T. K. Lim

Edible Medicinal and Non-Medicinal Plants

Volume 5, Fruits

Springer

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Contents

Poaceae

Introduction

This book continues as volume 5 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: Apiaceae, Brassicaceae, Chenopodiaceae, Cunoniaceae, Lythraceae, Papaveraceae, Poaceae, Polygalaceae, Polygonaceae, Proteaceae, Ranunculaceae, Rhamnaceae, Rubiaceae, Salicaceae, Santalaceae, Xanthorrhoeaceae and Zingiberaceae. However, not all the edible species in these families are included. The species with edible fruits dealt with in this work include lesser-known, wild and underutilized crops and also common and widely grown crops.

As in the preceding four 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.

Apiaceae or more commonly known as the parsley or carrot family comprises about 434 genera and 3,700 species. Most species are temperate, aromatic herbs with hollow stems and sheathing petioles. Four species with edible fruit/seed used as spices, namely *Carum carvi*, *Cuminum cyminum*, *Foeniculum vulgare* and *Trachyspermum ammi*, are covered in this volume. All have essential oils and various pharmacological properties. The fruits, seeds, flowers, leaves, shoots, stems, sprouted seedlings of fennel, together with the swollen petiole bases (*F. vulgare* subspecies var. *azoricum*) and swollen roots are all edible.

Brassicaceae commonly refer to as the mustard, cabbage or crucifer family is a medium-sized but economically important family of flowering plants with over 338 genera and 3,709 species (Warwick et al. 2006). In their Brassicaceae Species Checklist Database approximately 14,000 taxonomic names are listed and 39 *Brassica* species have been accepted. The family consists of economically well-known species such as the mustards (*Brassica nigra* – black mustard, *B. juncea* – brown mustard and white mustard *Sinapis alba*), *Brassica oleracea* (broccoli, Brussels sprouts, cabbage, cauliflower, kale, etc.), *Brassica rapa* (turnip, Chinese cabbage, etc.), *Brassica napus* (rapeseed/canola, etc.), *Brassica napobrassica* (rutabaga/swede), *Raphanus sativus* (common radish), *Armoracia rusticana* (horseradish), and *Matthiola* (stock) ornamental species. Only two species with edible seeds are covered in this volume, *B. nigra* a well known spice and *B. napus* the seeds are also used a spice but is better known for its oil, canola/rapeseed oil. Both species are rich in nutrients, glucosinolates, flavonoids and volatiles that posses important pharmacological properties that include anticancer, antimicrobial, antihyperlipidemic

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activities to name a few. Other edible species of this family used as leafy, flower or root vegetables are covered in subsequent volumes.

Chenopodium quinoa or quinoa, a psuedocereal, is the only member of the flowering plant family Chenopodiaceae, the goosefoot family, covered in this volume. The family has about 100 genera and 1,400 species of annual herbs or subshrubs, rarely small trees, in temperate and subtropical regions of both hemispheres in all continents except the polar ones. Quinoa is a highly nutritious, gluten-free grain, containing more proteins than other cereals with a good balance of all 8 essential amino acids, high in fibre and has a low glycaemic index (GI). Other important economic edible species include *Beta vulgaris* and *Spinacea oleracea* which are covered in later volumes.

Cunoniaceae is a lesser known, small family of flowering trees, shrubs and liana with 265 species in 29 genera. The species are found in tropical and temperate regions especially in the southern hemisphere – Australasia, South Africa, South America and in Central America and Malaysia. One species *Davidsonia pruriens* or locally called Davidson's plum is indigenous to Australia and is covered in this volume. This species has edible fruit that makes excellent jams, sauces, cordial and a full-flavoured, dry red wine. Like members of the family it has anthocyanins that can be used as food colorants.

Poaceae a large and cosmopolitan family of monocotyledonous annual or perennial flowering plants, herbaceous, sometimes tall woody culms (bamboos) usually cylindrical, jointed, often hollow in the internodes, closed at the nodes. The family has been called grass family and represent the fifth-largest plant family with 777 plant genera and 11,461 species name names being accepted (The Plant List 2010). Grasses are of major economic significance as they provide about 60% of food for human consumption, for animal feed, industry and lawns. The principal cereals are, in order of importance, wheat, rice, maize, barley, oats, sorghum, rye and several grasses usually grouped together and termed 'millets'. Rice is grown largely in the tropics and subtropics, is the staple diet for half the world's population, while wheat is the preferred cereal crop in temperate regions and maize in Central and South America. Grasses are of prime importance to the meat, poultry, dairy and wool industries as they provide feed for animals in the form of grazing pastures, fodder and grains. Ten cereal species are covered in this volume: *Avena sativa*, *coix lachryma-jobi*, *Echinochloa frumentacea*, *Hordeum vulgare*, *Oryza sativa*, *Setaria italicum*, *Sorghum bicolor*, *Trticum aestivum*, *Zea mays* and *Zizania palustris*.

Papaveraceae or commonly known as the poppy family, is an economically important family of flowering plants with 44 genera and about 770 species. The family is cosmopolitan, occurring in temperate and subtropical climates but almost non-existent in the tropics. Unripe capsules of *Papaver somniferum* is the source of commercial opium, and numerous species from *Papaver*, *Eschscholtzia*, *Meconopsis*, *Argemone*, etc. are cultivated as ornamentals. *P. somniferum* is included in this volume as poppy seeds are an important food item providing poppy seed spice and the healthful edible poppy seed oil.

Polygalaceae, the milkwort family, comprises about 17 genera and 900–1,000 species of herbs, shrubs and trees, in tropical and subtropical regions of both hemispheres. One species with edible fruit indigenous to Malaysia, Indonesia and the Philippines, *Xanthophyllum amoenum* is treated in this volume. The fruit has been used in local folkloric medicine.

Polygonaceae is a family of flowering plants commonly known as knotweed family, smartweed family and buck-wheat family. It has about 1,200 species in about 50 genera of herbs, shrubs, or rarely trees found worldwide but with greatest diversity in the northern temperate zone. Economically important genera with edible species include *Rumex* (sorrel), *Persicaria* (e.g. Vietnamese mint), *Fagopyrum*, *Coccoloba*, and *Rheum* (rhubarb). *Coccoloba uvifera*, sea-grape with edible fruit and *Fagopyrum esculentum* buckwheat with edible grains are treated in this volume. The other remaining genera consumed as vegetables and potherbs are treated in later volumes.

Proteaceae family comprises 80 genera and about 1,780 species of mainly flowering shrubs and trees (exception *Stirlingia* herbaceous plant). The species are widespread in the southern hemispheres with a few species in the northern hemisphere. Together with the Platanaceae and Nelumbonaceae, they make up the order Proteales. In Australia, well known genera include *Protea*, *Banksia*, *Embothrium*, *Grevillea*, *Hakea*, *Dryandra* and *Macadamia*. Many are cultivated by the nursery industry for their prominent and distinctive flowers and foliage. Some are cultivated for the fresh and dried cut-flower industry. Others are cultivated for their edible nuts like *Gevuina avellana* (Chilean hazelnut) in Chile and New Zealand and Macadamia species in Australia, South Africa and Hawaii. *Macadamia integrifolia* and *M. tetraphylla*, indigenous to Australia are covered in this volume.

Rubiaceae, the coffee or madder family, is the fifth largest family of flowering plant by number of genera, and the fourth or fifth largest by number of species with about 611 genera and 13,000 species. The species are shrubs (mostly), trees, lianas and herbs with the greatest diversity in the warm, humid, tropical climates. Following molecular phylogenetic studies by the Angiosperm Phylogeny Group, a number of traditionally accepted families (Dialypetalanthaceae, Henriqueziaceae, Naucleaceae, and Theligonaceae) are now subsumed under Rubiaceae. Economically important crops are coffee (world's second most important economic commodity after petroleum), noni, cinchona (whose bark yields quinine), and ornamental plants like *Ixora*, *Pentas*, *Coprosma* and *Gardenia*. Included in this volume are four species with edible fruits, *Nauclea orientalis*, *Morinda citrifolia* (noni), *Coffea arabica* (Arabica coffee), *C. canephora* (robusta coffee) and *C. liberica* (liberica coffee). The pharmacological impact of coffee consumption and health are elaborated under the three *Coffea* chapters.

Ranunculaceae (buttercup or crowfoot) family comprises about 60 genera and 2,500 species distributed globally. Most are herbaceous plants, but with some woody climbers (such as *Clematis*) and subshrubs (e.g. *Xanthorhiza*). Many are common and well-known ornamentals such as many genera are well known as cultivated flowers, such as *Aconitum* (monkshood), *Clematis*, *Consolida* (larkspur), *Delphinium* (larkspur), *Helleborus* (Christmas rose), *Ranunculus* (Buttercup), *Trollius* (globeflower). One species with edible seeds used as spice in Asian and Middle Eastern cuisine, *Nigella sativa* or black cumin, is treated in this volume. Black cumin has been used in herbal folk medicine and has various pharmacological attributes like anticancer, antiinflammatory, antiarthritic, antimicrobial, antidyslipidemic, hypotensive, cardioprotective, antinociceptive, anxiolytic antidiabetic activities etc. A volatile oil and fixed oil are obtained from the seeds.

