Review of nut phytochemicals, fat-soluble bioactives, antioxidant components and health effects

Cesarettin Alasalvar1* and Bradley W. Bolling2

1TÜBİTAK Marmara Research Centre, Food Institute, PO Box 21, 41470 Gebze, Kocaeli, Turkey
2Department of Food Science, University of Wisconsin-Madison, 1605 Linden Dr., Madison, WI 53706, USA

(Submitted 17 June 2014 – Final revision received 8 September 2014 – Accepted 19 September 2014)

Abstract
The levels of phytochemicals (total phenols, proanthocyanidins, gallic acid + gallogallnins, ellagic acid + ellagittannins, flavonoids, phenolic acids, stilbenes and phytates), fat-soluble bioactives (lipid, tocols, phytosterols, sphingolipids, carotenoids, chlorophylls, alkyl phenols, essential oils and among others(1,2,4–11) and phytochemicals (phenolic acids such as hydroxybenzoic acid and hydroxycinnamic acid; flavonoids such as flavonols, flavones, flavonols or catechins, flavanones, anthocyanidins and isoflavones; stilbenes; lignans; naphthoquinones; hydrolysable tannins (ellagittannins and gallogallnins); condensed tannins or proanthocyanidins; ellagic acid; phenolic aldehydes; alkaloids; coumestan; phytates; terpenes; phytoestrogens and among others(14,11–24). Moreover, nuts contain numerous types of antioxidants with different properties(17,25).

Nuts are recognised for their health-promoting aspects, particularly for their role in reducing CVD risk. This may be due to the favourable lipid profile and low-glycaemic nature of nuts.(20,27). Other evidence suggests that increased consumption of nuts increases antioxidant defences and reduces inflammation in populations with increased risk for CVD(26,29). Furthermore, emerging observational and/or clinical studies suggest that increased consumption of nuts may reduce risk for cancer(30), benefit cognitive function (31), and reduce the risks of asthma(32,33) and inflammatory bowel disease(34), and among others.

The present review reported the levels of major phytochemicals, fat-soluble bioactives as well as natural antioxidants present in commonly consumed nuts. Recent studies adding new evidence for the health benefits of nuts are also discussed. Research findings from over 112 references, many of which have been published within last 10 years, have been compiled and reported.

Key words: Nuts: Phytochemicals: Bioactives: Natural antioxidants: Antioxidant activity: Health effects

Nuts contain a number of bioactives and health-promoting components.(1,2). They are highly nutritious and contain macronutrients (fat, protein and carbohydrate)(3,4), micronutrients (minerals and vitamins)(4), fat-soluble bioactives (MUFA, PUFA, monacxglycerols, diacylglycercols, TAG, phosholipids, sterol esters, tocopherols, tocotrienols, phytosterols, phytostanols, squalene, terpenoids, sphingolipids, carotenoids, chlorophylls, alkyl phenols, essential oils and among others(1,2,4–11) and phytochemicals (phenolic acids such as hydroxybenzoic acid and hydroxycinnamic acid; flavonoids such as flavonols, flavones, flavonols or catechins, flavanones, anthocyanidins, anthocyanidins and isoflavones; stilbenes; lignans; naphthoquinones; hydrolysable tannins (ellagittannins and gallogallnins); condensed tannins or proanthocyanidins; ellagic acid; phenolic aldehydes; alkaloids; coumestan; phytates; terpenes; phytoestrogens and among others(14,11–24). Moreover, nuts contain numerous types of antioxidants with different properties(17,25).

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The present review reported the levels of major phytochemicals, fat-soluble bioactives as well as natural antioxidants present in commonly consumed nuts. Recent studies adding new evidence for the health benefits of nuts are also discussed.

Phytochemicals in nuts
Nuts are rich in phenolic phytochemicals and are identified among the richest sources of dietary polyphenols(35).

