19 Garcinia

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19.1. Introduction

The genus *Garcinia* belongs to the family Clusiaceae (Guttiferae). It consists of about 180 species, of which ~ 30 species are found in India. The genus is also found in Africa. The well-known and widespread species in Asia are *G. mangostana*, *G. cambogia*, *G. dulcis* and *G. tinctoria*. About 40 species of *Garcinia* produce edible fruits (Yapwattanaphum *et al.*, 2002). *G. dulcis* has a wider potential as a home garden fruit in the tropics, along with *G. mangostana*, but other species are not suitable (Martin *et al.*, 1987).

Maximum density of the *Garcinia* species is seen in the north of the Malaysian Archipelago, with approximately 28 species in Malaysia, about 23 in Thailand, about 20 in Indonesia and 19 in the Philippines. Myanmar and Indochina have fewer species. The Malaysian distribution is linked to the 18 tropical species found in the Andaman and Nicobar Islands. In other parts of India also, e.g. the north-east, Assam, Tamil Nadu and Western Ghats, the species are linked to the Malaysian distribution (Bin Osman and Rahman Milan, 2006). Table 19.1 shows the area and production of *G. mangostana* in major producing countries.

Of the *Garcinia* species, only three appear to have been moved to another region or continent. *G. cochinensis* Choisy, native to Indochina, moved to Brazil and Florida and is often cultivated in Cambodia; *G. livingstonei* T. Anders moved from Africa to Florida and *G. tinctoria* moved to Australia and Madagascar. There is evidence of incipient domestication and primitive cultivation for the fruits of *G. atroviridis* and *G. hombroniana* Pierre in Malaysia, *G. indica* Choisy in north-east India, *G. multiflora* Champ. in Vietnam and Laos and *G. pedunculata* Roxb. in Assam (India) and Bangladesh. Domestication to some extent is also noted for *G. dulcis* in Indonesia, Malaysia and the Phillippines and *G. tinctoria* in India and Malaysia (Bin Osman and Rahman Milan, 2006).

19.2. Botany and Uses

Botany

Garcinia species are evergreen trees or shrubs with a straight trunk tapering to a conical canopy and branches in alternating pairs at an acute angle on the trunk. These species are mostly understorey trees of lowland evergreen forests. The trees resemble *Eugenia* in shape but the branching habit

Table 19.1. Area and production of *Garcinia mangostana*.

Country	Year	Area (ha)	Production (t)
Indonesia	Undated[1]	10,750	NA
Malaysia	1998[2]	7,632	NA
Philippines	2000[3]	1,354	4,692
Thailand	2000[4]	11,000	46,000

Source: [1]BAPPEDA (2001); [2]MOA (2001); [3]DA-AMAS (2004); [4]Maneesin (2002).

and presence of latex distinguish it from *Eugenia*. The leaves are simple and entire, opposite or in whorls of three, coriaceous, often with glandular and resinous cells. The flowers are unisexual on separate trees but occasionally bisexual, borne in tufts or singly in the axils of leaves, regular with four persistent sepals and four petals in red, pink, yellow or white. The male flowers have seven or more stamens inserted on a receptacle and the female flowers have a large hypogynous ovary mounted on a receptacle. The ovaries are many chambered. The fruits are fleshy berries and contain one to four flattened seeds in a pulpy mass. Among the species, *G. cambogia*, *G. indica* and *G. atroviridis* have attracted wide attention all over the world due to the presence of hydroxy citric acid, which is generally known as an antiobesity factor.

G. cambogia is a small to medium-sized tree with a rounded crown. It has horizontal or drooping branches; its leaves are dark green and shiny, elliptic obviate, fruits are ovoid, yellow or red when ripe, with six to eight grooves and the fruits have six to eight seeds surrounded by a succulent aril. The tree is commonly found in the evergreen forests of Western Ghats, from Konkan southward to Travancore, and in the Shola forests of Nilgiris up to an altitude of about 1800 m (6000 ft). It flowers during the hot season and the fruits ripen during the rainy season. The seeds of *G. cambogia* contain 31% edible fat.

G. indica is a slender evergreen tree with drooping branches. It has ovate or oblong lanceolate leaves; the fruits are globose or spherical, dark purple when ripe and enclosing five to eight large seeds. The tree is found in the tropical rainforests of Western Ghats, from Konkan southward to Mysore, Coorg and Wynad. It flowers in November–February and the fruits ripen in April–May. The root is astringent. The seeds of the fruit have edible fat, commercially known as Kokam butter.