Rhamnaceae, the Buckthorn family contains 50–60 genera and about 900 species of flowering plants distributed globally but mostly in tropical or subtropical areas. Members are deciduous or evergreen often thorny trees, shrubs, woody climbers, or lianas, rarely herbs. Economically important plants include some *Rhamnus* species used as medicine, source of dyes and drugs; *Alphitonia*, *Colubrina*, *Hovenia*, and *Ziziphus* species providing timber for construction, fine furniture, carving, lathe work, and musical instruments; *Hovenia*, *Paliurus*, and *Rhamnus* species cultivated as ornamentals and *Ziziphus* and *Hovenia* spp yielding edible plant parts. *Z. jujuba* (Chinese jujube) and *Z. mauritania* (Indian jujube) yielding edible fruit and *Hovenia dulcis* (Chinese raisin tree) cultivated for its edible fruit and fleshy inflorescence stalks are included in this volume. All three also have medicinal attributes.

Salicaceae or the willow family is placed under the order Malpighiales. Recent phylogenetical studies by the Angiosperm Phylogeny Group (APG) has greatly expanded the circumscription of the family to contain 55 genera and about 1,210 species. Many members of the Flacourtiaceae including the type genus *Flacourtia*, have now been transferred to the Salicaceae in the molecular phylogeny-based classification, known as the APG II system. Other members have been transferred mostly to Achariaceae and Samydaceae. Thus, the botanical family, Flacourtiaceae, is now defunct. The species in Salicaceae are mostly evergreen (deciduous) trees and less often shrubs, distributed pan-tropically to temperate and to arctic zones. Seven species with edible fruit, namely *Dovyalis hebecarpa*, *Flacourtia indica*, *Flacourtia inermis*, *Flacourtia jangomas*, *Flacourtia rukam and Pangium edule* are covered in this volume. Several of these species have been used in traditional medicine.

Santalaceae comprises about 36 genera and 500 species distributed world wide but chiefly in tropical and warm dry regions. They are partially parasitic on other plants and grow as shrubs, tree and herbs, semiparasitic on the roots of host plants. *Santalum album* or sandalwood tree is of economic importance providing valuable fragrant timber used in carving and carpentry, and as a form of incense and for joss sticks. Sandalwood oil is used in soap, perfumes, and massage oils. *Exocarpos cupressiformis* called the Australian cherry has edible fruit. Another species with edible fruit *Santalum acuminatum* (sweet quandong) is indigenous to Australia. It has been used in folkloric medicine by Australian aborigines and is treated in this volume.

Xanthorrhoeaceae is a small family of flowering plants in the order Asparagales. The family comprises 24 genera and 456 accepted species name although 1,318 species names have been recorded. The family has a wide but scattered distribution in the tropics and temperate regions. Many species are cultivated as ornamentals and for cut-flowers. Several species of *Aloe* are cultivated for their leaf sap with medicinal and cosmetic uses. One species with edible fruit, *Dianella caerula*, found in Australia and New Guinea is treated in this volume.

Zingiberaceae, the ginger family, contains about 52 genera and more than 1,300 species distributed pantropically in Africa, Asia and the Americas with greatest diversity in southeast Asia. The species are aromatic, perennial herbs with distichous leaves with basal sheaths that overlap to form a pseudostem and creeping horizontal or tuberous rhizomes. At the Third Symposium on Zingiberaceae, Dr. W. John Kress proposed a new classification of Zingiberacea based on recent research, including molecular phylogenetic analyses and morphological features. He has proposed four subfamilies and six tribes: Siphonochiloideae with tribe Siphonochileae, Tamijioideae with tribe Tamijieae, Alpinioideae with tribes Akpinieae and Riedelieae, Zingiberoideae with tribes Zingibereae and Globbeae. The family include many important ornamental, spices and medicinal plants. Ornamental species include the shell gingers (*Alpinia* spp.), Siam or summer tulip (*Curcuma alismatifolia*), *Globba* spp., ginger lily (*Hedychium* spp.), *Kaempferia* spp., torch-ginger *Nicolaia* spp., *Renealmia* spp. and ginger (*Zingiber* spp.). Spices include ginger (*Zingiber* spp.), galangal or Thai ginger (*Alpinia galanga* and others), melegueta pepper (*Aframomum melegueta*), myoga (*Zingiber mioga*), turmeric (*Curcuma longa*) and cardamom (*Amomum* spp., *Elettaria* spp.). Six species with edible fruits are covered in this volume: *Amomum aromaticum*, *A. compactum*, *A. longiculare*, *A. subulatum*, *Amomum taso-ko* and *Elletaria cardamomum*. Other edible members are treated in subsequent volumes.

Selected References

Angiosperm Phylogeny Group (1998) An ordinal classification for the families of flowering plants. Ann Mo Bot Gard 85(4):531–553

Angiosperm Phylogeny Group II (2003) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. Bot J Linn Soc 141:399–436

Angiosperm Phylogeny Group III (2009) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot J Linn Soc 161:105–121

Bedford DJ, Lee AT, Macfarlane TD, Henderson RJF, George AS (1986) Xanthorrhoeaceae. In: George AS (ed) Flora of Australia: Iridaceae to Dioscoreaceae, vol 46. Australian Government Publishing Service, Canberra, pp 88–171

Bremer B (2009) A review of molecular phylogenetic studies of Rubiaceae. Ann Mo Bot Gard 96(1):4–26

Chantaranothai P, Larsen K, Sirirugsa P, Simpson D (eds) (2002) Proceedings of the third symposium on the Family Zingiberaceae. Khon Kaen, Thailand, 7–12 July 2002

Chase MW, Zmarzty S, Lledó MD, Wurdack KJ, Swensen SM, Fay MF (2002) When in doubt, put it in Flacourtiaceae: a molecular phylogenetic analysis based on plastid rbcL DNA sequences. Kew Bull 57(1):141–181

Chen Y, Schirarend C (2007) Rhamnaceae. In: Wu ZY, Raven PH, Hong DY (eds) Flora of China, vol 12, Hippocastanaceae through Theaceae. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis

Chen SK, Ma HY, Parnell JAN (2008) Polygalaceae. In: Wu ZY, Raven PH, Hong DY (eds) Flora of China, vol 11, Oxalidaceae through Aceraceae. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis

Clayton WD, Harman KT, Williamson H (2006 onwards) GrassBase – the online World Grass Flora. http://www.kew.org/data/grasses-db.html

Davis AP, Govaerts R, Bridson DM, Ruhsam M, Moat J, Brummitt NA (2009) A global assessment of distribution, diversity, endemism, and taxonomic effort in the Rubiaceae. Ann Mo Bot Gard 96(1):68–78

Graham SA, Thorne RF, Reveal JL (1998) Validation of subfamily names in Lythraceae. Taxon 47(2): 435–436

Graham SA, Hall J, Sytsma K, Shi SH (2005) Phylogenetic analysis of the Lythraceae based on four gene regions and morphology. Int J Plant Sci 166(6):995–1017

Hall JC, Sytsma KJ, Iltis HH (2002) Phylogeny of Capparaceae and Brassicaceae based on chloroplast sequence data. Am J Bot 89(11):1826–1842

Heywood VH, Brummitt RK, Seberg O, Culham A (2007) Flowering plant families of the world. Firefly Books, Richmond Hill

Huxley AJ, Griffiths M, Levy M (eds) (1992) The new RHS dictionary of gardening (4 Vols). MacMillan, New York

Kress WJ, Prince LM, Williams KJ (2002) The phylogeny and a new classification of the gingers (Zingiberaceae): evidence from molecular data. Am J Bot 89(10): 1682–1696

Miller RB (1975) Systematic anatomy of the xylem and comments on the relationships of Flacourtiaceae. J Arnold Arbor 56(1):79

Morris DI (2009) Papaveraceae. Flora of Tasmania online. Version 2009:1. http://demo1.tmag.tas.gov.au/treatments/families/Papaveraceae/Papaveraceae_2009_1.pdf

Orchard E (ed) (1995) Proteaceae. Flora of Australia, Volume 16: Elaeagnaceae, Proteaceae 1. Australian Biological Resources Study/CSIRO Publishing, Melbourne. 522 pp

She M, Pu F, Pan Z, Watson M, Cannon JFM, Holmes-Smith I, Kljuykov EV, Phillippe LR, Pimenov MG (2005) Apiaceae. In: Wu ZY, Raven PH, Hong DY (eds) Flora of China, vol 14, Apiaceae through Ericaceae. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis, pp 1–205

Stevens PF (2001 onwards). Angiosperm phylogeny website. Version 9, June 2008. http://www.mobot.org/MOBOT/research/APweb/

The Plant List (2010) Version 1. Published on the Internet; http://www.theplantlist.org/

Warwick SI, Francis A, Al-Shehbaz IA (2006) Brassicaceae: species checklist and database on CD-Rom. Plant Syst Evol 259:249–258

Watson L, Dallwitz MJ (1992 onwards) The families of flowering plants: descriptions, illustrations, identification, and information retrieval. Version: 4th March 2011. http://delta-intkey.com