*Corresponding author: C. Alasalvar, email cesarettin.alasalvar@tubitak.gov.tr

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Table 1. Reported phytochemicals in nuts (mg/100 g)

<table>
<thead>
<tr>
<th>Nut</th>
<th>Total phenols*</th>
<th>Proanthocyanidins</th>
<th>Gallic acid + gallotannins</th>
<th>Ellagic acid + ellagitannins</th>
<th>Flavonoids†</th>
<th>Phenolic acids</th>
<th>Stilbenes</th>
<th>Phytates‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond</td>
<td>47–418</td>
<td>176*</td>
<td>14–41§</td>
<td>49–63§</td>
<td>11</td>
<td>0·2–0·7</td>
<td>0·008</td>
<td>350</td>
</tr>
<tr>
<td>Brazil nut</td>
<td>112–310</td>
<td>+‡</td>
<td>8·3***</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>190</td>
</tr>
<tr>
<td>Cashew</td>
<td>137–274</td>
<td>2*</td>
<td>22‡</td>
<td>ND</td>
<td>2</td>
<td>ND</td>
<td>ND</td>
<td>290</td>
</tr>
<tr>
<td>Chestnut</td>
<td>1580–3673</td>
<td>+†</td>
<td>276–907*</td>
<td>149–1052*‡‡</td>
<td>0·02</td>
<td>4–142**</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>291–835</td>
<td>491*</td>
<td>0·2–4·3†††</td>
<td>ND</td>
<td>12</td>
<td>2†</td>
<td>ND</td>
<td>230</td>
</tr>
<tr>
<td>Heartnut</td>
<td>148–248†††</td>
<td>ND</td>
<td>9–24†††</td>
<td>34–62†††</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>150</td>
</tr>
<tr>
<td>Macadamia</td>
<td>46–156</td>
<td>+†</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>4†</td>
<td>ND</td>
<td>150</td>
</tr>
<tr>
<td>Peanut</td>
<td>0–1–420</td>
<td>11††</td>
<td>ND</td>
<td>1</td>
<td>3–6†</td>
<td>0·005–0·08*</td>
<td>ND</td>
<td>170</td>
</tr>
<tr>
<td>Pecan</td>
<td>1284–2016</td>
<td>477*</td>
<td>22€</td>
<td>301‡‡</td>
<td>34</td>
<td>6–10***</td>
<td>ND</td>
<td>180</td>
</tr>
<tr>
<td>Pine nut</td>
<td>32–68</td>
<td>+†</td>
<td>ND</td>
<td>0·5</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>200</td>
</tr>
<tr>
<td>Pistachio</td>
<td>867–1657</td>
<td>226*</td>
<td>1–2†††</td>
<td>ND</td>
<td>16</td>
<td>1†</td>
<td>0·009–0·16*</td>
<td>290</td>
</tr>
<tr>
<td>Walnut</td>
<td>1558–1625</td>
<td>60*</td>
<td>0·1111</td>
<td>6–823*</td>
<td>3–65†</td>
<td>36*</td>
<td>ND</td>
<td>200</td>
</tr>
</tbody>
</table>

ND, not detected.

* Data are expressed as mg of gallic acid equivalents/100 g and obtained from Rothwell et al. (104), except heartnut.
† Data are obtained from USDA (105), except walnut that is obtained from Rothwell et al. (104) and USDA (105).
‡ Detected, but by qualitative method or not quantified on whole nut basis. Data are obtained from Venkatachalam & Sathe (3).
§ Data are obtained from Xie et al. (45).
‖ Data are obtained from Bolling et al. (111).
| Data are obtained from Xie & Bolling (49).
†† Data are obtained from Chandrasekara & Shahidi (47) and on a defatted kernel basis.
‡‡ Data are obtained from Abe et al. (92).
| Data are obtained from Ottes & Selek (106).
§§ Data are obtained from Pelvan et al. (107).
‖‖ Data are expressed as mg of gallic acid equivalents/100 g and obtained from Li et al. (108).
| Data are obtained from de la Rosa et al. (109).
††† Data are obtained from Mandalari et al. (110).
‡‡‡ Data are obtained from Gómez-Caravaca et al. (111).
A recent comprehensive review on tree nut phytochemicals has been published by Bolling et al.\textsuperscript{(11)} Therefore, a detailed compositional comparison was not intended for this review. It should be noted that quantitative values for phytochemicals in nuts vary widely in some instances. Proanthocyanidins and hydrolysable tannins are generally the most abundantly found polyphenols in some nuts (Table 1). Nuts also have a significant phytate content as well as flavonoid, phenolic acid and stilbene polyphenol classes. Fig. 1 shows the chemical structures of some phytochemicals present in nuts.