G. atroviridis is a moderate-sized graceful tree, 9–15 m (30–50 ft) high, found in the north-eastern districts of upper Assam. The leaves are glabrous, large, glossy green and the base is contracted. It has terminal flowers; the female flower is solitary and large. The fruits are orange-yellow, subglobose, fluted, with a firmly textured outer rind and a rather thin and translucent pulp surrounding the seeds.

Uses

The fruit of *G. indica* has an agreeable flavour and a sweetish acid taste. It is used as a garnish to give an acid flavour to curries and also for preparing syrups during hot months. In Ceylon, the dried fruit rinds of *G. cambogia* are used along with salt in the curing of fish. The fruit rinds of *G. atroviridis* are also too acidic to be eaten raw, but the taste is excellent when stewed with sugar. In Malay, the sun-dried rinds of underripe fruits of *G. atroviridis* are sold for the dressing of fish and as a sour relish for use in curries in place of tamarind. The acidic pulps of *G. mangostana*, *G. atroviridis*, *G. parviflora*, *G. cambogia* and *G. indica* have been reported as a substitute for tamarind to impart flavour. The dried rinds of *G. cambogia* and *G. indica* are used as a condiment for flavouring curries in place of tamarind or lemon. Kokam butter extracted from the seeds of *G. indica* is used in confectionery and cooking as a substitute for ghee. Oil extracted from *G. mangostana* is used as a substitute for kokam butter. *G. indica* seed contains 23–26% oil, which is used in the preparation of chocolates, cosmetics and medicines. The rind of mangosteen is reported to contain tannins and is used to tan leather and to dye fabric black. The fruit of *G. atroviridis* is used as a fixative with alum in the dyeing of silk. It is also used as an ingredient in soap and shampoo preparations. Gamboge, a gum resin collected from *Garcinia* after making incisions in the bark, is used as a pigment and traded in the world market. *Garcinia* species are also used in the paint and lacquer industries.

19.3. General Composition

The nutritional composition of ripe edible aril indicates that mangosteen contains a high percentage of carbohydrates, mostly in sugar form. It is relatively low in minerals and vitamins. The calcium and phosphorus content is high. The percentage of total soluble solids ranges from 13 to 15.2% in immature and 18.3 to 19% in mature fruits (Table 19.2).

A gum resin obtained from *G. hanburyi*, gamboges, consists mainly of resin (71.6–74.2%), gum (21.8–24%), moisture (4.8%), traces of starch and woody fibre. The resin has the nature of an acid (gambogic acid) and is the active principle of the gum. Its specific gravity is 1.221. It forms soluble salts with alkalis and insoluble precipitates with salts of heavy metals; this class of compound has been called gambogiates.

Table 19.2. Composition of 100 g ripe mangosteen aril.

Parameter	Range
Moisture (%)	79.2–84.9
Calories	60–81
Protein (%)	0.5–0.7
Fat (%)	0.1–0.8
Carbohydrates (%)	14.3–19.8
Total sugars (%)	17.5
Reducing sugars (%)	4.3
Fibre (%)	0.3–5.1
Ash (%)	0.20–0.23
Calcium (%)	0.01–18.00
Phosphorus (%)	0.02–17.00
Iron (%)	0.2–0.9
Vitamin A (IU)	0–14
Thiamine (%)	0.03–0.09
Riboflavin (%)	0–0.06
Niacin (%)	0–0.1
Ascorbic acid (%)	1–66
Acid	0.49
Citric acid (g/100 g)	0.63

Source: Kanchanapom and Kanchanapom (1998).

19.4. Chemistry

Volatiles

The aroma of mangosteen is contributed by 52 volatile compounds, 28 of which have been identified. In terms of quantity, the major compounds are (*Z*)-hex-3-en-1-ol (27%), octane (15%), hexyl acetate (8%) and α-copaene (7%). The main contributors to the mangosteen flavour are hexyl acetate, (*Z*)-hex-3-enyl-acetate (*cis*-hex-3-enyl-acetate) and (*Z*)-hex-3-en-1-ol (MacLeod and Pieris, 1982). The major groups of compounds found in mangosteen aril are alcohols, aldehydes and ketones, esters, hydrocarbons, terpenes, etc. The compounds present are given in Table 19.3.