Wilson AJG (ed) (1999) Flora of Australia: Volume 17B: Proteaceae 3: Hakea to Dryandra. Australian Biological Resources Study/CSIRO Publishing, Melbourne

Wilson AJG (ed) (2000) Flora of Australia. Volume 17A Proteaceae 2 Grevillea. Australian Biological Resources Study/CSIRO Publishing, Melbourne, 524 pp

Zhu G, Mosyakin SL, Clemants SE (2003) Chenopodiaceae Ventenat. In: Wu ZY, Raven PH, Hong DY (eds) Flora of China, vol 5, Ulmaceae through Basellaceae. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis

Carum carvi

Scientific Name

***Carum carvi* L.**

Synonyms

Bunium carvi (L.) M. Bieb., *Carum aromaticum* Salisb., *Carum carvi* f. *gracile* (Lindl.) H. Wolff, *Carum carvi* var. *gracile* (Lindl.) H. Wolff, *Carum carvi* f. *rhodochranthum* A.H. Moore, *Carum carvi* subsp. *rosellum* (Woronow) Vorosch., *Carum carvi* f. *rubriflora* H.Wolff, *Carum carvi* f. *rubriflorum* H. Wolff, *Carum decussatum* Gilib. (Inval.), *Carum gracile* Lindl., *Carum officinale* Gray, *Carum rosellum* Woronow, *Carum velenovskyi* Rohlena, *Carvi careum* Bubani, *Falcaria carvifolia* C.A. Mey., *Foeniculum carvi* (L.) Link, *Karos carvi* Nieuwl. & Lunell, *Lagoecia cuminoides* Soy.-Will., *Ligusticum carvi* Roth, *Pimpinella carvi* Jess., *Selinum carvi* E.H.L. Krause, *Seseli carum* Scop., *Seseli carvi* Spreng., *Sium carum* F.H. Wigg., *Sium carvi* Bernh.

Family

Apiaceae

Common/English Names

Caraway, Carum, Carvies, Medidein Fennel, Persian Cumin, Wild Cumin.

Vernacular Names

Albanian: Qimnoni;
Arabic: Al-Karawya, Kammûn Armanî, Karaway, Karawiaa, Karawiya;
Azeri: Adi Cirə;
Armenian: Chaman, Chaman;
Basque: Xarpoil;
Belarusian: Kmen;
Brazil: Alcarávia (Portuguese);
Bulgarian: Kim;
Burmese: Ziya;
Catalan: Comi De Prat;
Chinese: Goht Leuih Ji (Cantonese), Fang Feng, Ge Lü Zi, Yuan Sui (Mandarin);
Croatian: Kim;
Czech: Kmín, Kmín Kořenný, Kmín Luční;
Danish: Almindelig Kommen, Karve, Kommen, Vild Kommen;
Dutch: Echte Karwij, Karwij, Karwijzaad, Kummel, Wilde Komijn;
Eastonian: Harilik Köömen;
Egypt: Karawyâ;
Esperanto: Karvio;
Farsi: Miweh Zireh;
Finnish: Kumina, Saksan Kumina, Tavallinen Kumina;
French: Anis Des Vosges, Carvi, Cumin De Montagne, Cumin Des Prés, Carvi, Faux Anis, Faux Cumin, Grains De Carvi, Kummel;
Gaelic: Carbhaidh, Carvie, Cearbhas, Lus Dearg;
Galician: Alcaravea, Alcaravía;
Georgian: T'mini;

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German: Echter Kümmel, Feldkümmel, Feld-Kümmel, Gemeiner Kümmel, Kümmel, Matten-kümmel, Wiesenkümmel;
Greek: Κάρο, Καρβί, Karo, Karon, Karvi;
Hebrew: Cravy Tarbutit, Kravyah, Kimel, Kimmel, Kravyah, Qimel;
Hungarian: Köméný, Köménymag, Konyhakömény, Réti Kömény;
Icelandic: Kúmen;
India: Jira (Bengali), Farili Dhamui (Dhivehi), Gunyan, Jangi Dhania, Jeerka, Jeero, Kaalaa Jiiraa, Kalazera, Kalazira, Kalazird, Shiajira, Siya Jeera, Vilayati jira, Zira (Hindu), Gonyorog (Lahaul), Sajiragam, Sajirakam (Malayalam), Shahajire (Marathi), Sahajira (Oriya), Bahugandha, Bhedanika, Bhedini, Hridya, Jarana, Jiraka, Kalajiraka, Kalameshi, Karavi, Karavi Asitajiraka, Karunjiraka, Krishna, Krishnajaji, Krishnajeeraka, Krishnajiraka, Krsnajiraka, Mashmirajiraka, Nila, Nilakana, Patu, Raka, Ruchya, Sugandha, Sushavi, Syahajira, Udgarashodhini, Vantishodhini, Varshakali (Sanskrit), Gonyod (Spiti), Appaka-caccompucceti, Appakacam, Cimai Compu, Cimai Peruncirakam, Cimaiccirakam, Cimaic-compu, Cimaivitai, Karuncirakam, Kekku Vitai, Kekkuvirai, Kekkuvitai, Keturuvirai, Malaiccompu, Pilappu-Chirakam, Shimayi-Shombu, Simaishembu (Tamil), Seema Jeeraka, Seemai Sompu, Shimaisapu (Telugu), Karawiyah, Syah Zira, Zeera Siyah, Zira Siyah (Urdu);
Indonesia: Jintan;
Italian: Caro, Carvi, Comino, Comino Tedesco, Cumino, Cumino Dei Prati, Cumino Tedesco, Finocchio Medionale, Kümmel, Seme Di Carvi;
Japanese: Himeuikyō, Kyarawei;
Korean: Kaereowei, Kaerowei;
Latin: Careum, Carvum;
Latvian: Pļavas Ķimene, Ķimenes;
Lithuanian: Paprastasis Kmynai;
Macedonian: Kim, Kimel;
Malaysia: Jintan;
Mongolian: Gon'd;
Morocco: Faux Cumin;
Norwegian: Karve, Karvi, Karving, Kømming, Kyrdd;
Pashto: Carabia;
Persian: Karoya, Kharawjá;
Polish: Kminek, Kminek Zwyczajny;
Portuguese: Alcaravia, Semente De Alcarávia, Cominho;
Romanian: Chimion, Chimen;
Russian: Tmin, Tmin Obyknovennyi;
Serbian: Kim, Divlji Kumin;
Slovaščina: Kumina, Kumina Navadna, Navadna Kumina;
Slovencina: Rasca Lúčna, Rasca, Kmin;
Spanish: Alcarahueya, Alcaravea, Alcaravia, Carvi, Comino De Prado, Hinojo De Prade, Hinojo De Prado;
Swahili: Kisibiti;
Swedish: Brödkummin, Karven, Kommel, Kommen, Kumin, Kummil, Kummin, Kumming;
Thai: Hom pom, Tian takap;
Tibetan: Go-snyod, Gonyod, Zi Ra Nag Po;
Turkish: Frenk Kimyonu, Hakiki Kimyon, Karaman Kimyonu;
Ukrainian: Dikyj Anis, Kmyn, Kmyn Zwychajnyj;
Vietnamese: Ca Rum;
Yiddish: Kimmel, Kiml.

Origin/Distribution

This species is native to Europe and West Asia but its exact origin is unclear. It is cultivated in many areas of Europe, the Mediterranean, South-west, Middle and temperate Eastern Asia, India and North America. Major producing countries are Norway, Sweden, Finland, Great Britain, the Netherlands, Germany, Poland, Czech Republic, Austria, Hungary, Ukraine, Russia, Morocco, Egypt, Syria and India. The Netherlands is usually the main exporting country. Within India, it is found growing wild in Himachal Pradesh and is cultivated in the hills and plains of North India and in the hills of South India.

Agroecology

Its natural habitat includes forests, brushy alpine meadows, riparian grasslands, fields, ruderal areas from 1,500 to 4,300 m. The plant prefers warm, sunny locations and well-drained soil rich in organic matter. In warmer regions it is planted in the winter months as an annual. In temperate climates, it is planted as a summer annual or biennial.

Edible Plant Parts and Uses

Caraway fruit have a pungent, aromatic anise-like flavour and is used as a spice in culinary dishes, confectionery, bread, beverages and liquors. The whole fruit, or powder or the essential oil is used. Caraway is widely used in southern German and Austrian cuisine, with meat (roast pork *Schweinsbraten*), vegetable or rye bread. It is also popular in Scandinavia particularly in the Baltic states, but is hardly known in Southern European cuisine. Caraway is commonly added to *sauerkraut* (fermented cabbage). It is also used to add flavor to cheeses such as *bondost*, *pultost*, *nøkkelost* and *havarti*. Caraway is also used in casseroles, curries, salads and other foods. In Britain, it has been used to make '*seedy cake*' similar to a Madeira cake. Caraway is also important in cuisines of North Africa, particularly in Tunisia and Yemen, in Tunisian *harissa* (fiery paste with chillies) and Yemenese *zhoug*. The essential oil is used as a flavouring in ice creams, candy, soft drinks, liquors. It is used in the traditional Scandinavian spirit '*Akavit*,' and other liquors like kümmel.

