T. K. Lim

Edible Medicinal and Non-Medicinal Plants

Volume 4, Fruits

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Contents

Introduction

This book continues as volume 4 of a multi-compendium on *Edible Medicinal and Non-Medicinal Plants.* It covers edible fruits/seeds used fresh, cooked or processed into other by-products, or as vegetables, cereals, spices, stimulant, edible oils and beverages. It covers selected species from the following families: Fagaceae, Grossulariaceae, Hypoxidaxeae, Myrsinaceae Olacaceae, Oleaceae, Orchidaceae, Oxalidaceae, Pandanaceae, Passifloraceae, Pedaliaceae, Phyllanthaceae, Pinaceae, Piperaceae, Rosaceae and Rutaceae. However, not all the edible species in these families are included. The edible species dealt with in this work include to a larger extent lesser-known, wild and underutilized crops and also common and widely grown crops.

As in the preceding three volumes, topics covered include: taxonomy (botanical name and synonyms); common English and vernacular names; origin and distribution; agro-ecological requirements; edible plant part and uses; plant botany; nutritive and medicinal/ pharmacological properties with up-to-date research findings, traditional medicinal uses; other non-edible uses; and selected/cited references for further reading.

Fagaceae or more commonly known as the beech family comprises about 900 species of evergreen and deciduous trees and shrubs. It includes economically important species like the oak (*Quercus*), beech (*Fagus*) and the chestnut (*Castanea*) – all provide invaluable timber. The cork oak (*Quercus suber*) provides cork for bottles and other uses while *Castanea* also provides the delectable tasty and nutritive chestnut. Wood chips from the genus, *Fagus* are often used in flavoring beers. *Castanea sativa* and another lesser known species *Quercus infectoria* are covered in this volume. The latter has edible seeds that is used in food and nut galls used in herbal drinks and tea. Both species also possess medicinal properties.

Several edible species of *Ribes* of the family Grossulariaceae, namely gooseberry, black currant and red currant are covered in this volume. *Ribes* is a genus of about 150 species found in the temperate areas in the northern hemisphere. Besides being rich in nutrients, currants and gooseberries contain many phenolic compounds that include phenolic acids, flavonoids, anthocyanins and carotenoids with good antioxidant activity.

Hypoxidaceae is a family of flowering plants belonging to the Monocots, under the order Asparagales. Members are small to medium herbs, with grass-like leaves and an invisible stem, modified into a corm or a rhizome. Many are ornamental genera such as *Curculigo*, *Hypoxis*, and *Rhodohypoxis*. *Molineria latifolia* (*Curculigo latifolia*) produces an edible fruit which contains a high intensity sweetening protein called neoculin which is 430–2,070 times sweeter than sucrose on a weight basis (Yamashita et al. 1995; Kurihara 1992).

Myrsinaceae or Myrsine family comprises about 35 genera and about 1,000 species of trees, shrubs and lianas. The members occur in both temperate and tropical climates. Some economically important genera include *Ardisia* (medicine,

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oil, edible, wild vegetables), *Maesa* (edible, tea, dye), *Aegiceras* (tannin, fine fuel), *Embelia* (vermifuge, edible) and *Myrsine* (medicine, fine wood, tannin, fuel). Two *Ardisia* species, *Ardisia crenata* and *A. elliptica* are covered in this volume. Both species produce edible fruit and leaves. Both plants contain bioactive phytochemicals which impart numerous pharmacological properties that include antimicrobial, anticancer, antiplatelet and antimalarial properties.

Members of the family Olacaceae comprising 180–250 species from 23 to 27 genera, are found in tropical and warm-temperate regions worldwide. They comprised scandent shrubs, trees, or lianas, sometimes hemiparasitic. Edible fruit species of this family include *Ximenia* (false sandalwood, hog-plum) and *Scorodocarpus borneensis* (wood garlic, forest onion). The latter treated herein has fruit (nut), bark and leaves which are edible and medicinal. Many parts of wood garlic have medicinal properties, the nuts contain alkaloids and sesquiterpenes (Wiart et al. 2001), the leaves have megastigmanes and flavonoids (Abe and Yamauchi 1993).

The Oleaceae or olive family, comprises 30 genera and about 600 species of mesophytic shrubs, trees and occasionally vines. Many species have economic significance such as the olive (*Olea europaea*) valued for its fruit and oil extracted from it, the ashes (*Fraxinus*) important for their timber, and the ornamental plants forsythia, lilacs, jasmines, osmanthuses, privets and fringetrees. Olive leaves, fruit, pomace and oil have a host of pharmacological properties that include anticancer, antiathrogenic, cardioprotective, antiinflammatory, antihyperglycemic, antihihyperlipidemic, antihypertensive, antiplatelet, antinociceptive antimicrobial and wound healing activities. Olive wood is hard and durable and olive branch is an ancient symbol for peace.