The main essential oil components of the edible fruits of *G. huillensis* Welw. ex. Oliv. growing wild in the Gutu and Rusape areas of Zimbabwe are α-humulene (23.0%), valencene (18.2%), caryophyllene (12.6%), caryophyllene oxide (6.3%) and δ-selinene (5.0%) (Chagonda Lameck and Chalchat, 2005).

Table 19.3. Volatile flavour components of mangosteen aril.

Group	Compounds
Alcohols	Hexan-1-ol, (*Z*)-hex-3-en-1-ol
Aldehydes and ketones	Acetone, benzaldehyde, hexanal, (*E*)-hex-2-enal, 2-furaldehyde, furfuryl methyl ketone, 5-methyl-2-furaldehyde, nonanal, phenylacetaldehyde
Esters	Hexyl acetate, (*Z*)-hex-3-enyl-acetate
Hydrocarbons	Ethyl cyclohexane, heptane, octane, toluene, *o*-, *m*-, *p*-xylene
Terpenes	α-Copane, α-terpineol, guaiene, valencene, δ-cadinene, γ-cadinene
Miscellaneous	Dichloromethane, pyridine

Source: MacLeod and Pieris (1982).

Non-volatiles

In general, the *Garcinia* species contains xanthones and phenolic compounds. Xanthones and xanthone derivatives have been isolated from the various species of *Garcinia* (Rama Rao *et al.*, 1980; Minami *et al.*, 1994). However, the isolation of (–)-hydroxycitric acid [(–)-HCA] from a few species of *Garcinia* and its biological properties has attracted the attention of biochemists and health practitioners. (–)-HCA is found in the fruit rinds of *G. cambogia*, *G. indica* and *G. atroviridis* (Lewis and Neelakantan, 1965; Lewis, 1969), which are abundant in the Indian subcontinent and western Sri Lanka (CSIR, 1956; Watt, 1972).

Hydroxycitric acid ((–)-HCA)

The dried rind of the fruit of *G. cambogia*, popularly known as 'Malabar tamarind', is used extensively all over the west coast of South India for culinary purposes and in Colombo for the curing of fish. The organic acids responsible for the bacteriostatic effect of the pickling medium in the 'Colombo curing' of fish (Lewis *et al.*, 1964; Lewis and Neelakantan, 1965) were identified mistakenly as tartaric and citric acids (Sreenivasan and Venkataraman, 1959). Lewis and Neelakantan (1965) isolated the principal acid in the fruit rinds of *G. cambogia* and identified it as (–)-HCA on the basis of chemical and spectroscopic studies. This is known to have a body-trimming effect and hence has become a very valuable commodity for health practitioners. The fruit rinds of *G. cambogia* and *G. indica* contain 20–30% (–)-HCA. The structure of hydroxycitric acid and its derivatives is given in Fig. 19.1.

Regulation of fatty acid synthesis through (–)-HCA

The biological effect of (–)-HCA stems from the inhibition of extramitochondrial cleavage of citrate to oxaloacetate and acetyl-CoA catalysed by ATP:citrate lyase. This limits the availability of acetyl-CoA units required for fatty acid synthesis and lipogenesis (Sullivan, 1984). The inhibition of ATP:citrate lyase by (–)-HCA leads to less dietary carbohydrate utilization for the synthesis of fatty acids, resulting in more glycogen storage in the liver and muscles. Many *in vitro*

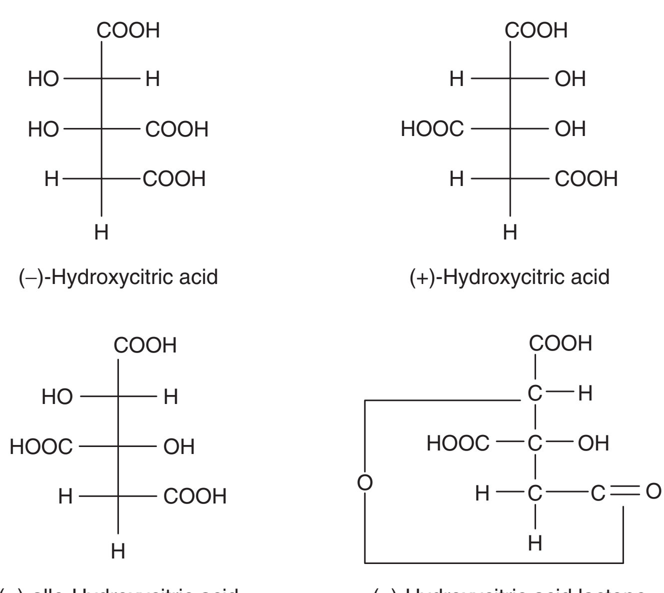


Fig. 19.1. Structure of hydroxy citric acid and its derivatives.