The crushed fruits and leaves are brewed into a tea, with a soothing effect on digestion. The leaves are eaten raw or cooked as a flavouring in soups and dishes or as spinach. Young leaves are less spicy than the seeds and are used in salads. The roots are used as a root vegetable like parsnip.

Botany

A glabrous, branched plant, 30–70 (120) cm tall with elongated fusiform taproot. Leaves are green, bipinnatisect with ultimate segments linear or linear-lanceolate, 3–5 × 1–2 mm; lower leaves petiolate, upper sessile, base sheathing, and leaves reduced upwards. ultimate segments linear or linear-lanceolate, 3–5 × 1–2 mm. Leaves reduced upwards. Umbels 2.5–6 cm across, rays 3–10, 0.6–4 cm, extremely unequal; bracteoles absent; umbellules 4–15-flowered. Calyx teeth obscure, petals white or pinkish. Fruits ellipsoid to crescent-shaped yellowish brown achenes, 4–6 mm long by 1–1.5 mm wide, with five prominent pale ridges (Plate 1), furrows 1-vitta; commissure 2-vittae.

Plate 1 Caraway fruits

Nutritive/Medicinal Properties

The nutrient value of caraway seeds per 100 g edible portion had been reported to be: water 9.87 g, energy 333 kcal (1,393 kJ), protein 19.77 g, total lipid (fat) 14.59 g, ash 5.87 g, carbohydrate 49.90 g, total dietary fibre 38.0 g, total sugars 0.64 g, Ca 689 mg, Fe 16.23 mg, Mg 258 mg, P 568 mg, K 1,351 mg, Na 17 mg, Zn 5.50 mg, Cu 0.910 mg, Mn 1.300 mg, Se 12.1 μg, vitamin C 21.0 mg, thiamin 0.383 mg, riboflavin 0.379 mg, niacin 3.606 mg, vitamin B-6 0.360 mg, total folate 10 μg, total choline 24.7 mg, β- carotene 206 μg, α- carotene 8 μg, β-cryptoxanthin 6 μg, vitamin A 18 μg RAE, vitamin A 363 IU, lycopene 20 μg, lutein + zeaxanthin 454 μg, vitamin E (α-tocopherol) 2.50 mg, total saturated fatty acids 0.620 g, 10:0 (capric acid) 0.010 g, 12:0 (lauric acid) 0.010 g, 14:0 (myristic acid) 0.040 g, 16:0 (palmitic acid) 0.400 g, 18:0 (stearic acid) 0.110 g, total monounsaturated fatty acids 7.125 g, 16:1

undifferentiated (palmitoleic acid) 0.090 g, 18:1 undifferentiated (oleic acid) 7.035 g, total polyunsaturated fatty acids 3.272 g, 18:2 undifferentiated (linoleic acid) 3.122 g, 18:3 undifferentiated (linolenic acid) 0.150 g, tryptophan 0.244 g, threonine 0.756 g, isoleucine 0.826 g, leucine 1.218 g, lysine 1.031 g, methionine 0.361 g, cystine 0.329 g, phenylalanine 0.867 g, tyrosine 0.642 g, valine 1.037 g, arginine 1.252 g, histidine 0.550 g, alanine 0.914 g, aspartic acid 2.084 g, glutamic acid 3.169 g, glycine 1.322 g, proline 0.917 g, and serine 0.946 g (USDA 2012).

Caraway oil is the essential oil obtained by distillating the fruit. The components of caraway fruit oil were: *cis*-carveol, carveol, dihydrocarveol, isodihydrocarveol, neodihydrocarveol (Rothbaecher and Suteu 1975); α-pinene, α-phellandrene, β-phellandrene, α-thujene, β-fenchene, camphene, sabinene, β-pinene, myrcene, *p*-cymene (Salveson and Svendsen 1976); anethofuran (Zheng et al. 1992); main components carvone, limonene (Tewari and Mathela 2003; Iacobellis et al. 2005) and germacrene D, and *trans*-dihydrocarvone (Iacobellis et al. 2005); monoterpenoids and their glucosides: *p*-menthane-2,8,9-triol (Matsumura et al. 2001): *p*-menth-8-ene-1,2-diol, *p*-menthane-1,2,8,9-tetrol, 8,9-dihydroxy-8,9-dihydrocarvone, *p*-menth-ene-2,10-diol 2-*O*-β-D-glucopyranoside, *p*-menthane-1,2,8,9-tetrol 2-*O*-β-D-glucopyranoside, 7-hydroxycarveol-7-*O*-β-D-glucopyranoside (Matsumura et al. 2002b); 2-methoxy-2-(4′-hydroxyphenyl)ethanol, junipediol A 2-*O*-β-D-glucopyranoside and L-fucitol (Matsumura et al. 2002a); flavonoids quercetin 3-glucuronide, isoquercitrin, quercetin 3-*O*-caffeylglucoside and kaempferol 3-glucoside (Kunzemann and Herrmann 1977).

Besides the volatile components in the fruit, caraway oil also contained carvacrol (De Martino et al. 2009) which had been reported to be converted from carvone during the storing process (Rothbaecher and Suteu 1978). Essential oil yields were relatively low and ranged from 0.86 to 1.20% (w/w). Forty-one volatile compounds were identified, the main ones being carvone (76.78–80.53%) and limonene (13.05–20.29%). The main components of the caraway essential oil were identified to be (R)-carvone (37.98%) and D-limonene (26.55%) followed by α-pinene (5.21), *cis*-carveol (5.01%) and β-myrcene (4.67%) (Fang et al. 2010). Twelve major constituents were found in Canadian caraway oil, with a corresponding percentage of 93.9% (Embong et al. 1977). D(+)-carvone and D(+)-limonene accounted for 87.5% of the oil. There were 23 minor and at least 13 trace constituents. FT-Raman spectroscopy showed characteristic bands that could be assigned to lignin, unsaturated fatty acids, and polysaccharides in caraway fruit (Seidler-Lozykowska et al. 2010). Additionally, the essential oil composition showed a great variation in carvone and limonene content among European and breeding accessions.

Total fatty acid (TFA) proportion of caraway seeds varied from 2.95 to 5.68% (w/w) (Laribi et al. 2010). The fatty acid composition of Tunisian caraway seed oil was rich in an unusual fatty acid, petroselinic acid (31.53 and 38.36% of TFA).

Caraway seed oil was found to contain petroselinic and *cis*-vaccenic acid (Reiter et al. 1998).

The following flavonoids were found in caraway leaves: quercetin 3-glucuronide, isoquercitrin, quercetin 3-*O*-caffeylglucoside, kaempferol 3-glucoside, and also isorhamnetin glycosides in low amounts (Kunzemann and Herrmann 1977). Caraway flower was found to contain flavonoids: kaempferol, isoquercetrin, astragalin, hyperoside (Khaleel 2005). Roots of caraway have also been found to contain flavonoids (mean 0.312 mg/g dry weight) (Najda et al. 2008). The seed and root of caraway showed the presence of polyacetylenic compounds (Nakano et al. 1998).

Antioxidant Activity

Cold-pressed black caraway (*Carum carvi*), carrot, cranberry and hemp seed oil extracts exhibited significant antioxidant activities (Yu et al. 2005). The ORAC (oxygen radical absorbing capacity) value ranged from 28 to 220 μmol TE (trolox equivalent)/g oil for the cold-pressed hemp, carrot, and black caraway seed oils, whereas the $ABTS^{\cdot+}$ – scavenging capacity ranged from 8.9 to 30.8 μmol TE/g oil. The greatest total phanolic content, 3.53 mg gallic acid equivalent (GE) per gramme of oil, was detected in the cold-pressed black caraway seed oil extract. Caraway oil extract significantly suppressed the lipid peroxidation in human LDL, with TBARS (thiobarbituric acid-reactive substance) reduction of 3.77 mg/g. Results suggested that the cold-pressed black caraway seed oil may be used as a natural antioxidative food additive for improving food quality and stability and as a dietary source of natural antioxidants for health promotion and disease prevention. The amount of aqueous extract of caraway fruit needed for 50% scavenging of superoxide radicals was found to be 105 μg, for 50% inhibition of lipid peroxide was 2,100 μg and the amount needed for 50% inhibition of hydroxyl radicals was 1,150 μg (Satyanarayana et al. 2004).

Caraway essential oil was found to reduce on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals in a dose and to neutralize hydrogen peroxide, reaching 50% neutralization with IC_{50} values of < 2.5 μl/mL (Samojlik et al. 2010). Caraway essential oil strongly inhibited lipoid peroxidation in both systems of induction. Caraway essential oil appeared promising for safe use in folk medicine and the pharmaceutical and food industries.