Orchidaceae, the orchid family, is a morphologically diverse and widespread family of monocots in the order Asparagales. This family is regarded to be the largest family of flowering plants having between 22,000 and 26,000 currently accepted species, found in 880 genera. The family includes *Orchis* (type genus) and many commonly cultivated orchids, such as *Phalaenopsis*, *Dendrobium, Epidendrum* and *Cattleya and Vanilla* (*Vanilla planifolia* which is covered in this volume). The dried seed pods of *Vanilla* are commercially important as flavouring in confectionery, dairy products, for perfume manufacture and aromatherapy.

The Oxalidaceae, or wood sorrel family, is a small family of eight genera of herbaceous plants, shrubs and small trees, with vast majority of the 900 species in the genus *Oxalis* (wood sorrels). The family is represented in this volume by an under-utilised, lesser known tropical fruit *Sarcotheca diversifolia*. The genus *Averrhoa* of which starfruit is a member, is often included in this family, but some botanists placed it in a separate family Averrhoaceae. Several currently recognised *Averrhoa* species with edible fruits have been dealt with in Volume 1 of the multi-compendium under Averrhoaceae.

Pandanaceae is a large family of flowering plants found in the tropical and subtropical regions of the Old World from West Africa through to the Pacific. Pandanaceae is a highly variable genus complex of trees, climbing or scrambling shrubs that are adapts well from sea level in salted beaches to montane cloud- forest, and riverine forest habitat. One distinctive feature is that the stems have aerial prop roots to provide support and display sympodial branching. Seven species producing edible drupes are covered in this volume.

Passifloraceae, the passion fruit family, comprises about 530 species of flowering plant in about 18 genera of trees, shrubs, lianas and climbing plants, mostly found in tropical America and Asia. Seven species with edible fruits and medicinal properties are covered in this volume.

Pedaliaceae, the sesame family, is a small family of 13 genera and 70 species. Its native distribution is exclusively the Old World, in tropical and dry habitats, and its best-known member is *Sesamum indicum* (sesame). Sesame seeds are rich in lignans like sesamin, sesamolin and other bioactive phytochemicals responsible for its culinary and pharmacological attributes.

Phyllanthaceae comprises about 2,000 species grouped into 54–60 genera of mostly trees, shrubs and herbs. A few are climbers or succulents and one *Phyllanthus fluitans,* an aquatic plant. Several genera produce edible fruits such as *Phyllanthus, Upaca, Antidesma* and *Baccaurea*. Some species of the latter two genera are covered in this volume. *Baccaurea* was previously classified under the family Euphorbiaceae. Unlike many of the Euphorbiaceae, no member of Phyllanthaceae has latex and only a very few produce a resinous exudate.

Pinaceae or pine family comprises shrubs or trees and include many of the familiar conifers of commercial importance such as cedars, firs, hemlocks, larches, pines and spruces. The family is the largest extant conifer family with between 220 and 250 species in 11 genera found mostly in temperate regions but also in sub-arctic to tropical areas. Two *Pinus* species providing edible pine nuts are discussed in this volume.

Piperaceae, better known as the pepper family, is a large family of flowering herbs, shrubs and small trees. It has been reported to have 3,610 currently accepted species in five genera distributed pantropically. The vast majority of peppers can be found within the two main genera: *Piper* (2,000 species) and *Peperomia* (1,600 species). Three *Piper* species are covered including *Piper nigrum* which provide the important spice, peppercorns. *Piper nigrum* (black pepper) is used not only in human dietaries but also for a variety of other purposes such as medicinal, as a preservative, and in perfumery.

Rosaceae or the rose family is a medium-sized family of about 2,830 species in 95 genera of flowering herbs, shrubs, climbers and trees. Among the largest genera are *Prunus* (430) *Alchemilla* (270), *Sorbus* (260), *Crataegus* (260), *Cotoneaster* (260), and *Rubus*. *Rubus* consists of about 750 species (Daubeny 1996) which have been separated into blackberry (subgenus *Rubus* including *R. armeniacus*, *R. laciniatus* and *Rubus* hybrids) and raspberry (subgenus *idaeobatus* including, *Rubus idaeus* and *Rubus occidentalis*) types according to the abscission of the fruit; in raspberry this comes off a woody or fleshy receptacle which remains on the plant, and in blackberry the fruit separates from the plant with the soft, edible receptacle included (Clark et al. 2007). Also included in the genus are the hybridberries (including boysenberries, loganberries and other hybrid types). Most raspberry species are diploid (2x = 14) as are a few blackberries, but the bulk of blackberry species and all hybridberries are polyploids, ranging from 3x = 21 to 18x = 126.