**Total phenols**

Data from the Folin–Ciocalteu assay, a non-specific method to characterise the content of phenols, indicate that nuts have a significant phenolic content. Chestnut, pecan and pistachio have greater than 1 g gallic acid equivalents/100 g, while most
nuts have >0.1 g gallic acid equivalents/100 g (Table 1). Thus, several nuts are among the top dietary sources of polyphenols. It should be noted that the Folin–Ciocalteu assay could be confounded with the differential contribution of individual flavonoids to total phenol values.

### Proanthocyanidins

Proanthocyanidins are the most abundantly found class of polyphenols in almond, hazelnut, pecan and pistachio (Table 1). Nut proanthocyanidins are predominantly B-type, although A-type proanthocyanidins have been found in almond, peanut and hazelnut. Nut proanthocyanidins are highly polymerised, with mean degrees of polymerisations ranging from 2.6 to 10.8.

### Hydrolysable tannins

The hydrolysable tannins consist of glucose-bound gallic acid (gallotannins) or hexahydroxydiphenic acid (ellagitannins), which release gallic acid and ellagic acid upon acid hydrolysis, respectively. Most studies have quantified gallic or ellagic acid following hydrolysis of a nut extract. Thus, tannin structures are not well characterised for most nuts. Further analysis of hydrolysable tannins characterised in the presence of glansregilins A and B and glansirins A–D in walnut. Most nuts likely have hydrolysable tannins, with almond, pecan and walnut having the highest contents. Gallic acid was also identified in extracts of hazelnut and was present at 22 mg/100 g of defatted cashew kernels. Brazil nut has 5.2 mg free and 8.2 mg bound gallic acid/100 g of defatted whole Brazil nut. By contrast, peanut does not appear to have a significant gallic acid or hydrolysable tannin content.

### Flavonoids

Pecan, walnut, hazelnut and pistachio are rich sources of flavonoids (Table 1). Almond contains catechins, as well as flavonols such as naringenin, quercetin and kaempferol, predominantly as glycosides or rutinosides. Flavonoids such as hazelnut, pistachio and pecan are mainly sources of catechins and gallo catechins, and pistachio has additional flavanone and flavone polyphenols.

### Phenolic acids

Walnut and Brazil nut have the highest phenolic acid content among nuts with 36 and 11 mg/100 g, respectively, although this polyphenol class has not been well characterised in most nuts (Table 1). Peanut has p-coumaric acid and protocatechuic acid, with caffeic acid only in Spanish peanut. When gallic acid (free or derived from hydrolysable tannins) is included with phenolic acids, chestnut, pecan and almond have a significant phenolic acid content ranging from 14 to 900 mg/100 g (Table 1).

### Stilbenes

The presence of stilbenes has been reported in almond, peanut and pistachio. These nuts have comparable levels of stilbenes, presented in the μg/100 g range. Almond contains resveratrol-3-O-glucoside, concentrated in the skin. The variability of resveratrol content among 109 US peanut cultivars over 2 years was 0.003–0.026 mg/100 g peanut.

### Free and bound phenolics

Nuts contain solvent-extractable phenolics as well as non-extractable and covalently bound phenolics. Bound phenolics are associated with dietary fibre, lignins or other cell wall components. Nuts are composed of 3–15% of dietary fibre, with almond and pistachio having the highest content. Bound phenolics may contribute 10–60% of the total antioxidant capacity of nut extracts. Notably, macadamia has the highest level of bound phenolics among nuts, but has proportionally lower extractable phenolics and flavonoids. Almond contains 1–2 mg of bound proanthocyanidins and approximately 8 mg of bound phenolic acids per 100 g. Few studies have characterised the nature and types of bound phenolics in nuts, and analysis is inherently complicated by the use of harsh acidic or alkaline conditions used in their extraction.