Anticancer Activity

Three monoterpenes, anethofuran, carvone and limonene, potential cancer chemopreventive agents, were isolated from caraway oil (Zheng et al. 1992). These compounds induced the detoxifying enzyme glutathione S-transferase in several mouse target tissues. The α, β-unsaturated ketone system in carvone appeared to be critical for the high enzyme-inducing activity. Caraway oil, supplemented in diet or painted on the skin, inhibited 7,12-dimethylbenz[a]anthracene- (DMBA) and croton oil-induced skin tumors in female BALB/c mice (Shwaireb 1993). The inhibition was manifested by disappearance of carcinomas, reduced incidence and number of papillomas, delay of their appearance, retardation of their development, and regression of already established papillomas. Caraway oil was more effective when topically applied than when supplemented in the diet. The fruit and root of caraway was found to have antiproliferative polyacetylenes (Nakano et al. 1998). The antiproliferative activity was determined by MTT assay using the tumor cell lines MK-1 (human gastric carcinoma), HeLa (human epithelial carcinoma) and B16F10 (mouse cutaneous melanoma).

Studies showed that caraway seed extract containing high levels of both flavonoids and steroid-like substances and prepared in three different organic solvents suppressed cytochrome P450 1A1 (CYP1A1) enzyme activity in rat hepatoma cells in a dose-dependent manner (Naderi-Kalali et al. 2005). The extracts added above 0.13 μM could significantly inhibit ethoxy resorufin dealkylation (EROD) activity and higher levels of each extract (1.3 and 13 μM) caused approximately tenfold suppression in the enzyme activity. The data showed that substances in caraway seeds extractable in organic solvents could potentially reverse the TCDD (2, 3, 7, 8-tetrachlorodibenzo-*p*-dioxin)-dependent induction in cytochrome P450 1A1.

Studies in rats showed that caraway supplementation significantly reversed diminished levels of intestinal, colonic and caecal lipid peroxidation products, such as conjugated dienes, lipid hydroperoxides and thiobarbituric acid reactive substances (TBARS) and also the antioxidants superoxide dismutase, catalase, reduced glutathione and glutathione reductase caused by subcutaneous injection of the carcinogen, 1,2-dimethylhydrazine (DMH) (Kamaleeswari and Nalini 2006). Additionally caraway supplementation significantly reduced enhanced activity of intestinal, colonic and caecal glutathione peroxidase, glutathione S-transferase and colonic ascorbic acid and α-tocopherol levels observed in carcinogen-treated rats. Thus, the study showed that caraway supplementation at a dose of 60 mg/kg had a modulatory role on tissue lipid peroxidation, antioxidant profile and prevented DMH-induced histopathological lesions in colon cancer rats. In further studies, caraway supplementation to 1,2-dimethylhydrazine (DMH)-induced colon cancer rats significantly reduced aberrant crypt foci development and also decreased the levels of fecal bile acids, neutral sterols, and tissue alkaline phosphatase activities and modulated oxidative stress significantly as compared to the unsupplemented DMH-treated group (Deeptha et al. 2006; Kamaleeswari et al. 2006). The histological alterations induced by DMH were also significantly improved. The results showed that all three doses, 30, 60, and 90 mg/kg body weight, of caraway inhibited tumorigenesis though the effect of the intermediary dose of 60 mg/kg body weight was more effective than the other two doses. In a recent study, the number of aberrant crypt foci (ACF) and aberrant crypt (AC) induced by 1,2-dimethylhydrazine (DMH) were found to be significantly inhibited in colon of rats treated with caraway essential oils in diet (0.01 and 0.1%) (Dadkhah et al. 2011). Histopathological and biochemical data clearly showed that inhibition of colon premalignant lesions induced by DMH in rats was mediated by interference of caraway oil components in the activities of the main hepatic xenobiotic metabolizing enzymes, cytochrome P4501A1 (CYP1A1) and glutathione S-transferae.

The apoptotic activity of caraway ethanol extract was determined against human leukaemic cell lines: ML-1 – human acute myeloblastic leukaemia, J-45.01 – human acute T cell leukaemia, EOL -human eosinophilic leukaemia, HL-60 – human Caucasian promyelocytic leukaemia, 1301 – human T cell leukaemia lymphoblast, C-8166 – human T cell leukaemia, U-266B1 – human myeloma, WICL – human Caucasian normal B cell, and H-9 – human T cell (Bogucka-Kocka et al. 2008).

Antimutagenic Activity

Hot water, methanol and hexane extracts of caraway were not mutagenic for *Salmonella typhimurium* strains TA98 and TA100 by the Ames assay (Higashimoto et al. 1993). However, when the extracts were treated with nitrite, samples of the water and methanol extracts were mutagenic for strain TA100 without metabolic activation. Its hot water extract (equivalent to 1–2 mg of spice powder) exhibited antimutagenic activity, it reduced the mutagenicity induced by 2.7 nmole (397 ng) of N-methyl-N′-nitro-N-nitrosoguanidine by more than 84%, and that induced by dimethylnitrosamine (1.48 mg) or acridine mustard ICR-170 (10 ng) by 30–60%. However, they did not inhibit the mutagenic activity of 1-nitropyrene, 3-nitrofluoranthene, AF-2, methyl methanesulfonate, N-ethyl-N′-nitro-N-nitrosoguanidine, 2-aminoanthracene, 2-acetylaminofluorene, benzo[a]pyrene or IQ (2-amino-3-methylimidazo[4, 5-f]quinoline).

Hot water extract of caraway seeds inhibited N-methyl-N′-nitro-N-nitrosoguanidine (MNNG)-induced mutation only in the ogt+strains of *Salmonella typhimurium* (Mazaki et al 2006). In the presence of caraway extract, O6-methylguanine DNA adducts in strain YG7100 were decreased in proportion to the decrease of MNNG-induced mutagenesis. Caraway had no effect on cellular concentrations of acid-soluble thiols. These results indicated that caraway did not directly inactivate MNNG and that Ogt-O6-methylguanine-DNA methyltransferase may be involved in the antimutagenic activity of caraway.

Antiulcerogenic Activity

Extracts from the plants *Iberis amara*, *Melissa officinalis*, *Matricaria recutita*, *Carum carvi*, *Mentha x piperita*, *Glycyrrhiza glabra*, *Angelica archangelica*, *Silybum marianum* and *Chelidonium majus*, singly and combined in the form of a commercial preparation, STW 5 (Iberogast) and a modified formulation, STW 5-II, lacking the last three plant constituents, produced a dose dependent anti-ulcerogenic activity associated with a reduced acid output and an increased mucin secretion, an increase in prostaglandin E2 release and a decrease in leukotrienes (Khayyal et al. 2001). The most beneficial effects were observed with the combined formulations STW 5 and STW 5-II in a dose of 10 mL/kg b.w., comparable with cimetidine in a dose of 100 mg/kg b.w. The anti-ulcerogenic activity of the extracts was also confirmed histologically. The cytoprotective effect of the extracts could be partly due to their flavonoid content and to their free radical scavenging properties.

Antihyperlipidaemic Activity

After a single oral administration, caraway fruit extract produced a significant decrease on triglycerides levels in normal rats (Lemhadri et al. 2006). In streptozotocin (STZ)-induced diabetic rats, cholesterol levels were decreased significantly 6 h after caraway treatment. Further, repeated oral caraway extract administration exhibited a significant hypotriglyceridemic and hypocholesterolemic activities in both normal and STZ diabetic rats 15 days after caraway treatment. The authors concluded that the aqueous extract of *Carum carvi* (20 mg/kg) exhibited a potent lipid lowering activity in both normal and severe hyperglycemic rats after repeated oral administration of the extract.

AntihyperglycemicActivity

Aqueous extracts of caraway exhibited a potent anti-hyperglycaemic activity in streptozotocin diabetic rats without affecting basal plasma insulin concentrations (Eddouks et al. 2004). After a single dose or 14 daily doses, oral administration of the aqueous caraway extract (20 mg/kg) produced a significant decrease on blood glucose levels in STZ diabetic rats; the blood glucose levels were nearly normalised 2 weeks after daily repeated oral administration of the extract. No changes were observed in basal plasma insulin concentrations after treatment. Results of another study showed that the normal control, the caraway control and the diabetic rats treated with 10 mg/kg body weight of black caraway oil showed progressive and steady increase in the percent mean weekly body weights, while the diabetic untreated rats and the other test groups showed decreasing and alternating increments respectively in the percent mean weekly body weights (Ene et al. 2007). The blood glucose level in the 10 mg caraway treatment group was significantly reduced compared to the diabetic control and the other treatment groups. They inferred the 10 mg/kg B.W. of caraway oil to be the safe dose that can be used in managing diabetes mellitus. Recent studies showed that caraway had both antihyperglycemic and hypolipidemic activity in diabetic rats (Haidari et al. 2011). Oral administration of caraway caused a significant decrease in blood glucose level of treated rats and alleviated their body weight loss. Further, it caused significant decrease in total cholesterol, and low-density lipoprotein cholesterol levels in the treated animals compared with the diabetic control rats, and with no significant change in triglyceride and high-density lipoprotein cholesterol levels.

Antibacterial Activity

Caraway seed essential oil exhibited antibacterial activity against eight pathogenic bacteria, causing infections in the human body (Singh et al. 2002). The oil was equally or more effective when compared with standard antibiotics, at a very low concentration. The MIC (minimum inhibitory concentration) value of caraway essential oil against *Escherichia coli* was 0.6 and 0.5% against *Staphylococcus aureus* (Mohsenzadeh 2007). The MBC (minimum bactericidal concentration) values were 0.8 and 0.6% for *Escherichia coli* and *Staphylococcus aureus* respectively. Caraway essential oil possessed stronger antifungal and antibacterial potential than did citronella oil when tested 19 fungal and 7 bacterial species, food contaminants, spoilage fungi, as well as plant or fungi and animal pathogens (Simic et al. 2008).

