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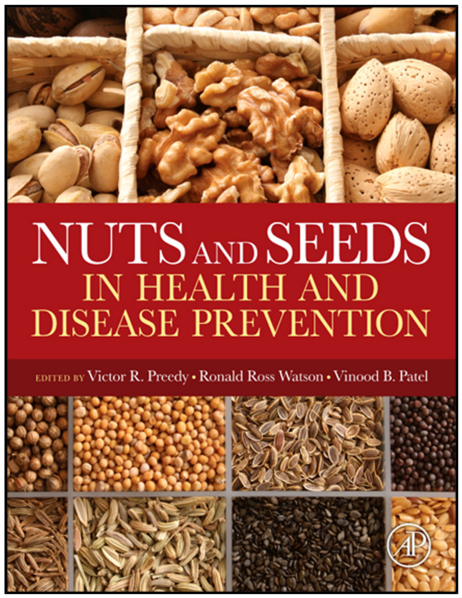

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CHAPTER 73

Hazelnut (*Corylus avellana* L.) Cultivars and Antimicrobial Activity

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CHAPTER OUTLINE

LIST OF ABBREVIATIONS

FAO, Food and Agriculture Organization of the United Nations
HDL, high density lipoprotein
LDL, low density lipoprotein
MIC, minimal inhibitory concentration
MUFA, monounsaturated fatty acid
PUFA, polyunsaturated fatty acid
SFA, saturated fatty acid
WHO, World Health Organization

INTRODUCTION

The hazelnut is one of the most cultivated and consumed nuts in the world, not only as a fruit but also incorporated as an ingredient into a diversity of manufactured food products.

Turkey is the world's largest hazelnut producer, contributing to approximately 65% of the total world global production (around 815,361 MT in 2007) (FAO, 2009), followed by Italy (16%), the United States (4.0%), and Azerbaijan (3.4%). Other countries, such as Georgia, Iran, and Spain, among others, contribute only 10% of the total production (FAO, 2009).

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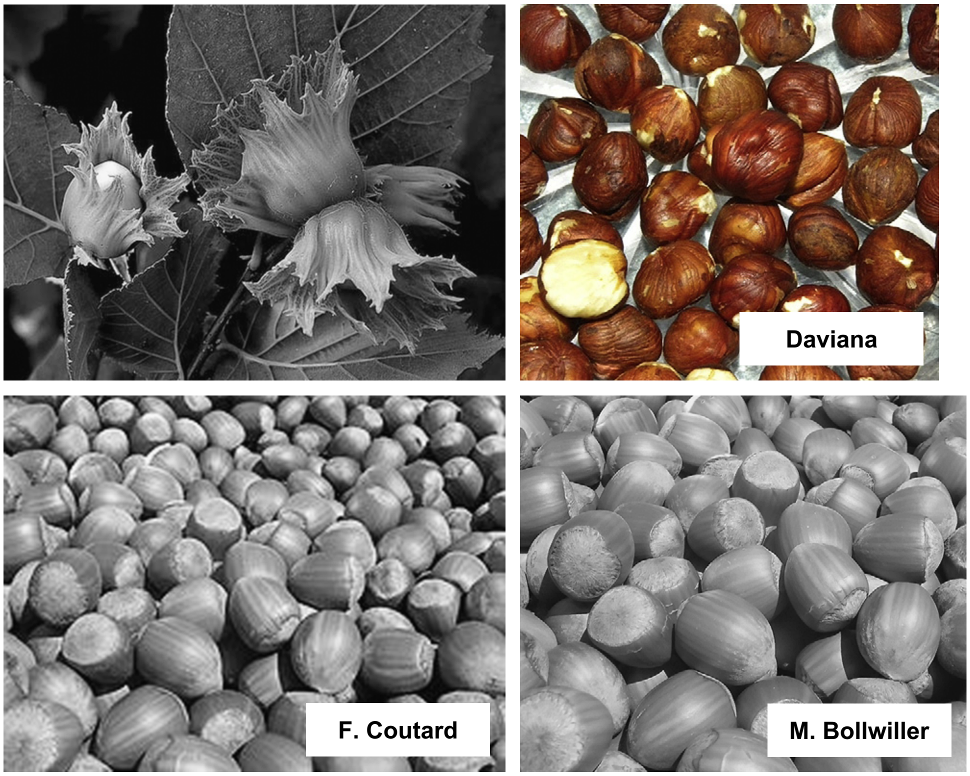

FIGURE 73.1
Green fruit with leaf cover and different varieties of hazelnuts. The photographs show the green fruit with leaf cover, and three varieties of hazelnuts, namely Daviana, Fertile de Coutard, and Merveille de Bollwiller.