### Phytates

Phytates have been found in most nuts. Phytates are composed of various inositol phosphates and range from inositol phosphate-1 to inositol phosphate-6 in almond and hazelnut. Nuts have similar phytate contents ranging from 150 to 290 mg/100 g.

### Other classes

Juglone, a naphthoquinone, has been reported to be present in significant quantity in walnut, which had 7–19 mg/100 g among ten cultivars.

### Fat-soluble bioactives in nuts

There has been an increasing interest in discussing the functional characteristics of nut oils as they seem to be an interesting source of bioactive constituents. Fig. 2 shows chemical structures of some fat-soluble bioactives present in nuts. Table 2 summarises the fat-soluble bioactives in nuts (lipid, tocots, phytosterols, sphingolipids, carotenoids, chlorophylls and alkyl phenols).

### Lipid

The oil content of nuts ranges from 2.26% for European chestnut to 75.77% for macadamia. The benefits of including nuts in human diet are partly related to their fat components. MUFA is the predominant fat-soluble bioactive in most nut oils, except Brazil nut, European chestnut, heartnut, pine nut and walnut that are rich in PUFA.
The mean content of total toccols range from 6.15 mg/100 g for macadamia oil to 59.60 mg/100 g for chestnut oil (Table 2)\(^{(10)}\). Oils extracted from various nuts have been reported to show significant toccol (tocopherols and tocotrienols) differences and patterns\(^{1,4,5,9,53–61}\). Data for toccol levels and patterns in twelve nuts (almond, Brazil nut, cashew, chestnut, heartnut, hazelnut, macadamia, peanut, pecan, pine nut, pistachio and walnut) have been reported elsewhere\(^{(10)}\). Vitamin E, consisting of \(\alpha\)-, \(\beta\)-, \(\gamma\)- and \(\delta\)-tocopherols as well as tocotrienols, is a fat-soluble vitamin that generally functions as a potent antioxidant activity via chain-breaking reactions during peroxidation of unsaturated lipids\(^{(62)}\). It is considered to be a significant health-promoting component of nuts and affords health benefits to those who routinely consume nuts\(^{(63)}\). Compared with other nut oils, hazelnut oil has been reported to serve as an excellent source of vitamin E\(^{(53)}\), followed by pistachio, almond, pine nut\(^{(1)}\) and peanut\(^{(56)}\), respectively. Vitamin E content in nut oils range from 1.13 to 41.92 mg/100 g, being lowest in European chestnut and highest in hazelnut\(^{(10)}\).

**Phytosterols**

Phytosterols, which are lipophilic plant-synthesised steroids, are one of the important bioactive classes of constitutes.
Phytosterols are a collective term, and saturated sterols are known as stanols. Sterols and stanols are differentiated by an alkane bond at the C₁ position on the B ring. The total phytosterol content of nut oils expressed as mg/100 g is given in Table 2. Sweet chestnut oil contains the lowest total phytosterol content (283 mg/100 g) and almond (271 mg/100 g). By contrast, hazelnut (307 mg/100 g), peanut (284 mg/100 g), pecan (284 mg/100 g) is given in Table 2. Sweet chestnut oil contains the lowest total phytosterol content (283 mg/100 g) and almond (271 mg/100 g). By contrast, hazelnut (307 mg/100 g), peanut (284 mg/100 g), pecan (284 mg/100 g), pistachio and walnut have a comparatively low sphingolipid content.