Caraway was one of four essential oil that was found promising for the treatment of intestinal dysbiosis (Hawrelak et al. 2009). The essential oil displayed the greatest degree of selectivity, inhibiting the growth of 12 potential pathogens at concentrations that had no effect on the beneficial members of the human gastrointestinal tract microflora. Caraway seed was found to be inhibitory to the gram-negative bacterium, *Helicobacter pylori* now recognized as the primary etiological factor associated with the development of gastritis and peptic ulcer disease (Mahady et al. 2005). It had an MIC of 25 μg/mL. Caraway, ajowan and *Xanthium brasilicum* exhibited highest in-vitro activity of ten active plants against ten clinical isolates of *Helicobacter pylori* (Nariman et al. 2009). Of three essential oils, caraway oil exhibited the most potent antioxidant activity, due to its content of carvacrol and was most effective against *Bacillus cereus* and *Pseudomonas aeruginosa* but was ineffective against *Lactobacillus* strains (De Martino et al. 2009). Carvacrol proved most active against *Escherichia coli*, and completely inhibited the growth of *Penicillium citrinum*. Caraway volatile oil was found to have antibacterial activity against *Pseudomonous aeruginosa* but not *Proteus vulgaris* (Deb et al. 2010). Caraway effectively inhibited aflatoxin (AFB1) production without any obvious effect on growth of *Aspergillus parasiticus* (Razzaghi-Abyaneh et al. 2009).

Antidyspeptic Activity

Holtmann et al. (2001) using a multicenter, placebo-controlled, double-blind, randomized trial showed that a fixed peppermint oil/caraway oil combination (FPCO) (2×1 capsule daily) improved the NDI (Nepean Dyspepsia Index) subscores for pain and discomfort of the patients (primary efficacy variables) as well as the NDI symptom score and the NDI total score (secondary efficacy variables) compared to the placebo. They also demonstrated that not only patients with severe pain but also patients with severe discomfort responded significantly better to FPCO than to placebo (Holtmann et al. 2002). Overall, efficacy of FPCO combination appeared comparable to chemically defined treatment, e.g. with prokinetics (Holtmann et al. 2003). Due to its good tolerability and safety the fixed peppermint oil/caraway oil could be considered an alternative for the long-term management of these patients.

Ethanol caraway extracts reduced significantly the response of dispersed guinea pig smooth muscle cells to acteylcholine in a dose-dependent manner (Al-Essa et al. 2010). This response may partly explain the beneficial effect of caraway in relieving gastrointestinal symptoms associated with dyspepsia.

Diuretic Activity

Studies in normal maleWistar rats demonstrated that aqueous caraway extract exhibited strong diuretic action confirming their ethnopharmacological use in traditional medicine (Lahlou et al. 2007). From the pattern of excretion of water, sodium and potassium, it was postulated that there were at least two types of active principals present in these extracts, one having a furosemide-like activity and the other a thiazide-like activity.

Adaptogenic Activity

Daily administration of caraway at doses of 100, 200 and 300 mg/kg body weight 1 h prior to induction of stress inhibited the stress induced urinary biochemical changes in a dose dependent manner in rats (Koppula et al. 2009). However no change in the urinary excretion of vanillylmandelic acid and ascorbic acid was observed in normal animals at all the doses studied. The conditioned avoidance response of rats administered with the caraway extract or vehicle increased gradually to 95% over 7–11 days. The cognition, as determined by the acquisition, retention and recovery in rats was observed to be dose dependent. Caraway extract produced significant inhibition of lipid peroxide formation in comparison with ascorbic acid in a dose dependent manner in both liver and brain. The results provided scientific support for the antistress (adaptogenic), antioxidant and nootropic activities of *Carum carvi* extract and substantiates its traditional use as in combating stress induced disorders.

Nephroprotective Activity

High dose of *Carum carvi* aqueous seeds extract (60 mg/kg) showed renoprotection against STZ induced diabetic nephropathy in rats (Sadiq et al. 2010). Administration of caraway extract decreased the elevated levels of glucose, urea, creatinine, total urinary volume, and protein microalbuminuric levels in diabetic rats and increased the decreased body weight of diabetic rats.

Elevated kidney lipid peroxidation and plasma urea/creatinine ratio levels were readily reversed in septic rats treated with caraway essential oil but not in those treated with hydroalcoholic extract (Dadkhah and Fatemi 2011). Unlike lipid peroxidation, the heart and kidney GSH levels were not affected in all treated groups. The data implied that caraway oil probably had a protective role in kidney tissue against oxidative injury in advanced stages of sepsis.

Antiasthmatic and Antianaphylatic Activities

Intragastric administration of carveol and carvone produced protective effects against histamine and acetylcholine -induced asthma in guinea pigs (Tang et al. 1988, 1999). Aerosol administration produced relaxation effect on isolated guinea pig trachea and antagonized the carbachol-induced contractions. Carveol and carvone also inhibited the release of slow-reactive substances (SRS-A) in ovalbumin sensitized guinea pig lung tissue and antagonized SRS-A-induced contractions of isolated guinea pig ileum and inhibited the Dale Schultz reaction of isolated guinea pig trachea.

Antispasmodic Activity

Caraway essential oil inhibited isolated rat uterus contraction to KCl (80 mM) and the phasic contraction to acetylcholine (320 nM) in a concentration-dependent manner, reducing the response to zero at their highest used concentrations. The results indicated that the essential oil may be useful for control of uterus spasm (Sadraei et al. 2003).

Drug Potentiating Activity

CC-1a, chemically standardized butanolic fraction from caraway seed, enhanced the plasma levels of anti-TB drugs, rifampicin, pyrazinamide, and isoniazid in Wistar rat, resulting in increased bioavailability indices (C(max) and AUC) of the drugs (Sachin et al. 2009). A permeation-enhancing property of CC-1a across small intestinal absorptive surface was found to be a contributing factor in its bioavailability enhancing profile.

Insecticidal Activity

Caraway essential was one of five aromatic plants that showed significant larvicidal activity after 24 h exposure against *Anopheles dirus*, the major malaria vector in Thailand, and *Aedes aegypti*, the main vector of dengue and dengue hemorrhagic fever (Pitasawat et al. 2007).

Traditional Medicinal Uses

Caraway has a long history of traditional medicinal use (CSIR 1950; Grieve 1971; Chopra et al. 1986; Bown 1995; Chevallier 1996). Caraway fruit is antispasmodic, antiseptic, aromatic, carminative, digestive, emmenagogue, expectorant, galactogogue and stimulant. It can be chewed raw for immediate relief of indigestion and can also be made into infusions, decocotions or tisanes. It is used in the treatment of bronchitis and as an ingredient in cough remedies for children. The fruit is also used as a remedy for colic, loss of appetite, digestive disorders and as a galactogogue to promote lactation in nursing mothers. A tea made from the fruits or leaves is a stomachic, carminative and is drank to treat flatulence. An infusion of fruits and foliage is used as a vermifuge to dispel intestinal worms. Caraway fruit is one of many plants most commonly used for the treatment of diabetes and hypertension in Moroccan traditional medicine (Tahraoui et al. 2007) and as a diuretic in Moroco (Lahlou et al. 2007). The pungent fruit is used in Tibetan medicine where it is regarded to have an acrid taste and a heating potency.

Other Uses

Caraway seed essential oil is used as a fragrance component in soaps, lotions, and perfumes and as a parasiticide.

The antibacterial activity of caraway essential oil was particularly high against the genera *Clavibacter*, *Curtobacterium*, *Rhodococcus*, *Erwinia*, *Xanthomonas*, *Ralstonia*, and *Agrobacterium*, which are responsible for plant or cultivated mushroom diseases worldwide (Iacobellis et al. 2005). In general, a lower activity was observed against bacteria belonging to the genus *Pseudomonas*. These results suggested the potential use of the caraway essential oil for the control of phytobacterial diseases.