Rosaceae provides many economically important products which include edible fruits *Malus* spp. (apples), *Prunus* spp. (apricot, cherry, nectarine, peach, plums, prune, damson, sloe), *Cydonia* (quince), *Pyrus* (pears), *Eriobotrya* (loquat), *Rubus* (blackberry, boysenberry, loganberry, black and red raspberry), *Fragaria* (strawberry), *Mespilus* (medlar), *Amelanchie*r spp. (serviceberry, Juneberry); *Prunus dulcis* (almond nuts); many ornamental trees and shrubs or hedge-plants, e.g. *Spiraea*, *Photinia*, *Cotoneaster*, *Kerria*, *Filipendula* (meadowsweets) *Pyracantha* (firethorns), *Crataegus* (hawthorns), *Rhodotypos*, *Rosa* (roses), *Sorbus* (mountain ash, rowan) and *Potentilla (*cinquefoils). Roses can be herbs, climbers, shrubs or small trees. Many of the edible fruit species in the genera *Malus, Pyrus, Prunus, Rubus, Cydonia, Mespilus, Eriobotrya, Fragaria, Chaenomeles* and *Sorbus* also have important nutrients and bioactive secondary phytochemicals with a diverse range of pharmacological activities.

Rutaceae, the rue or citrus family is a large, morphologically diverse, cosmopolitan family of flowering plants of 160 genera and 1,900 species with great economic importance in warm temperate and sub-tropical climate areas. The most economically important genus is *Citru*s. Several taxonomical studies employing molecular DNA techniques have supported a wider polyphyletic classification of Citreae and *Citrus*. Studies by Araújo et al. (2003) and Bayer et al. (2009) supported the broader definition of *Citrus* to include *Clymenia*, *Eremocitrus*, *Fortunella, Microcitrus*, *Oxanthera* and *Poncirus.* Bayer et al. (2009) also supported the monophyly of the subfamily Aurantioideae and the transfer of *Murraya* sensu stricto and *Merrillia* from Clauseneae to Citreae. Likewise, data from Guerra et al. (2000) supported segregation of *Bergera* from *Murraya*, and movement of *Murraya* sensu stricto and *Merrillia* from

Clauseneae to Citreae. The results of studies by Groppo et al. (2008) supported monophyly of Spathelioideae and Aurantioideae, but not of other subfamilies and tribes. Thus, the genus *Citrus* boast of many economic important edible fruits such as oranges, mandarins, citrons, grapefruits, pumello, lemons, limes, kumquats and a diverse host of *Citrus* hybrids. More taxonomical work is required to classify the many hybrids. Other edible non-Citrus fruits include white sapote (*Casimiroa edulis*), orangeberry (*Glycosmis pentaphylla*), clymenia (*Clymenia polyandra*), limeberry (*Triphasia trifolia*), elephant apple (*Limonia acidissima*), wampee (*Clausena lansium*) and the bael (*Aegle marmelos*). *Bergera kongii* although has edible fruit is cultivated mainly for its aromatic spicy leaves (curry leaf) and is treated in a later volume. Other important genera include *Ruta* (treated in later volume), *Zanthoxylum* and *Boronia,* a large Australian genus, some members of which are plants with highly fragrant flowers and are used in commercial ornamental, cutflower and oil production. *Zanthoxylum* is represented in this volume by *Z. simulans*, an important source of Szechuan pepper. Rutaceous species in general possess extraordinary array of secondary chemical metabolites, many have medicinal, antimicrobial, insecticidal, or herbicidal properties. *Citrus* species in particular are important sources of bioactive polyphenolic flavonoid compounds such as the flavones, flavonols and flavonones with many important pharmacological properties (antioxidant, anticancer, antiviral, antidiabetic, antilipidemic, antihypercholesterolemic, antiinflammatory, etc.).

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Castanea sativa

Scientific Name

Castanea sativa Mill.

Synonyms

Castanea castanea (L.) H. Karst. nom inval., *Castanea prolifera* (K. Koch) Hickel, *Castanea sativa f. discolor* Vuk., *Castanea sativa* var. *hamulata* A. Camus, *Castanea sativa* var. *microcarpa* Lavialle, *Castanea sativa* var. *prolifera* K. Koch, *Castanea sativa* var. *spicata* Husn., *Castanea sativa* var. *typica* Seemen, nom. inval., *Castanea vesca* Gaertn., *Castanea vulgaris* Lam., *Fagus castanea* L. (basionym), *Fagus castanea* var. *variegata* Weston, *Fagus procera* Salisb.

Family

Fagaceae

Common/English Names

Chestnut, Chestnut Tree, Edible Chestnut, European Chestnut, Italian Chestnut, Marron, Portuguese Chestnut, Spanish Chestnut, Sweet Chestnut.

Vernacular Names

Afrikaans: Kastaiing;
Brazil: Castanha Européia, Castanha Portuguesa (Portuguese);
Bulgarian: Kecteh;
Chinese: Ou Zhou Li, Wu Shu Li;
Croatian: Kestenjaste Boje;
Czech: Kaštanovník Jedlý, Kaštanovník Setý;
Danish: Ægte Kastanie, Ægte Kastanje;
Dutch: Europese Kastanje, Kastanje, Kastanjeboom, Tamme Kastanje, Tamme Kastanjeboom, Tame Kastanjeboom Soort;
Eastonian: Harilik Kastanipuu;
Finnish: Aito Kastanja, Jalokastanja;
French: Châtaigne, Châtaigner Commun, Châtaignier, Châtaignier Commun Marron, Marron Comestible;
German: Cheschtene, Cheste, Echte Kastanie, Edelkastanie, Edel-Kastanie, Edelkastanienbaum, Eßkastanie, Eßkastanienbaum, Ess-Kastanie, Essbare Kastanie, Keschte, Marone, Maroni;
Greek: Kastania;
Hungarian: Édes Gesztenye, Szelídgesztenye;
Icelandic: Kastaníuhneta;
Indonesia: Berangan:
Italian: Castagno, Castagno Comune, Castagno Domestico, Marone;
Japanese: Yooroppa Guri;
Latvian: Kastanis;