BOTANICAL DESCRIPTION

Hazelnut (*Corylus avellana* L.) belongs to the *Betulaceae* family. The hazel is a tree or shrub that may grow to 6 m high, exhibiting deciduous leaves. These are rounded, 6–12 cm in length and width, softly hairy on both surfaces, and with a double-serrate margin. Hazel is mainly distributed on the coasts of the Black Sea region of Turkey, Southern Europe (Italy, Spain, Portugal, France, and Greece), and in some areas of the USA (Oregon and Washington). It can also be cultivated in other countries, such as New Zealand, China, Azerbaijan, Chile, Iran, and Georgia, among others. Green, ready-to-harvest hazelnut fruit are shown in Figure 73.1.

Several hazelnut varieties exist worldwide. The most common European varieties may be classified according their main use (Table 73.1). In Turkey, the main world producer, the most frequent are Acı, Cavcava, Çakıldak, Foşa, İncekara, Kalınkara, Kan, Kara, Karafındık, Kargalak, Kuş, Mincane, Palaz, Sivri, Tombul, Uzunmusa, Yassıbadem, Yuvarlak Badem, Yassi Badem, and Imperial de Trebizonde (Açkurt *et al.*, 1999; Özdemir *et al.*, 2001; Özdemir & Akinci, 2004; Köksal *et al.*, 2006). Daviana, Fertile de Coutard, and M. Bollwiller are hazelnut cultivars widely distributed.

HISTORICAL AND PRESENT-DAY CULTIVATION AND USAGE

Hazelnuts were and are still typically consumed as the whole nut (raw or roasted), or used as an ingredient in a variety of foods, especially in bakery products, snacks, chocolates, cereals, dairy products, salads, entrees, sauces, ice cream, and other dessert formulations. After cracking the hazelnut's hard shell, the hazelnut kernel may be consumed raw (with its skin)

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TABLE 73.1 Classification of Main Hazelnut Varieties According to their Final Use

Table	Industry	Dual Use
Butler	Camponica	Da veiga
Cosford	Casina	I. Eugénie
Daviana	Comum	Ribet
Ennis	Couplat	San Giovani
Fertile de Coutard	Dawton	Sta. M. di Gesu
Grada de Viseu	Gironela	Segorbe
Griffol	Morell	Tonda di Giffoni
Grosse de Espanha	Mortarella	
Gunslebert	Negret	
Lansing	Pauetet	
L. d'Espagne	R. de Piémont	
M. Bollwiller	Tonda G. Romana	
Mollari		
Provence		

or roasted (without its skin). Hazelnut oil is also becoming increasingly popular in Turkey and elsewhere, being widely utilized for cooking, deep frying, salad dressings, and flavoring ingredients, among others uses (Alasalvar *et al.*, 2006a).

Several by-products, such as the leaves, the hazelnut green leafy cover, the hazelnut hard shell, and hazelnut skin, are obtained through the harvesting, shelling/hulling, cracking, and roasting processes, respectively. These by-products have a lower commercial value than hazelnut kernels. However, among these by-products, the hazelnut's hard shell is currently used for burning as a heat source, for mulching, and as a raw material for the production for furfural in the dye industry. Moreover, the hazelnut green leafy covers and tree leaves are sometimes used as organic fertilizers for hazelnut trees and other crops upon composting. Hazel leaves are also widely used in folk medicine, in the preparation of infusions for the treatment of hemorrhoids, varicose veins, phlebitis, and edema of the lower limbs, as consequence of its astringency, vasoprotective, and anti-edema properties (Valnet, 1992).