**Table 2. Reported fat-soluble bioactives in nut oils (mg/100 g)**

<table>
<thead>
<tr>
<th>Nut</th>
<th>Lipid (%)*</th>
<th>Tocols†</th>
<th>Phytosterols‡</th>
<th>Sphingolipids§</th>
<th>Carotenoids</th>
<th>Chlorophylls</th>
<th>Alkyl phenols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond</td>
<td>49.93</td>
<td>28.60</td>
<td>271</td>
<td>240</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Brazil nut</td>
<td>66.43</td>
<td>20.15</td>
<td>208</td>
<td>290</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cashew</td>
<td>43.85</td>
<td>7.10</td>
<td>199</td>
<td>ND</td>
<td>0·09††</td>
<td>ND</td>
<td>146–242††</td>
</tr>
<tr>
<td>Chestnut</td>
<td>2·26</td>
<td>59·60</td>
<td>800</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>60·75</td>
<td>51·31</td>
<td>165</td>
<td>ND</td>
<td>20</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Heartnut</td>
<td>51·00</td>
<td>22·50</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Macadamia</td>
<td>76·77</td>
<td>6·15</td>
<td>128</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Peanut</td>
<td>49·24</td>
<td>29·72</td>
<td>284</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Pecan</td>
<td>71·97</td>
<td>49·11</td>
<td>283</td>
<td>320</td>
<td>0·014**</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Pine nut</td>
<td>68·37</td>
<td>45·80</td>
<td>164</td>
<td>280</td>
<td>ND</td>
<td>0·007††</td>
<td>ND</td>
</tr>
<tr>
<td>Pistachio</td>
<td>45·39</td>
<td>39·77</td>
<td>184</td>
<td>330</td>
<td>6·70‡‡</td>
<td>24·09§§</td>
<td>44§§</td>
</tr>
<tr>
<td>Walnut</td>
<td>65·21</td>
<td>43·72</td>
<td>307</td>
<td>290</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Data are obtained from Alasalvar & Pelvan(10), except sweet chestnut that is obtained from Zlatanov et al.(112).**

**Data are obtained from Trevisan et al.(80). The total amount of alkyl phenols in cashew oil was calculated based on oil content of cashew (43·85 g/100 g).**

**Data are obtained from Miralakbari & Shahidi(73). The oils of nuts were extracted using chloroform/methanol.**

**Data are obtained from Miralakbari & Shahidi(73). Chlorophyll content in pistachio oil was calculated based on oil content of pistachio (45·39 g/100 g).**

**Data are mean value of lutein (27th week after flowering date) and obtained from Bouali et al.(78).**

**Data are mean value of lutein that is obtained from Bellomo & Fallico(76). Carotenoid content in pistachio oil was calculated based on oil content of pistachio (45·39 g/100 g).**

**Data are mean value of chlorophylls b and a from three ripe pistachio samples and obtained from Bellomo & Fallico(76). Chlorophyll content in pistachio oil was calculated based on oil content of pistachio (45·39 g/100 g).**

**Data are obtained from Salita et al.(81).**

**Data are obtained from Zlatanov et al.(112).**

**Data are mean value of chlorophylls b, a and c from three ripe pistachio samples and obtained from Trevisan et al.(80). The total amount of alkyl phenols in cashew oil was calculated based on oil content of cashew (43·85 g/100 g).**

**Data are mean value of lutein and obtained from Cheikh-Rouhou et al.(11).**

**Data are mean value of lutein from three ripe pistachio samples and obtained from Miralakbari & Shahidi(1,73,74), utilising a non-specific method of quantification. Thus, more effort is needed to gain reliable data on the sphingolipid content in nuts. Compared with other foods such as milk, egg, soyabeans, meat (chicken, beef and pork) and cereal (wheat), nuts have a comparatively low sphingolipid content.**

**Carotenoids**

In contrast to other plant foods, certain nuts contain very low amounts of carotenoids such as α- and β-carotene, β-cryptoxanthin, lutein, lycopene and zeaxanthin(11,75–77). Pistachio oil presents only traces of β-carotene and lutein (<5/100 g oil)(75). Among twelve nuts (Table 2), only cashew oil (0·09 mg/100 g), pecan oil (0·014 mg/100 g) and pistachio oil (6·70 mg/100 g) have been reported to contain carotenoids(76,77,78). Trox et al.(77) have reported that raw cashew contains traces of β-carotene, lutein and zeaxanthin. Bolling et al.(11) have mentioned that as most nuts are not significant dietary sources of carotenoids, an effort to improve carotenoid data may not be worthwhile.