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Lithuanian: Kaštonas;
Malaysia: Buah Berangan;
Norwegian: Edelkastanje, Ekte Kastanje, Kastanje;
Polish: Kasztan Jadalny;
Portuguese: Castanheiro-Comum, Castanheiro, Reboleiro;
Romanian: Castan, Castană;
Russian: Kashtan Nastoiashchii (Kaštan Nastojaščij), Kashtan Posevnoi (Kaštan Posevnoj);
Serbian: Kesten;
Slovašcina: Evropski, Pravi, Pravi Kostanj, Žlahtni Kostanj;
Slovencina: Gaštan Jedlý;
Spanish: Castaña, Castaño, Castaño Común, Castaño Regoldo, Regoldo;
Swedish: Äkta Kastanj, Kastanje;
Turkish: Kestane Ağacı;
Vietnamese: Cây Hạt Dẻ.

Origin/Distribution

A species of chestnut originally native to the Mediterranean in south-eastern Europe to Caucasus in Asia Minor. Wild or naturalized populations occur throughout southern Europe, northern Africa and southwestern Asia. It is cultivated in mild temperate regions in Europe and in the southern hemisphere and some subtropical regions.

Agroecology

Chestnut requires a mild cool climate Mediterranean or sub-temperate climate with good annual rainfall of 750–1,200 mm. The tree is frost sensitive. Sub-zero temperatures are injurious to the tree. The tree thrives in full sun on deep well-drained, fertile, sandy or loamy soils as it has a deep root system. It is highly tolerant of acidic soils, gravelly or stony soils but intolerant of calcareous soils, heavy clays and impermeable soils. The soil pH range is from 4 to 6.5 with an optimum from 5.5 to 6.5. It will tolerate partial shade under forest conditions. Adult trees are drought tolerant but adequate moisture is required for good growth and a good nut harvest.

Edible Plant Parts and Uses

Chestnuts can be eaten raw or dried but are usually eaten roasted, fried or cooked (boiled or steamed). Roasting, frying or cooking brings out the delicious, sweet chestnut flavour and floury texture. The dried or cooked nuts are used in confectionery, pastries, chocolates, puddings, desserts and cakes. They are used for flour, bread making, as a cereal substitute, coffee substitute, a thickener in soups and other cookery uses, as well as for fattening pig stock. A sugar can be extracted from it. The Italian and Corsican polenta (type of porridge) is made with sweet chestnut flour. A local variety of Corsican beer also uses chestnuts.

Botany

A medium to large, deciduous tree growing to 15–35 m high with a spreading crown and trunk diameter reaching 2 m and deeply fissured bark (Plate 1). Branchlets are tomentose. Leaves are elliptic to ovate-lanceolate, 14–28 cm × 5–9 cm, with 11–14 pairs of nerves more prominent on the under surface, serrated margin, acuminate tip, oblique base, coriaceous, glabrous, pale green and puberulous on the under surfaces (Plate 2). Inflorescences or catkins are unisexual (male) or androgynous with female flowers (cupules) at the base of an otherwise male inflorescence. Staminate catkins are pendulous, pubescent, creamy yellow, consists of male flowers in dense cymules. Male flowers are apetalous, with 4–6 (–9), scale-like, connate or distinct sepals, filiform filaments with dorsifixed or versatile anthers opening by longitudinal slits; and with or without a rudimentary pistil. Female inflorescences of 1–7 or more flowers subtended individually or collectively by a spiny protective cupule formed from numerous fused bracts, arranged individually or in small groups along an axis or at base of an androgynous inflorescence. Female flower

Plate 1 Tree habit with spreading crown

Plate 2 Elliptic leaves with serrated margins

with 1–7 perianth, 1 pistil, inferior ovary with 3–6(–9) locules, style and carpels as many as locules; placentation axile; ovules anatropous, 2 per locule. Fruit is 1.3–2.5 cm in diameter, with each spiny cupule or burr (Plate 3) consisting of 1–4

Plate 3 Chestnut catkins

Plate 4 Spiny chestnut cupules

Plate 5 Harvested chestnuts

nuts. Seed (nut) is brown to reddish-brown, usually solitary by abortion and is non-endospermic with a large embryo (Plate 5).