APPLICATIONS TO HEALTH PROMOTION AND DISEASE PREVENTION

Hazelnuts are highly nutritious, due to their high fat content. Table 73.2 shows their composition in terms of protein (10–20%) and oil (> 50%), which are the major constituents. The most important fatty acids in hazelnuts are the monounsaturated and polyunsaturated fatty acids (MUFAs and PUFAs, respectively) (Parcerisa *et al.*, 1998; Köksal *et al.*, 2006; Venkatachalam & Sathe, 2006; Oliveira *et al.*, 2008). The presence of MUFAs and PUFAs, notably the ω-3 and ω-6 fatty acids, is considered more desirable in terms of nutritional quality than the saturated fatty acids, and because of their possible health benefits (Venkatachalam & Sathe, 2006), as there is evidence that a MUFA-rich diet can lower the risk of coronary heart disease and may have a preventive effect against atherosclerosis. Oleic acid is the most important (> 70%), followed by linoleic acid. Taking into account the lipid classes that are present in hazelnuts – namely, non-polar lipids (triacylglicerols) and polar lipids (monogalactosyldiacylglycerols and phospholipids, the latter including phosphatidylinositol and phosphatidylcholine) – oleic acid is the main fatty acid in these classes, followed by linoleic acid (Parcerisa *et al.*, 1997). In terms of triacylglycerol composition, trioleoylglycerol is predominant, followed by dioleoyl-linoleoylglycerol, at 48.32–71.31% and 12.36–18.10%, respectively (Alasalvar *et al.*, 2006a).

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TABLE 73.2 Energy, Oil, Protein and Fatty Acid Composition of Hazelnut (*Corylus avellana* L.) Kernels

Reference	Energy (kcal/g)	Oil (% Dry Weight)	Protein (% Dry Weight)	Fatty Acid Composition (% of Total Oil)								
				Oleic (18:1ω-9)	Linoleic (18:2 ω-6)	Palmitic (16:0)	Stearic (18:0)	Linolenic (18:3)	Myristic (14:0)	SFA (%)	MUFAs (%)	PUFAs (%)
Oliveira *et al.*, 2008	6.49–6.77	58.0–64.2	15.6–16.2	80.67–82.63	9.84–11.26	4.95–5.76	1.74–1.87	0.15–0.19	0.03–0.04	6.97–7.77	81.12–83.05	9.99–11.43
Alasalvar *et al.*, 2006a				82.78	8.85	4.81	2.69	0.12	0.04	7.79	83.24	8.97
Balta *et al.*, 2006		57.5–74.1	10.7–19.2	73.48–81.57	10.46–15.61	4.39–8.85	1.67–3.18	0.02–0.34	0.01–0.16			
Köksal *et al.*, 2006		56.07–68.52	12.2–21.9	74.2–82.8	9.82–18.7	4.72–5.87	0.86–2.49	0.029–0.076		7.1	92.8	13.1
Venkatachalam & Sathe, 2006				82.95	7.55	5.78	3.12	0.24	0.03	9.11	83.10	7.79
Özdemir & Akinci, 2004	6.49–6.80	57.39–62.90	18.25–22.06									
Özdemir *et al.*, 2001		67.1–72.0		75.7–80.7	10.1–13.8	6.6–8.3	1.8–3.8					
Parcerisa *et al.*, 1998				74.13–82.83	8.17–17.78	4.66–6.04	1.38–3.36	0.10–0.17		6.87–9.00	74.50–83.16	8.27–17.89

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Hazelnut kernels also contain essential amino acids — for example, arginine, histidine, izoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine — with arginine and leucine being the most abundant (Köksal *et al.*, 2006; Venkatachalam & Sathe, 2006). Non-essential amino acids (alanine, aspartic acid/asparagine, glutamic acid/glutamine, glycine, proline, serine, and tyrosine) also exist in hazelnut kernels, with glutamic acid/glutamine found in the greatest quantity, followed by aspartic acid/asparagine, and alanine (Köksal *et al.*, 2006; Venkatachalam & Sathe, 2006). Venkatachalam and Sathe (2006) performed a study on the chemical composition of several edible nut seeds, including hazelnuts, and verified that, with the exception of almonds and peanuts (which were deficient in the sulfur amino acids, methionine and cysteine), all other tree nuts appear to contain adequate amounts of all of the essential amino acids when compared to the FAO/WHO recommended essential amino acid pattern for an adult.