**Chlorophylls**

The chlorophyll pigments are important quality parameters as they correlate with colour, which is a basic attribute for evaluating oil quality. Among commonly consumed nuts, only pine nut oil (0·007 mg/100 g) and pistachio oil (24·09 mg/100 g) have been reported to contain the lipid subclasses of chlorophyll(76,79). In ripe pistachio samples, chlorophyll a is approximately 3-fold higher than chlorophyll
Natural antioxidants in nuts

Natural antioxidants present in nuts are in the form of nutrient and non-nutrient (phytochemicals) antioxidants. Every food plant including nuts contains numerous types of natural antioxidants with different properties. In addition to well-known nutrient antioxidants (e.g. vitamins A, C and E and the mineral Se), there are numerous non-nutrient antioxidants (e.g. carotenoids such as β-carotene and lycopene and phenolics) in food plants.

Nuts are good sources of nutrient antioxidants (such as vitamin E and Se). Among antioxidant vitamins (A, C and E), vitamin E is the most abundantly found vitamin in most nuts. At suggested consumption level (1.5 oz or approximately 42.5 g/d), almond and hazelnut provide up to 74.8 and 72.7% vitamin E, respectively, of the daily 15 mg recommended for adult males and females. The other nuts contain much lower amount of vitamin E compared with almond and hazelnut. In general, nuts are not good sources of vitamins A and C. With respect to Se, Brazil nut itself serves as an excellent source of this mineral compound. Only one kernel of Brazil nut (approximately 5 g) supplies 174% of Se for RDA.

With regard to non-nutrient antioxidants, several thousands of phytochemicals, some of which possess strong antioxidant activities (e.g. catechin, quercetin, tannins, ellagic acid, chlorogenic acid and cyanidin), have been reported. Several studies have also reported that phenolic compounds possess much stronger antioxidant activities than nutrient antioxidants.

Recently, Vinson & Cai measured the levels of free and total polyphenols (μmol catechin equivalents/g) in both raw and roasted nuts (almond, Brazil nut, cashew, macadamia, peanut, pecan, pistachio and walnut). Walnut had the highest antioxidant activity in all assays among nuts, followed by pecan, almond, macadamia, pistachio, cashew and Brazil nut. Roasting causes a decline in efficacy. The total antioxidant activity of nuts has been assessed by different researchers using different assays (such as ferric-reducing ability of plasma, total oxyradical scavenging capacity, 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity and 2,2-azino-bis (3-ethylbenz-thiazoline-6-sulfonic acid) radical scavenging activity), and nut possession the highest antioxidant activity in all assays among nuts.

Health benefits of nuts

Traditionally, nuts have been used for improving immunity, digestion, wound healing and circulation, as well as analgesics. Today, nut consumption is recognised for its potential to reduce CVD risk. In 2003 and 2004, the US Food and Drug Administration granted a qualified health claim that consumption of 1.5 oz (approximately 42.5 g/d) of most nuts, or specifically, walnut, may reduce the risk of heart disease as part of a diet low in saturated fat and cholesterol. In 2011, European Food Safety Authority (EFSA) allowed an Article 13 claim that the consumption of 30 g of walnuts in the context of a balanced diet leads to improvement of endothelium-dependent vasodilation. Claims can also be made for LDL-cholesterol reduction based on the MUFA/PUFA and linoleic/α-linoleic content of nuts.