Nutritive/Medicinal Properties

Food value of raw peeled, European chestnuts per 100 g edible portion was reported as follows (USDA 2011): water 52.00 g, energy 196 kcal (820 kJ), protein 1.63 g, total lipid (fat) 1.25 g, ash 0.96 g, carbohydrate 44.17 g; minerals – calcium 19 mg, iron, 0.94 mg, magnesium 30 mg, phosphorus 38 mg, potassium 484 mg, sodium 2 mg, zinc 0.49 mg, copper 0.418 mg, manganese 0.336 mg, vitamins – vitamin C (total ascorbic acid) 40.2 mg, thiamine 0.144 mg, riboflavin 0.016 mg, niacin 1.102 mg, pantothenic acid 0.476 mg, vitamin b-6 0.352 mg, folate (total) 58 mcg, vitamin A 26 IU; lipids – fatty acids (total saturated) 0.235 g, 14:0 (myristic acid) 0.005 g, 16:0 (palmitic acid) 0.212 g, 18:0 (stearic acid) 0.012 g; fatty acids (total monounsaturated) 0.430 g, 16:1 undifferentiated (palmitoleic acid) 0.012 g, 18:1 undifferentiated (oleic acid) 0.413 g, 20:1 (gadoleic acid) 0.005 g; fatty acids (total polyunsaturated) 0.493 g, 18:2 undifferentiated (linoleic acid) 0.440 g, 18:3 undifferentiated (linolenic acid) 0.053 g; amino acids – tryptophan 0.018 g, threonine 0.058 g, isoleucine 0.064 g, leucine 0.096 g, lysine 0.096 g, methionine 0.038 g, cystine 0.052 g, phenylalanine 0.069 g, tyrosine 0.045 g, valine 0.091 g, arginine 0.116 g, histidine 0.045 g, alanine 0.109 g, aspartic acid 0.281 g, glutamic acid 0.210 g, glycine 0.084 g, proline 0.086 g and serine 0.081 g.

In an analysis conducted in Turkey (Ylldiz et al. 2009), the following nutrient data was reported for wild chestnut (*C. sativa*): moisture 54.84%, crude lipid 2.24%, crude protein, 8.93%, crude fibre, 3.92%, crude energy 4,046 kcal/100 g, ash 2.078%, dry matter 45.16%, total carbohydrate 11.21%, and ether soluble extract 4.44%. Zinc 5099.4 mg/kg, manganese 3031.9 mg/kg, sodium 1058.6 mg/kg and calcium 308.5 mg/kg were established as major minerals of chestnut fruit. Aluminium 21.52 mg/kg, boron 15.87 mg/kg, arsenic 7.82 mg/kg, bismuth 1.54 mg/kg, copper 0.12 mg/kg, chromium 5.72 mg/kg, strontium 15.22 mg/kg and titanium 768.72 mg/kg, iron 38.15 mg/kg were found in minor amounts.

Chestnut with a low fat content, completely free of cholesterol, a low sodium and high potassium content, moderate but high quality protein content, and rich in energy, vitamin C and amino acids especially lysine, tryptophan and sulphur containing amino acids provide a balanced and quality food (Bounous et al. 2000). Chestnuts also contained folate and vitamin Bs and A and the macro minerals. Chestnut was found to be characterized by the presence of seven organic acids: oxalic, cis-aconitic, citric, ascorbic, malic, quinic and fumaric acids (Ribeiro et al. 2007). Roasting, boiling and frying procedures led to significant reduction of total organic acids contents. Moisture was the major component in four Portuguese chestnut cultivars followed by carbohydrates, protein and fat, resulting in an energetic value lower than 195 kcal/100 g of fresh fruit (Barreira et al. 2009). Fatty acids (FA) profiling revealed a clear prevalence of C18:1 and C18:2, two FA very well-known due to their beneficial effects on human health, e.g., in the prevention of cardiovascular diseases. Triacylglycerols (TAG) profiling revealed that OLL, PLL, OOL and POL were the major compounds (O = oleic acid, P = palmitic acid, L = linoleic acid).

Chestnuts are mostly consumed as processed forms, and the different types of processing clearly affect the nutrient and non-nutrient composition of the fruits. Chestnut fruit industrial processing could be divided into four major stages: harvest, post-harvest storage (during 3 months at ±0°C), industrial peeling (by flame or fire – "brûlage" – at temperatures of 800–1,000°C) and freezing (tunnel with a CO_2 flow at −65°C during 15–20 minutes) (De Vasconcelos et al. 2010b). Starch and hemicelluloses were the predominant polysaccharides but free sugars, mainly sucrose (saccharose), were also present. Vitamin C and vitamin E (predominantly δ-tocopherol) were present in the fruits with lower levels of carotenoids (lutein and lutein esters). The fibre and free sugars contents were found to increase during industrial processing, while the interaction of cultivar × processing stage had the greatest influence on the starch content. Various phenolics, mainly gallic and ellagic acids and lower levels of ellagitannins, were also detected. De Vasconcelos et al. (2010c) also found that potassium and phosphorous were predominant in the fruits of all cultivars for both harvest years. Calcium, magnesium, iron, zinc and manganese were also present. Fruits from both harvest years had a significant content of free sugars, with sucrose predominating, and these sugars were more affected by the processing stage. Significant levels of lutein, lutein esters, γ-tocopherol and vitamin C were also found in the chestnut fruits. The contents of vitamin C and carotenoids were adversely affected during industrial processing.