Regarding hazelnut sugars, few studies have involved these compounds. In 2006, Venkatachalam and Sathe (2006), when analyzing the chemical composition of several edible nut seeds, determined a sugar percentage in hazelnuts of $1.41 \pm 0.05\%$ (wet weight). However, these values are indicative, as the sugar content of nut seeds varies considerably, depending on the growing conditions, seed maturity, cultivar, and location.

Hazelnuts also contain vitamins. The predominant soluble vitamins are vitamins B_1, B_2, B_6, niacin, ascorbic acid, and folic acid (only determined in some varieties) (Açkurt *et al.*, 1999; Köksal *et al.*, 2006). The major insoluble vitamins detected are α-tocopherol (Parcerisa *et al.*,1998; Açkurt *et al.*, 1999; Köksal *et al.*, 2006), followed by retinol and δ-tocopherol (Köksal *et al.*, 2006). Alasalvar *et al.* (2006a) and Amaral *et al.* (2006) analyzed hazelnuts of the Tombul variety and cultivars collected in several Portuguese localities, respectively, in relation to tocol (tocopherol and tocotrienol) composition, and detected and quantified seven tocols: α-tocopherol, β-tocopherol, γ-tocopherol, δ-tocopherol, α-tocotrienol, β-tocotrienol, and γ-tocotrienol. Once more, α-tocopherol was the most abundant.

There is great interest in determining the mineral composition of hazelnuts, due to some metals having pro-oxidant activity and health benefits. The mineral composition of hazelnut kernels depends not only on the variety but also on the growing conditions, such as the soil type and geographical factors. In the studies performed by Açkurt *et al.* (1999), Ozdemir *et al.* (2001), and Köksal *et al.* (2006), potassium was the predominant mineral, followed by calcium and magnesium. Moreover, the presence of iron, zinc, and copper, and a high potassium: sodium ratio, mean that hazelnuts are of interest for human diets, and especially for electrolyte balance. However, iron and copper are considered to be pro-oxidant minerals that might reduce both the shelf-life and the sensory characteristics of hazelnuts, because they are involved in rancidity (Açkurt *et al.*, 1999). Therefore, varieties with low unsaturated: saturated ratios, and that are low in pro-oxidant components, rich in antioxidant components, and low in enzymatic activities, are preferred, because they minimize post-harvest quality losses, and packaging and refrigeration costs (Açkurt *et al.*, 1999).

In recent years, some studies have been performed in order to evaluate the potential of hazelnut by-products as sources of natural antioxidants and as functional food ingredients (Alasalvar *et al.*, 2006b; Shahidi *et al.*, 2007; Contini *et al.*, 2008) — which may be of great importance to the hazelnut industry. Several phenolic compounds have been detected in hazelnut kernels and leaves. Gallic acid, caffeic acid, *p*-coumaric acid, ferulic acid, and sinapic acid (Figure 73.2) were observed in kernels (Alasalvar *et al.*, 2006b; Shahidi *et al.*, 2007). In addition to these, the leaves were found to contain 3-caffeoylquinic acid, 4-caffeoylquinic acid, 5-caffeoylquinic acid, caffeoyltartaric acid, *p*-coumaroyltartaric acid, myricetin 3-rhamnoside, quercetin 3-rhamnoside, and kaempferol 3-rhamnoside (Figure 73.2) (Oliveira *et al.*, 2007). The former group of compounds has also been detected in hazelnut skins, hard shells, and green leafy covers (Shahidi *et al.*, 2007).