Recent observational studies further support the association of increased nut consumption and reduced mortality. Data from the Nurses’ Health Study and the Health Professionals Follow-up Study, two prospective cohort studies of 118,962 adults with 24 and 30 years of follow-up, respectively, were used to examine the association between nut consumption and mortality. Increasing frequency of nut consumption was associated with lower hazard ratios for death (P<0.001) with 0.80 (95% CI 0.73, 0.86) for individuals consuming nuts seven or more times per week. Rates of death from cancer, CVD, heart disease and respiratory disease were inversely related to frequency of nut consumption. Observational data from the Australian Blue Mountains Eye Study also supported this finding. Higher frequency of nut consumption was associated with age- and sex-adjusted
rates of inflammatory disease activity ($P=0.02$), but this trend is insignificant upon multivariable adjustment ($P=0.02$). Intervention studies have also provided new data suggesting health benefits of nut consumption. The Prevención con Dieta Mediterránea intervention study evaluated the effect of consuming nuts or olive oil with participants adhering to a Mediterranean diet, relative to a low-fat control diet ($n=7447$ adults) ($P=0.02$). Participants in the nuts group consumed $30\text{g}$ of mixed walnut, hazelnut and almond per day. After a median follow-up of 4-8 years, both the Mediterranean diet with olive oil and nuts reduced the rates of cardiovascular events. The hazard ratio was $0.72$ (95% CI 0.54, 0.96) for the nut-supplemented group compared with the control diet group ($P=0.02$). The nut-supplemented group also had reduced risk of all-cause mortality. Those who consumed nuts more than three servings per week had the lowest rates of total mortality risk (HR 0.36, 95% CI 0.22, 0.66) ($P=0.02$). Furthermore, cognitive improvement occurred in a subset of Prevención con Dieta Mediterránea participants at high vascular risk ($n=522$) ($P=0.02$). Assessments of cognitive function by the mini-mental state examination and clock drawing test were higher after 6.5 years of the intervention in both nuts and olive-oil supplemented groups ($P=0.02$).

Other recent studies suggest that components in nuts beyond lipids contribute to mechanisms of cardioprotection. For example, apoE4/−/− mice fed a high-fat diet reduced athero-sclerotic plaque development by 55%, whereas walnut oil supplemented mice did not ($P=0.02$). Also, acute consumption of walnut skins ($5.6\text{g}$) for 3 days decreased the postprandial reactive hyperaemia index compared with baseline, in a crossover trial of $n=15$ healthy overweight and obese moderate hypercholesterolaemic adults ($P=0.02$).

Further evidence supports the emerging role of nuts in reducing risk for insulin resistance and type 2 diabetes mellitus. Almond consumption ($56\text{g/d}$ for 4 weeks) by Chinese adults with type 2 diabetes mellitus with mild hyperlipidaemia decreased C-reactive protein, IL-6 and TNF-α levels and increased resistance to Cu-induced LDL-oxidation relative to the control diet group ($P=0.02$). Inclusion of $42.5\text{g}$ of peanut butter in a carbohydrate-rich breakfast meal in a crossover study of $n=15$ women with high type 2 diabetes mellitus risk reduced postprandial glucose and enhanced gut satiety hormone secretion ($P=0.02$). Nut polyphenols could also limit glycaemia by inhibiting carbohydrate digestion. Almond and chestnut tannins were identified as potent α-amylase inhibitors and were confirmed to reduce blood glucose in rats fed maize (corn) starch ($P=0.02$).

Conclusions

Nuts, which contain phytochemicals, fat-soluble bioactives, minor components as well as nutrient and non-nutrient antioxidants beyond their basic nutritional functions, offer an excellent choice for heart-healthy snack food and food additive. Nuts should be consumed with their skin (pellicles), whenever possible, because of their high phytochemical content as well as antioxidant activity. The present report provides a detailed and up to date summary and scientific review of the available data on nut antioxidant components and health.

Acknowledgements

The authors’ contributions are as follows: C. A. contributed introduction, fat-soluble bioactives in nuts, natural antioxidants in nuts and conclusions; B. W. B. contributed introduction, phytochemicals in nuts, health benefits of nuts and conclusions. All authors declare that there are no conflicts of interest.

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Nut phytochemicals and health effects
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