The cooking processes was found to significantly affect primary and secondary metabolite composition of chestnuts (Gonçalves et al. 2010). Roasted chestnuts had higher protein contents, insoluble and total dietary fibre and lower fat contents whilst boiled chestnuts had lower protein, but higher fat contents. Cooking increased citric acid contents, especially in roasted chestnuts. In contrast, raw chestnuts had higher malic acid contents than cooked chestnuts. Moreover, roasted chestnuts had significantly higher gallic acid and total phenolic contents, and boiled chestnuts had higher gallic and ellagic acids contents, when compared to raw chestnuts. The data confirmed cooked chestnuts to be a good source of organic acids and phenolics and with low fat contents, properties that associated with positive health benefits.

Other Phytochemicals

All three Portuguese cultivars were found to have high moisture contents but were low in ash, crude fat, and crude protein contents, with high starch and low fiber contents (De Vasconcelos et al. 2007). The free amino acid contents, including various essential amino acids, varied depending on the cultivar. All three cultivars also had a significant content of polyphenolics with gallic acid; ellagic acid was predominant among hydrolyzable and condensed tannins. Chestnuts have become increasingly important with respect to human health, for example, as an alternative gluten-free flour source.

The chestnut fruit processing had been reported to generate large amounts of residues as pericarp (outer shell; 8.9–13.5%) and integument (inner shell; 6.3–10.1%) and studies showed that these materials clearly had the potential as sources of valuable co-products (de Vasconcelos et al. 2010a). The analyses of the pericarp and integument of four Portuguese chestnut cultivars revealed significant contents of total phenolics, low molecular weight phenolics (gallic and ellagic acid), condensed tannins and ellagitannins including castalagin, vescalagin, acutissimin A and acutissimin B. The integument tissues had the highest levels of total phenolics and condensed tannins. The most efficient extraction solvent for the total phenolics, total condensed tannins and low molecular weight phenolics was 70:30 acetone:water at 20°C.

Some low molecular weight phenolic compounds and hydrolyzable tannins were found in hardwood extracts of *Castanea sativa* before and after toasting (Sanz et al. 2010). The low molecular weight phenolic compounds were lignin constituents as the acids gallic, protocatechuic, vanillic, syringic, ferulic, and ellagic, the aldehydes protocatechuic, vanillic, syringic, coniferylic, and sinapic, and the coumarin scopoletin. Vescalagin and castalagin were the main ellagitannins, and acutissimin was also identified in the wood. Some gallotannins were tentatively identified, including different isomers of di, tri, tetra, and pentagalloyl glucopyranose, and di and trigalloyl-hexahydroxydiphenoyl glucopyranose, comprising 20 different compounds, as well as some ellagic derivatives such as ellagic acid deoxyhexose, ellagic acid dimer dehydrated, and valoneic acid dilactone. These ellagic derivatives as well as some galloyl and hexahydroxydiphenoyl derivatives were tentatively identified for the first time in chestnut wood. Seasoned and toasted chestnut wood showed a very different balance between lignin derivatives and tannins because toasting resulted in the degradation of tannins and the formation of low molecular weight phenolic compounds from lignin degradation. A chlorine-free environmentally-friendly process was developed for extraction of 4-O-methylglucuronoxylans (MGX) from *Castanea sativa* hardwood (Barbat et al. 2010). Chestnut sawdust was first delignified using metalled phthalocyanine or porphyrin in presence of hydrogen peroxide. Then, MGXs were easily extracted by hot water.

The parts of chestnut such as: seed, peeled seed, brown seed shell, red internal seed shell, leaves, catkin, spiny bur, as well as the new and old chestnut bark were found to have varying amounts of total phenolics, total flavonoids and tannins (Živković et al. 2009a, b). The highest content of total phenolic compounds (3.28)% GAE (Gallic acid equivalent) was found in dry extract of catkin, while the lowest content (0.42)% GAE was obtained for the dry extract of the seeds. The phenolic contents (% GAE) in other tissues were as follows: peeled chestnut 0.59%, brown seed shell 1.19%, red internal seed shell 2.82%, leaf 1.40%, new chestnut bark 3.00%, old chestnut bark 1.70%, spiny burs 0.49%. The total flavonoid content % CE (catechin equivalent) in various plant parts were reported as: seeds 0.17%, brown seed shell 0.65%, peeled chestnut 0.09%, red internal seed shell 1.44%, catkin 0.60%, leaf 1.40%, new chestnut bark 0%, old chestnut bark 0.69%, spiny burs 0.13%. The total condensed tannins (CT) content was highest in red internal seed shell 15.29% CE (vanillin assay) and 3.12% CT (acid butanol assay). The total condensed tannins content in other plant parts were estimated as follows: seeds 0.39% CE (vanillin assay) 0.88% CT (butanol assay); peeled chestnut 0% CE (vanillin assay), 0% CT (acid butanol assay); brown seed shell 2.78% CE (vanillin assay), 1.67% CT (acid butanol assay); catkin 0.49%CE (vanillin assay), 0.95% CT (acid butanol assay); leaf 0% CE (vanillin assay) 0.08% CT (acid butanol assay); new chestnut bark 3.91% CE (vanillin assay), 1.89% CT (acid butanol assay); old chestnut bark 0.76% CE (vanillin assay), 0.58% CT (acid butanol assay); and spiny burs 0% CE (vanillin assay), 0.08% (acid butanol assay).