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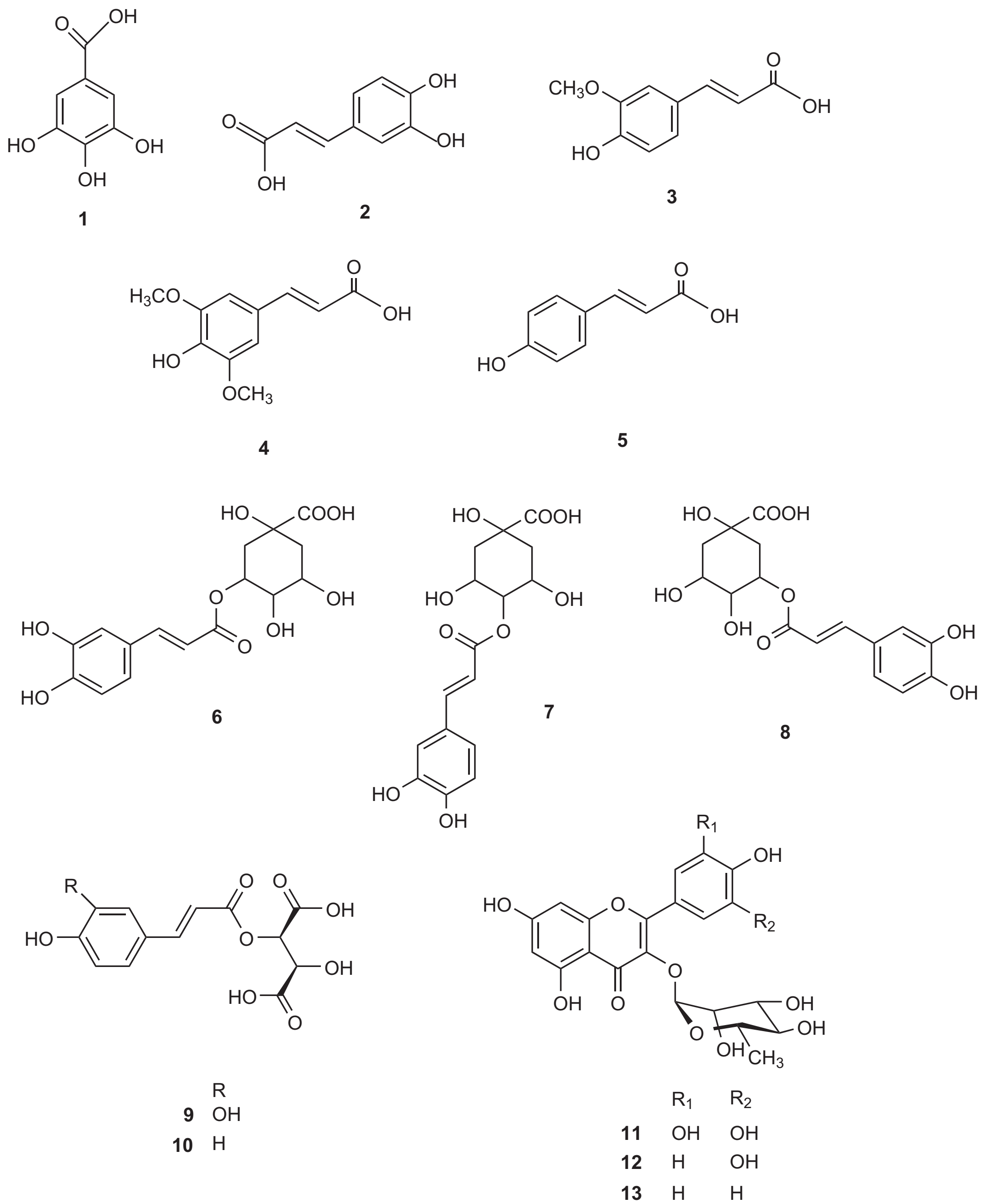

FIGURE 73.2
Chemical structures of identified phenolic compounds in hazelnut kernels and leaves. (1) Gallic acid, (2) caffeic acid, (3) ferulic acid, (4) sinapic acid, (5) *p*-coumaric acid, (6) 3-caffeoylquinic acid, (7) 4-caffeoylquinic acid, (8) 5-caffeoylquinic acid, (9) caffeoyltartaric acid, (10) *p*-coumaroyltartaric acid, (11) myricetin 3-rhamnoside, (12) quercetin 3-rhamnoside, (13) kaempferol 3-rhamnoside.