Caraway seed powder exhibited molluscicidal activity in a time and dose dependent manner against the snail *Lymnaea acuminata* with an LC_{50} of 140.58 mg/L at 96 h (Kumar and Singh 2006). The 96 h LC_{50} of column purified fraction of seed powder of *C. carvi* was 5.40 mg/L suggesting the product may be uses as potent molluscicides. Caraway essential oil also showed insecticidal activity. Among the essential oils tested, strong insecticidal activity against the Japanese termite *Reticulitermes speratus* was observed with the essential oils of ajowan (*Trachyspermum ammi*), allspice (*Pimenta dioica*), caraway (*Carum carvi*), dill (*Anethum graveolens*), geranium (*Pelargonium graveolens*), and litsea (*Litsea cubeba*) (Seo et al. 2009). Among the bioactive compounds, phenol compounds exhibited the strongest insecticidal activity among the test compounds. The alcohol and aldehyde groups were more toxic than the hydrocarbons. Responses varied in a dose-dependent manner for each compound. Caraway essential oil was found to possess strong contact toxicity against *Sitophilus zeamais* and *Tribolium castaneum* adults, with LD_{50} values of 3.07 and 3.29 μg/adult, respectively, and also showed strong fumigant toxicity against the two grain storage insects with LC_{50} values of 3.37 and 2.53 mg/L, respectively (Fang et al. 2010). Components of the essential oil, (R)-Carvone and D-limonene showed strong contact toxicity against *S. zeamais* (LD_{50} = 2.79 and 29.86 μg/adult) and *T. castaneum* (LD_{50} = 2.64 and 20.14 μg/adult). (R)-Carvone and D-limonene also possessed strong fumigant toxicity against *S. zeamais* (LC_{50} = 2.76 and 48.18 mg/L) and *T. castaneum* adults (LC_{50} = 1.96 and 19.10 mg/L). Caraway seed essential oil was one of eight plant essential oils that exhibited good insecticidal activity (>90%) against larvae of *Lycoriella ingénue* at 20×10^{-3} mg/mL air (Park et al. 2008).

Comments

The species is a declared terrestrial noxious weed and/or noxious-weed seed in some states in USA.

Selected References

Al-Essa MK, Shafagoj YA, Mohammed F, Afifi FU (2010) Relaxant effect of ethanol extract of *Carum carvi* on dispersed intestinal smooth muscle cells of the guinea pig. Pharm Biol 48(1):76–80

Bogucka-Kocka A, Smolarz HD, Kocki J (2008) Apoptotic activities of ethanol extracts from some Apiaceae on human leukaemia cell lines. Fitoterapia 79(7–8):487–497

Bown D (1995) Encyclopaedia of herbs and their uses. Dorling Kindersley, London, 424 pp

Chevallier A (1996) The encyclopedia of medicinal plants. Dorling Kindersley, London, 336 pp

Chopra RN, Nayar SL, Chopra IC (1986) Glossary of Indian medicinal plants. *(Including the supplement)*. Council Scientific Industrial Research, New Delhi, 330 pp

Council of Scientific and Industrial Research (CSIR) (1950) The wealth of India. A dictionary of Indian raw materials and industrial products. (Raw materials 2). Publications and Information Directorate, New Delhi

Dadkhah A, Fatemi F (2011) Heart and kidney oxidative stress status in septic rats treated with caraway extracts. Pharm Biol 49(7):679–686

Dadkhah A, Allameh A, Khalafi H, Ashrafihelan J (2011) Inhibitory effects of dietary caraway essential oils on 1,2-dimethylhydrazine-induced colon carcinogenesis is mediated by liver xenobiotic metabolizing enzymes. Nutr Cancer 63(1):46–54

De Martino L, De Feo V, Fratianni F, Nazzaro F (2009) Chemistry, antioxidant, antibacterial and antifungal activities of volatile oils and their components. Nat Prod Commun 4(12):1741–1750

Deb RS, Thakur S, Negi A, Kumari M, Sutar N, Jana GK (2010) In vitro antibiotic activity of volatile oils of *Carum carvi* and *Coriandrum sativum*. Int J Chem Anal Sci 1:149–150

Deeptha K, Kamaleeswari M, Sengottuvelan M, Nalini N (2006) Dose dependent inhibitory effect of dietary caraway on 1,2-dimethylhydrazine induced colonic aberrant crypt foci and bacterial enzyme activity in rats. Invest New Drugs 24(6):479–488

Eddouks M, Lemhadri A, Michel JB (2004) Caraway and caper: potential anti-hyperglycaemic plants in diabetic rats. J Ethnopharmacol 94(1):143–148

Embong MB, Hadziyev D, Molnar S (1977) Essential oils from spices grown in Alberta. Caraway oil (*Carum carvi*). Can J Plant Sci 57(2):543–549

Ene AC, Nwankwo EA, Samdi LM (2007) Alloxan-induced diabetes in rats and the effects of black caraway (*Carum carvi* L.) oil on their body weight. Res J Med Med Sci 2(2):48–52

Fang R, Jiang CH, Wang XY, Zhang HM, Liu ZL, Zhou L, Du SS, Deng ZW (2010) Insecticidal activity of essential oil of *Carum carvi* fruits from China and its main components against two grain storage insects. Molecules 15(12):9391–9402

Foundation for Revitalisation of Local Health Traditions (2008) FRLHT Database. http://envis.frlht.org

Grieve M (1971) A modern herbal. Penguin. 2 vols. Dover publications, New York. 919 pp

Haidari F, Seyed-Sadjadi N, Taha-Jalali M, Mohammed-Shahi M (2011) The effect of oral administration of *Carum carvi* on weight, serum glucose, and lipid profile in streptozotocin-induced diabetic rats. Saudi Med J 32(7):695–700

Hawrelak JA, Cattley T, Myers SP (2009) Essential oils in the treatment of intestinal dysbiosis: a preliminary in vitro study. Altern Med Rev 14(4):380–384

Higashimoto M, Purintrapiban J, Kataoka K, Kinouchi T, Vinitketkumnuen U, Akimoto S, Matsumoto H, Ohnishi Y (1993) Mutagenicity and antimutagenicity of extracts of three spices and a medicinal plant in Thailand. Mutat Res 30(3):135–142

Holtmann G, Gschossmann J, Buenger L, Wieland V, Heydenreich C-J (2001) Effects of a fixed peppermint oil/caraway oil combination (PCC) on symptoms and quality of life in functional dyspepsia. A multicenter, placebo-controlled, double-blind, randomized trial. Gastroenterology 120(Suppl 1):A–237

Holtmann G, Gschossmann J, Buenger L, Wieland V, Heydenreich CJ (2002) Effects of a fixed peppermint oil/caraway oil combination (FPCO) on symptoms of functional dyspepsia accentuated by pain or discomfort. Gastroenterology 122(Suppl 1):A–471

Holtmann G, Haag S, Adam B, Funk P, Wieland V, Heydenreich C-J (2003) Effects of a fixed combination of peppermint oil and caraway oil on symptoms and quality of life in patients suffering from functional dyspepsia. Phytomedicine 10(Suppl 4):56–57

Iacobellis NS, Lo Cantore P, Capasso F, Senatore F (2005) Antibacterial activity of *Cuminum cyminum* L. and *Carum carvi* L. essential oils. J Agric Food Chem 53(1):57–61

Johri RK (2011) *Cuminum cyminum* and *Carum carvi*: an update. Pharmacog Rev 5:63–72

Kamaleeswari M, Nalini N (2006) Dose-response efficacy of caraway (*Carum carvi* L.) on tissue lipid peroxidation and antioxidant profile in rat colon carcinogenesis. J Pharm Pharmacol 58(8):1121–1130

Kamaleeswari M, Deeptha K, Sengottuvelan M, Nalini N (2006) Effect of dietary caraway (*Carum carvi* L.) on aberrant crypt foci development, fecal steroids, and intestinal alkaline phosphatase activities in 1,2-dimethylhydrazine-induced colon carcinogenesis. Toxicol Appl Pharmacol 214(3):290–296

Khaleel AEM (2005) Phenolics and lipids of *Carum carvi* L. and *Coriandrum sativum* L. flowers. Egypt J Biomed Sci 18:35–47

Khayyal MT, El-Ghazaly MA, Kenawy SA, Seif-el-Nasr M, Mahran LG, Kafafi YA, Okpanyi SN (2001) Antiulcerogenic effect of some gastrointestinally acting plant extracts and their combination. Arzneimittelforschung 51(7):545–553

Koppula S, Kopalli SR, Sreemantula S (2009) Adaptogenic and nootropic activities of aqueous extracts of *Carum carvi* Linn (caraway) fruit: an experimental study in Wistar rats. Aust J Med Herbal 21(3):72–78

Kumar P, Singh DK (2006) Molluscicidal activity of *Ferula asafoetida, Syzygium aromaticum* and *Carum carvi* and their active components against the snail *Lymnaea acuminata*. Chemosphere 63(9):1568–1574

Kunzemann J, Herrmann K (1977) Isolation and identification of flavon(ol)-*O*-glycosides in caraway (*Carum carvi* L.), fennel (*Foeniculum vulgare* Mill.), anise (*Pimpinella anisum* L.), and coriander (*Coriandrum sativum* L.), and of flavon-C-glycosides in anise. I. Phenolics of spices. Zeit Lebens Unters Forsch 164(3):194–200

Lahlou A, Tahraoui A, Israili Z, Lyoussi B (2007) Diuretic activity of the aqueous extracts of *Carum carvi* and *Tanacetum vulgare* in normal rats. J Ethnopharmacol 110(3):458–463

Laribi B, Kouki K, Mougou A, Marzouk B (2010) Fatty acid and essential oil composition of three Tunisian caraway (*Carum carvi* L.) seed ecotypes. J Sci Food Agric 90(3):391–396

Lemhadri A, Hajji L, Michel JB (2006) Cholesterol and triglycerides lowering activities of caraway fruits in normal and streptozotocin diabetic rats. J Ethnopharmacol 106(3):3216