Antioxidant Activity

Studies had shown that the leaves had antioxidant properties. The leaf extract and an ethyl acetate fraction, which contained a high level of total phenolic compounds (29.1 g/100 g) demonstrated high antioxidant potentials, equivalent to at least those of reference compounds quercetin and vitamin E and standard extracts (pycnogenol, from French *Pinus maritima* bark, and grape marc extract) (Calliste et al. 2005). In another study, five phenolic compounds were identified in the leaf ethanol:water (7:3) extract, namely chlorogenic acid, ellagic acid, rutin, isoquercitrin and hyperoside (Almeida et al. 2008a). The content of total phenolics for *C. sativa* was 284 of gallic acid equivalents (GAE)/g of lyophilized extract. The extract presented a high potency to scavenge the tested reactive species viz. reactive oxygen species (ROS) such as superoxide radical, peroxyl radical, hydrogen peroxide, singlet oxygen and reactive nitrogen species (RNS) namely nitric oxide and peroxynitrite; all the IC_{50}s being found at the μg/ml level. The IC_{50} found for the iron chelation and DPPH (1,1-diphenyl-2-picryl hydrazyl) scavenging assays were 132.94 and 12.58 μg/ml, respectively.

The water soluble extracts obtained from leaves, catkins, and outer brown peel of *Castanea sativa* showed high antioxidant activity in scavenging •OH and DPPH radical (Živković et al. 2009b). The highest content of total phenolic compounds ((4.24)% of GAE) and flavonoids ((2.41)% of GAE) were determined in dry extract of outer brown peel of Lovran's Marrone cultivar. The TF/TP (total flavonoid/total phenolic) ratio was from 11.86 for the extract of peeled chestnut to 56.83% determined in the outer brown peel of Lovran's Marrone cultivar. All extracts, except for sweet chestnut catkins, showed the ability to protect liposomes from peroxidation. Phenolic compounds, as active antioxidants, have the ability to enter and protect cell membranes from lipid peroxidation, thus overcoming the body's refractory response to the antioxidant supplements in the diet. It was shown that phenolics were easily accessible natural antioxidants that could be used as food supplements or for the treatment of pathophysiological conditions related to oxidative stress. In a recent study, all the assayed by-products (almond green husks, chestnut skins and chestnut leaves) revealed good antioxidant properties, with very low EC_{50} values (lower than 380 μg/ml), particularly for lipid peroxidation inhibition (lower than 140 μg/ml) (Barreira et al. 2010). The correlation between the bioactive compounds (total phenols and flavonoids) and DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity, reducing power, inhibition of β-carotene bleaching and inhibition of lipid peroxidation in pig brain tissue through formation of thiobarbituric acid reactive substances, was also obtained. Although, all the assayed by-products proved to have a high potential of application in new antioxidants formulations, chestnut skins and leaves demonstrated better results. Studies proposed that glycerine with a pH around 5 was best vehicle for topical formulations incorporating *C. sativa* leaf extract with antioxidant activity for the prevention of photoaging and oxidative-stress-mediated diseases (Almeida et al. 2010).

Gamma irradiation is a possible feasible alternative to substitute the traditional quarantine chemical fumigation with methyl bromide to extend post-harvest shelf-life of food. Results of studies appeared to indicate that storage favoured chestnuts antioxidant potential as assessed by DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging activity, reducing power and inhibition of β-carotene bleaching capacity (Antonio et al. 2011). In addition, the application of gamma irradiation also appeared to be advantageous for antioxidant activity, independently of the dose used (0.27 or 0.54 kGy).

Photoprotective Activity

The in-vivo patch test carried out on 20 volunteers showed that, with respect to irritant effects, chestnut leaf extract could be regarded as safe for topical application (Almeida et al. 2008b). Topical application of natural antioxidants had proven to be effective in protecting the skin against ultraviolet-mediated oxidative damage and to provide a straightforward way to strengthen the endogenous protection system. Further studies proposed that glycerine with a pH around 5 was the best vehicle for topical formulations incorporating *C. sativa* leaf extract with antioxidant activity for the prevention of photoaging of the skin and oxidative-stress-mediated diseases (Almeida et al. 2010).

Anticancer Activity

The concentration of ellagic acid, a naturally occurring inhibitor of carcinogenesis, in chestnut fruits and bark was generally increased after hydrolysis due to the presence of ellagitannins in the crude extract (Vekiari et al. 2008). The concentration varied between 0.71 and 21.6 mg/g (d.w.) in non-hydrolyzed samples, and between 2.83 and 18.4 mg/g (d.w.) in hydrolyzed samples. In chestnut fruits, traces of ellagic acid were present in the seed, with higher concentrations in the pellicle and pericarp. However, all fruit tissues had lower concentrations of ellagic acid than the bark.