The composition of the hazelnut has led some recent research studies to indicate that enriching the diet with this nut may improve human health. The ingestion of hazelnuts might have benefits related to the blood serum lipid profile, as they protect low density lipoprotein (LDL) against oxidation, and decrease the plasma oxidized LDL level (Durak *et al.*, 1999; Orem *et al.*, 2008). Moreover, hazelnut supplementation may prevent peroxidation reactions, which are related to inflammatory and ischemic diseases, cancer, hemochromatosis, acquired immunodeficiency syndrome, emphysema, organ transplantation issues, gastric ulcers,

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hypertension and pre-eclampsia, neurologic diseases, alcoholism, smoking-related diseases, and others, due to the presence of antioxidant compounds.

Antimicrobial activity of hazelnuts

Nowadays, there is growing interest in discovering natural antimicrobial compounds that might be used as alternatives to the chemical preservatives used in food industry, and to antibiotics, thus decreasing their use, and lowering the probability of the occurrence of human resistance to these chemicals. Many studies have therefore focused on the antimicrobial agents and properties of plant-derived active principles, which have been used for some time in traditional medicine to overcome infections. As far as we know, only two studies regarding determination of the hazelnut's antimicrobial potential have been carried out; one with hazelnut kernels (Oliveira *et al.*, 2008), and one with leaves (Oliveira *et al.*, 2007), and involving three cultivars: M. Bollwiller, Fertile de Coutard, and Daviana. In both studies, the minimal inhibitory concentration (MIC) values were determined for gram-positive bacteria (*Bacillus cereus*, *Bacillus subtilis*, and *Staphylococcus aureus*), gram-negative bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*), and fungi (*Candida albicans* and *Cryptococcus neoformans*), using the agar streak dilution method based on radial diffusion (Figure 73.3). MICs are normally used to evaluate antimicrobial activity, and are considered to be the lowest concentration of the tested sample needed to inhibit the growth of bacteria or fungi after 24 hours (Oliveira *et al.*, 2007, 2008). For each MIC, the diameter of the inhibition zones are generally measured, linking an inhibition zone of less than 1 mm to no antimicrobial activity (−), an inhibition zone of 2−3 mm to slight antimicrobial activity (+), an inhibition zone of 4−5 mm to moderate antimicrobial activity (++), an inhibition zone of 6−9 mm to high antimicrobial activity (+++), and an inhibition zone of higher than 9 mm to strong antimicrobial activity (++++).

When comparing both studies (Table 73.3), the hazelnut kernels and leaves showed different antimicrobial activities. In the case of leaves, the samples revealed antimicrobial activity against all microorganisms with the exception of *P. aeruginosa* and *C. albicans*, which were resistant to the extracts at a concentration of 100 mg/ml. In the case of aqueous extracts of hazelnut kernels, high antimicrobial activity was only found against gram-positive bacteria; namely, *B. cereus*, *B. subtilis*, and *S. aureus*. On the contrary, gram-negative bacteria and fungi were resistant to the tested extracts at all the assayed concentrations.

Regarding hazelnut cultivars, the most promising is M. Bollwiller for leaves, and Daviana for aqueous extracts of hazelnut kernels, since smaller MICs and larger zones of inhibition of growth were determined for these varieties.