Mahady GB, Pendland SL, Stoia A, Hamill FA, Fabricant D, Dietz BM, Chadwick LR (2005) In vitro susceptibility of *Helicobacter pylori* to botanical extracts used traditionally for the treatment of gastrointestinal disorders. Phytother Res 19(11):988–991

Matsumura T, Ishikawa T, Kitajima J (2001) New *p*-menthanetriols and their glucosides from the fruit of caraway. Tetrahedron 57(38):8067–8074

Matsumura T, Ishikawa T, Kitajima J (2002a) Water-soluble constituents of caraway: aromatic compound, aromatic compound glucoside and glucides. Phytochemistry 61(4):455–459

Matsumura T, Ishikawa T, Kitajima J (2002b) Water soluble constituents of caraway: carvone derivatives and their glucosides. Chem Pharm Bull(Tokyo) 50(1):66–72

Mazaki M, Kataoka K, Kinouchi T, Vinitketkumnuen U, Yamada M, Nohmi T, Kuwahara T, Akimoto S, Ohnishi Y (2006) Inhibitory effects of caraway (*Carum carvi* L.) and its component on N-methyl-N′-nitro-N-nitrosoguanidine-induced mutagenicity. J Med Invest 53(1):123–133

Mohsenzadeh M (2007) Evaluation of antibacterial activity of selected Iranian essential oils against *Staphylococcus aureus* and *Escherichia coli* in nutrient broth medium. Pak J Biol Sci 10(20):3693–3697

Naderi-Kalali B, Allameh A, Rasaee MJ, Bach H-J, Behechti A, Doods K, Kettrup A, Schramm K-W (2005) Suppressive effects of caraway (*Carum carvi*) extracts on 2, 3, 7, 8-tetrachloro-dibenzo-*p*-dioxin-dependent gene expression of cytochrome P450 1A1 in the rat H4IIE cells. Toxicol Invitro 19(3):373–377

Najda A, Dyduch J, Brzozowski N (2008) Flavonoid content and antioxidant activity of caraway roots (*Carum carvi* L.). Veg Crops Res Bull 68:127–133

Nakano Y, Matsunaga H, Saita T, Mori M, Katano M, Okabe H (1998) Antiproliferative constituents in Umbelliferae plants II. Screening for polyacetylenes in some Umbelliferae plants, and isolation of panaxynol and falcarindiol from the root of *Heracleum moellendorffii*. Biol Pharm Bull 21(3):257–261

Nariman F, Eftekhar F, Habibi Z, Massarrat S, Malekzadeh R (2009) Antibacterial activity of twenty Iranian plant extracts against clinical isolates of *Helicobacter pylori*. Iran J Basic Med Sci 12:105–111

Park IK, Kim JN, Lee YS, Lee SG, Ahn YJ, Shin SC (2008) Toxicity of plant essential oils and their components against *Lycoriella ingenua* (Diptera: Sciaridae). J Econ Entomol 101(1):139–144

Pitasawat B, Champakaew D, Choochote W, Jitpakdi A, Chaithong U, Kanjanapothi D, Rattanachanpichai E, Tippawangkosol P, Riyong D, Tuetun B, Chaiyasit D (2007) Aromatic plant-derived essential oil: an alternative larvicide for mosquito control. Fitoterapia 78(3):205–210

Porcher MH et al (1995–2020) Searchable world wide web multilingual multiscript plant name database. The University of Melbourne, Parkville. http://www.plant-names.unimelb.edu.au/Sorting/Frontpage.html

Pu FT, Watson MF (2005) *Carum* Linnaeus. In: Wu ZY, Raven PH, Hong DY (eds) Flora of China, vol 14, Apiaceae through Ericaceae. Science Press/Missouri Botanical Garden Press, Beijing/St. Louis

Razzaghi-Abyaneh M, Shams-Ghahfarokhi M, Rezaee MB, Jimand K, Alinezahad S, Saberi R, Yoshinari T (2009) Chemical composition and antiaflatoxigenic activity of *Carum carvi* L., *Thymus vulgaris* and *Citrus aurantifolia* essential oils. Food Contr 20:1018–1024

Reiter B, Lechner M, Lorbeer E (1998) The fatty acid profiles–including petroselinic and *cis*-vaccenic acid–of different Umbelliferae seed oils. Fett/Lipid 100:498–502

Rothbaecher H, Suteu F (1975) Hydroxyl compounds of caraway oil. Planta Med 28(2):112–123

Rothbaecher H, Suteu F (1978) Origin of carvacrol in caraway oil. Chemiker-Zeitung 102(7–8):260–263

Sachin BS, Monica P, Sharma SC, Satti NK, Tikoo MK, Tikoo AK, Suri KA, Gupta BD, Johri RK (2009) Pharmacokinetic interaction of some antitubercular drugs with caraway: implications in the enhancement of drug bioavailability. Hum Exp Toxicol 28(4):175–184

Sadiq S, Nagi AH, Shahzad M, Zia A (2010) The renoprotective effect of aqueous extract of *Carum carvi* (black zeera) seeds in streptozotocin induced diabetic nephropathy in rodents. Saudi J Kidney Dis Transpl 21(6):1058–1065

Sadraei H, Ghannadi A, Takei-Bavani M (2003) Effects of *Zataria multiflora* and *Carum carvi* essential oils and hydroalcoholic extracts of *Passiflora incarnata, Berberis integerrima* and *Crocus sativu*s on rat isolated uterus contractions. Int J Aromather 13(2–3):1210–1217

Salveson A, Svendsen AB (1976) Gas-liquid chromatographic separation and identification of the constituents of caraway seed oil. I. The monoterpene hydrocarbons. Planta Med 30(1):93–96

Samojlik I, Lakić N, Mimica-Dukić N, Daković-Svajcer K, Bozin B (2010) Antioxidant and hepatoprotective potential of essential oils of coriander (*Coriandrum sativum* L.) and caraway *(Carum carvi* L.) (Apiaceae). J Agric Food Chem 58(15):8848–8853

Satyanarayana S, Sushruta K, Sarma GS, Srinivas N, Subba Raju GV (2004) Antioxidant activity of the aqueous extracts of spicy food additives – evaluation and comparison with ascorbic acid in in-vitro systems. J Herb Pharmacother 4(2):1–10

Seidler-Lozykowska K, Baranska M, Baranski R, Krol D (2010) Raman analysis of caraway (*Carum carvi* L.) single fruits. Evaluation of essential oil content and its composition. J Agric Food Chem 58(9):5271–5275

Seo SM, Kim J, Lee SG, Shin CH, Shin SC, Park IK (2009) Fumigant antitermitic activity of plant essential oils and components from ajowan (*Trachyspermum ammi*), allspice (*Pimenta dioica*), caraway (*Carum carvi*), dill (*Anethum graveolens*), geranium (*Pelargonium graveolens*), and Litsea (*Litsea cubeba*) oils against Japanese termite (*Reticulitermes speratus* Kolbe). J Agric Food Chem 57(15):6596–6602

Shwaireb MH (1993) Caraway oil inhibits skin tumors in female BALB/c mice. Nutr Cancer 19(3):321–326

Simic A, Rancic A, Sokovic MD, Ristic M, Grujic-Javanovic S, Vukojevic J, Marin PD (2008) Essential oil composition of *Cymbopogon winterianus* and *Carum carvi* and their antimicrobial activities. Pharm Biol 46:437–441

Singh G, Kapoor IP, Pandey SK, Singh UK, Singh RK (2002) Studies on essential oils: Part 10; Antibacterial activity of volatile oils of some spices. Phytother Res 16:680–682

Small E (1997) Culinary herbs. (NRC-CNRC Monograph). NRC Research Press, Ottawa, 710 pp

Tahraoui A, El-Hilaly J, Israili ZH, Lyoussi B (2007) Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in south-eastern Morocco (Errachidia province). J Ethnopharmacol 110(1):105–117

Tang FD, Xie QM, Bian RL (1988) Observation on the antiasthmatic and antianaphylactic effects of carvone. J Zhejiang Univ 17(3):115–117

Tang FD, Xie QM, Wang Y, Bian RL (1999) Effect of bronchodilation and antianaphylaxis of carvone. Chin Pharmacol Bull 15(3):235–237

Tewari M, Mathela CS (2003) Compositions of the essential oils from seeds of *Carum carvi* Linn. and *Carum bulbocastanum* Koch. Indian Perfumer 47(4):347–349

The Plant List (2010) Version 1. Published on the Internet; http://www.theplantlist.org/.

Uphof JCT (1968) Dictionary of economic plants, 2nd edn. (1st edn. 1959). Cramer, Lehre, 591 pp

U.S. Department of Agriculture, Agricultural Research Service (USDA) (2012) USDA National nutrient database for standard reference, release 25. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

Yu LLL, Zhou KQK, Parry J (2005) Antioxidant properties of cold-pressed black caraway, carrot, cranberry, and hemp seed oils. Food Chem 91(4):723–729

Zheng GQ, Kenney PM, Lam LK (1992) Anethofuran, carvone, and limonene: potential cancer chemopreventive agents from dill weed oil and caraway oil. Planta Med 58:338–341