and *in vivo* studies demonstrated that (–)-HCA suppresses *de novo* fatty acid synthesis and lipogenesis. Increase in the rate of *in vivo* hepatic glycogen synthesis with the administration of (–)-HCA has been reported by Sullivan *et al.* (1974). Increased hepatic fatty acid oxidation leading to increased levels of acetyl-CoA and ATP is responsible for the food intake-suppressive effects of (–)-HCA.

Though (–)-HCA is safe to consume, it has impacts on the production of fatty acids and cholesterol, which may influence the production of sterols directly, thus restricting the production of steroid hormones. Hence, (–)-HCA should not be recommended during pregnancy. Excessive exposure of tissues to fatty acids is likely to be the chief cause of the various anomalies that lead to sustained hyperglycaemia in type-2 diabetes. Disinhibition of hepatic fatty acid oxidation and inhibition of fatty acid synthesis with (–)-HCA and camitine (McCarty, 1995) has wide scope as a new weight-loss strategy, but diabetic patients may suffer from enhanced excessive hepatic gluconeogenesis.

Xanthone

The *Garcinia* species produce a range of xanthones, biflavonoids and lactones which have been isolated from the fruit rind, bark and roots. Most of these compounds are xanthones and xanthone derivatives (Rama Rao *et al.*, 1980; Bennet and Lee, 1989; Minami *et al.*, 1994). Xanthones are a unique class of biologically active compounds possessing numerous bioactive capabilities, such as antioxidant properties, maintenance of intestinal health, strengthening the immune system, neutralizing free radicals, supporting cartilage and joint function and promoting a healthy seasonal respiratory system (http://www.xango.com/learn/xanthones.html). Various xanthones, xanthone derivatives, biflavonoids and lactones have been isolated from different vegetative parts of the *Garcinia* species, the details of which are summarized below. Structures of some of the compounds are given in Fig. 19.2.

G. BRACTEATA Leaves and bark: 5-*O*-methylxanthone VI, bracteaxan-thones I and II, nemorosonol, simple-xanthones, garcibracteatone, neoiso-bractanins A and B, xerophenone C (Thoison *et al.*, 2005).

G. MANGOSTANA Heartwood: mangoxanthone and a new benzophenone(3′,6-dihydroxy-2,4,4′ trimethoxybenzophenone) (Nilar *et al.*, 2005).

Root bark, stem bark and latex: α-mangostin, β-mangostin, γ-mangostin, garcinone E, methoxy-β-mangostin and a new geranylated biphenyl derivative 3-hydroxy-4geranyl-5 methoxybiphenyl (Dharmaratne *et al.*, 2005). Pericarp: mangostinone, α-mangostin, β-mangostin, γ-mangostin, garcinone E, 1,5-dihydroxy-2-(3methylbut-2-enyl)-3-methoxy-xanthone and 1,7-dihydroxy-2-(3-methylbut-2-enyl) 3-methoxyxanthone (Asai *et al.*, 1995).

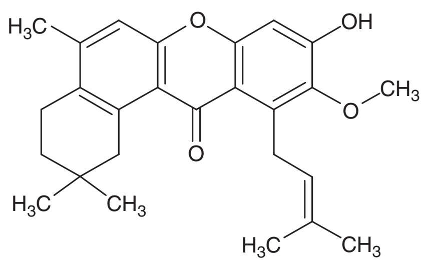
Green fruit hulls: mangostenol, mangostenone A and B, trapezifolixanthone, tovophyllin B, α- and β-mangostins, garcinone B, mangostinone, mangostanol and the flavonoid epicatechin (Suksamrarn *et al.*, 2002). Fruit hull: α- and γ-mangostins, procyanidins A-2 and B-2, (–)-epicatechin (Yoshikawa *et al.*, 1994). Three new tetraoxygenated xanthones (garcinones A, B and C) (Sen *et al.*, 1982). Phenolics, P_1 (1,3,6,7-tetrahydroxy-2,8-(3-methyl-2-butenyl)), P_2 [1,3,6-trihydroxy-7-methoxy-2,8-(3-methyl-2-butenyl) xanthone] and P_3 (epicatechin) (Yu *et al.*, 2006).

