew	1.98	ND	ND	ND	0.01	1.99
Hazelnut	5.25	ND	ND	6.71	0.03	11.99

Macadamia	ND	ND	ND	ND	ND	ND
Pecan	15.99	ND	ND	18.02	ND	34.01
Pistachio	6.85	ND	1.46	6.06	3.63	18.00
Walnut	ND	ND	ND	2.71	0.03	2.74

ND – not detected

Source: Bolling et al. 2016

Recent research often reported only a part of main phenolic acids. Therefore it is difficult to estimate the value of individual phenolic acids in selected types of tree nuts. The best researched are almonds, walnuts, hazelnuts and pistachio. No article found on content of main phenolic acids in macadamia nuts. Based on the available research. We can conclude that gallic acid and protocatechuic acid occur in the largest quantities.

Table 5. Content of main phenolic acids in selected tree nuts (mg/100 g fw)

	Gallic acid	Ellagic acid	Vanillic acid	Chlorogenic acid	Caffeic acid	Protocatechuic acid
Almond	0.34	1.20	0.94	1.61	0.22	2.5
Brazil nut	0.81	1.10	0.80	NR	NR	1.21
Cashew	0.11	NR	NR	NR	NR	NR
Hazelnut	0.86	NR	0.14	1.7	0.36	0.05
Macadamia	NS	NS	NS	NS	NS	NS
Pecan	2.33	1.03	NR	NR	NR	NR
Pistachio	3.2	NR	0.13	0.75	0.56	2.1
Walnut	0.18	4.41	0.14	0.11	0.18	0.34

NR- not reported, NS- No source of information

Sources: Chang et al. 2016. Lin et al. 2016. John and Shahidi 2010. Kalogeropoulos et al. 2013. Chandrasekara and Shahidi 2011. Pelvan et al. 2012. Yang et al. 2015. Rodriguez-Bencomo et al. 2015.

The pecan and pistachio nuts have high content of gallic acid 2.33 mg/100 g FW and 3.2 mg/100 g FW respectively. The almond and brazil nut have the highest content of protocatechuic acid 2.5 mg/100 g FW and 1.21 g/100 g FW. The ellagic acid content of walnuts is also particularly high (4.41 mg/100 g FW). However, it is necessary to conduct further research on this topic.

3. CONCLUSIONS

Tree nuts are an important element of a varied diet especially among consumers from our latitude. The consumption of nuts can have a very beneficial effect on health and the widespread belief that they have a negative effect on the gain of weight is not confirmed in research. However what scientific research confirms is tree nuts are a group very rich in healthy fatty acids (MUFA. PUFA. LA) fiber and plant sterols. They also could be source of some macronutrients like calcium, magnesium and potassium. Due to the antioxidant properties. The composition of total phenolic compounds flavonoids and phenolic acids is also very important. Each type of nut contains a characteristic composition of nutrients. So it is worth reaching for all of the types described. It should be noted that one of the very nutritious types of nuts are walnuts which is very beneficial because it is one of the most common nuts in our latitude. It is also worth remembering that the quantity and quality of nutrients supplied with the consumption of nuts depends on many factors related to their production as well as processing. It is necessary to conduct further research on the composition of tree-nuts and their health-related properties.

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