Xylans, 4-O-methylglucuronoxylan (MGX) and a homoxylan (HX), were purified from delignified holocellulose alkaline extracts of *Castanea sativa* (Barbat et al. 2008). The xylan, MGX inhibited the proliferation of A431 human epidermoid carcinoma cells with an IC_{50} value of 50 μM (Moine et al. 2007; Barbat et al. 2008). In addition, this xylan inhibited A431 cell migration and invasion. Preliminary experiments showing that secretion of metalloproteinases MMP2 and MMP9 by A431 tumour cells was inhibited by the purified MGX strongly suggesting that this mechanism of action may play a role in its anti-migration and anti-invasive properties.

Antigastroenteritic Activity

Seeds of *C. sativa* were reported to be used in paediatrics for treatment of gastroenteritis and as a gluten-free diet in cases of coeliac disease (Živković et al. 2009a, b). A new pyrrole alkaloid, methyl-(5-formyl-1*H*-pyrrole-2-yl)-4-hydroxybutyrate, was isolated from sweet chestnut seeds (Hiermann et al. 2002).

Antibacterial Activity

An ethyl acetate extract of *C. sativa* was shown to have pronounced antibacterial effects against seven of the eight strains of Gram-positive and Gram-negative bacteria used (MIC in the range of 64–256 μg/ml and MBC in the range of 256–512 μg/ml) (Basile et al. 2000). The active fraction contained rutin, hesperidin, quercetin, apigenin, morin, naringin, galangin and kaempferol. The highest bactericidal activity was shown by quercetin, rutin and apigenin. was tested.

Staphylococcal quorum sensing is encoded by the AGR locus and is responsible for the production of δ-hemolysin (Quave et al. 2011). Studies found that the extracts from three medicinal plants (*Ballota nigra, Castanea sativa*, and *Sambucus ebulus*) exhibited a dose-dependent response in the production of δ-hemolysin, indicating anti-quorum sensing activity in a pathogenic methicillin-resistant *Staphylococcus aureus* (MRSA) isolate.

Antithrombin Activity

Of selected Slovak medicinal plants, the methanol extract of *C. sativa* exhibited the most distinct inhibition activity to thrombin with IC_{50} = 73.2 μg/ml (Jedinak et al. 2010). The methanol extract also had strong inhibition activity to protease trypsin with IC_{50} values below 10 μg/ml.

Antidiarrhoeal Activity

Stop Fitan®, a dietary supplement based on the bioactive purified natural extract of chestnut (*Castanea sativa*) wood and *Saccharomyces boulardii*, a nonpathogenic yeast strain has been proposed as a co-adjuvant in the therapy of diarrhea (Budriesi et al. 2010). Studies showed that natural extract of chestnut wood rich in hydrolyzable tannins, exerted spasmolytic effects in guinea pig ileum and proximal colon. The findings, coupled with the antibacterial, antiviral, and antispasmodic properties of tannins, suggest that the combination of chestnut tannins and *S. boulardii* may be relevant to treat diarrhea by Stop Fitan®.

Hypersensitivity Problem

Only occasionally does chestnut cause hypersensitivity. There were only a few reported cases, depending on cross-reactivity in previously latex-hypersensitive patients. The case of oral allergy syndrome to chestnut appeared to be a manifestation of immediate IgE-dependent hypersensitivity resulting from direct contact between food and the oral mucosa (Antico 1996).

Traditional Medicinal Uses

In the Middle Ages the raw seeds were found useful in the treatment of heart disorders. *C. sativa* leaves were used in folk medicine as a tea in France to treat whooping cough and diarrhoea. Beside the leaves, the bark is also a good source of tannins. They are antiinflammatory, expectorant, tonic and astringent. The astringent activity is useful in the treatment of bleeding and diarrhoea. Leaf infusions are employed in respiratory diseases and are a common therapy for whooping cough, fevers and ague. The leaves are also employed in the treatment of rheumatism, to ease lower back pains and to relieve stiff muscles and joints. A decoction is used as gargle for treating sore throats. A hair shampoo can be made from infusing leaves and fruit husks. Leaves are used in homeopathy for therapy of depression and fatigue.

Other Uses

The Spanish chestnut is a magnificent huge shade tree for parks, estates and avenues and sometimes planted for erosion control in Mediterranean countries. The flowers provide good forage for bees. A blackish-brown dye is extracted from the leaves and the bark and also an oil which is medicinal. Tannin is obtained from the bark and used in tanning. The wood, leaves and seed husks also contain tannin. The seed meal can be used as a source of starch, for fattening stock and also for whitening linen cloth. A hair shampoo is made from the leaves and the husks of the fruits. The wood is good for carpentry, turnery, furniture, barrels, roof beams, props, basketry and fence posts. It is also a very good fuel.

Comments

Chestnut tree responds well to coppicing, a traditional method of woodland management.

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