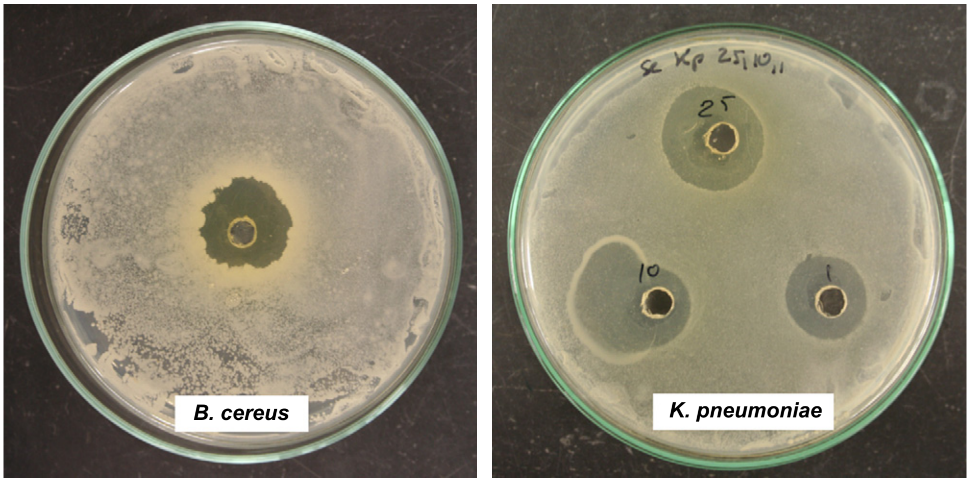

FIGURE 73.3
Antimicrobial activity of hazelnut extracts against *Bacillus cereus* and *Klebsiella pneumoniae*. The photographs show the inhibition zones obtained after application of hazelnut extracts to cultures of a gram-positive bacteria (*Bacillus cereus*) and a gram-negative bacteria (*Klebsiella pneumoniae*).

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TABLE 73.3 Antimicrobial Activity (MICs and Inhibition Zones) of Hazelnut Kernels and Leaves*

Cultivar	Gram-Positive Bacteria						Gram-Negative Bacteria						Fungi			
	B. cereus		*B. subtilis*		*S. aureus*		*P. aeruginosa*		*E. coli*		*K. pneumoniae*		*C. albicans*		*C. neoformans*	
	Kernel	Leaf	Kernel	Leaf	Kernel	Leaf	Kernel	Leaf	Kernel	Leaf	Kernel	Leaf	Kernel	Leaf	Kernel	Leaf
M. Bollwiller	0.1 (++++)	0.1 (++++)	1 (++++)	1 (++++)	0.1 (++++)	0.1 (++)	100 (–)	100 (–)	100 (–)	50 (++++)	100 (–)	1 (++)	100 (–)	100 (–)	100 (–)	100 (++++)
F. Coutard	0.1 (+++)	0.1 (++)	0.1 (++++)	1 (+++)	0.1 (++)	0.1 (++++)	100 (–)	100 (–)	100 (–)	100 (–)	100 (–)	10 (++++)	100 (–)	100 (–)	100 (–)	100 (–)
Daviana	0.1 (++++)	0.1 (++)	0.1 (+++)	1 (++)	0.1 (++++)	0.1 (++)	100 (–)	100 (–)	100 (–)	100 (++++)	100 (–)	50 (++++)	100 (–)	100 (–)	100 (–)	100 (–)

MIC, minimal inhibitory concentration, considered as the lowest concentration of the tested sample able to inhibit the growth of bacteria or fungi after 24 hours.
No antimicrobial activity (–), inhibition zone $<$ 1 mm; slight antimicrobial activity (+), inhibition zone 2–3 mm; moderate antimicrobial activity (++), inhibition zone 4–5 mm; high antimicrobial activity (+++), inhibition zone 6–9 mm; strong antimicrobial activity (++++), inhibition zone $>$ 9 mm.

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ADVERSE EFFECTS AND REACTIONS (ALLERGIES AND TOXICITY)

In areas where birch trees are endemic, hazelnut allergy might be observed. This is often the result of primary sensitization to the cross-reactive birch pollen allergen Bet v 1, usually resulting in a mild oral allergy syndrome in both adults and children (Flinterman *et al.*, 2006). On the other hand, sensitization to hazelnut in early childhood has been related to sensitization to other tree nuts and peanuts, which can all cause serious reactions. Moreover, hazelnuts, like other nuts, may, if not stored correctly, favor the development of aflatoxin fungi producers, such as *Aspergillus flavus*. This type of metabolite, due to its toxicity to humans, is of great concern regarding guaranteeing food safety and human health.

SUMMARY POINTS

- Hazelnuts are well adapted to different agro-climatic conditions, and a great number of varieties are known.
- The fruit is used in different forms, and in a large number of products.
- Hazelnuts possess a rich chemical composition, being beneficial to health mainly because of their high monounsaturated fatty acids content.
- Among the phytochemicals with biological properties, tocopherols and phenolic compounds are of great importance.
- Extracts of different *C. avellana* parts, such as leaves and fruits, and of different varieties, show the ability to inhibit the growth of different important pathogenic microorganisms.
- The consumption of these fruits, beyond other important biological properties, may promote human protection against infections, explaining their wide use in traditional medicine and showing their great potential as a source of bioactive substances.

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