Dry fruit hull: two new xanthones, a *bis*-pyrano xanthone, BR-xanthone-A and 1-methoxy-2,4,5-trihydroxyxanthone, BR-xanthone-B (Balasubramanian and Rajagopalan, 1988).

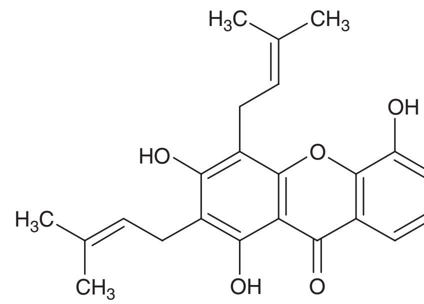
Leaves: 2-ethyl-3-methylmaleimide *N*-β-D-glucopyranoside (Krajewski *et al.*, 1996). A new triterpene,3*β*-hydroxy-26-*nor*-9,19-cyclolanost-23-en-25-one (Parveen *et al.*, 1991).

G. GRIFFITHII Stem bark: guttiferone I, cambogin, 1,7-dihydroxy-xanthone, 1,3,6,7-tetrahydroxyxanthone, 1,3,5,6-tetrahydroxyxanthone (Nilar *et al.*, 2005). Griffipavixanthone (Xu *et al.*, 1998).

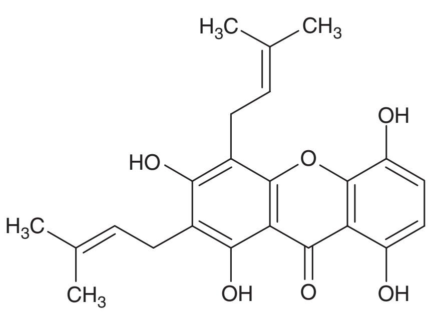
G. KOLA Root: 3″,4′,4′,5,5″,7,7″-heptahydroxy-3,8″ biflavanone (Han *et al.*, 2005).



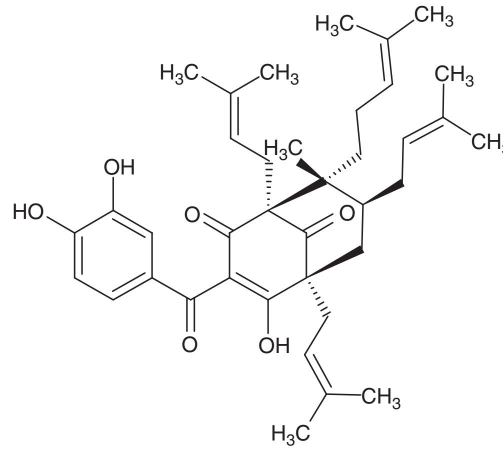
α-Mangostin



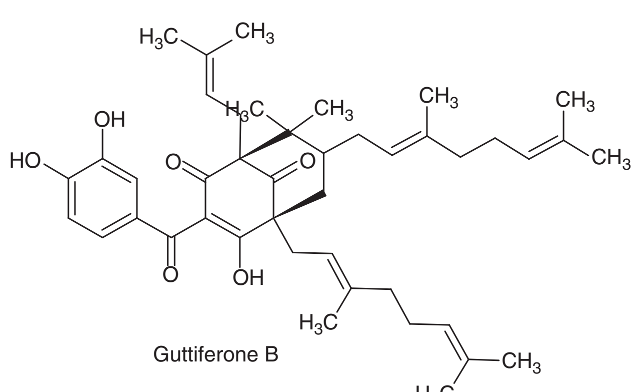
8-Desoxygaranin



Gartanin



Guttiferone A



Guttiferone B

Fig. 19.2. Structures of some of the compounds isolated from *Garcinia* sp. *Continued*

Biflavnonoids (Iwu *et al.*,1990). 6-Asyl-1,2 benzopyran derivative, garcipyran (Niwa *et al.*, 1994).

Leaf: glycosides, flavonoids and tannins (Obuekwe and Onwukaeme, 2004).

G. COWA Latex: cowa xanthone A–E and six previously reported xanthones (Mahabusarakam *et al.*, 2005). Cowanin, cowanol, cowa-xanthone, 1,3,6-trihydroxy-7-methoxy-2,5-*bis*(3-methyl-2-butenyl)

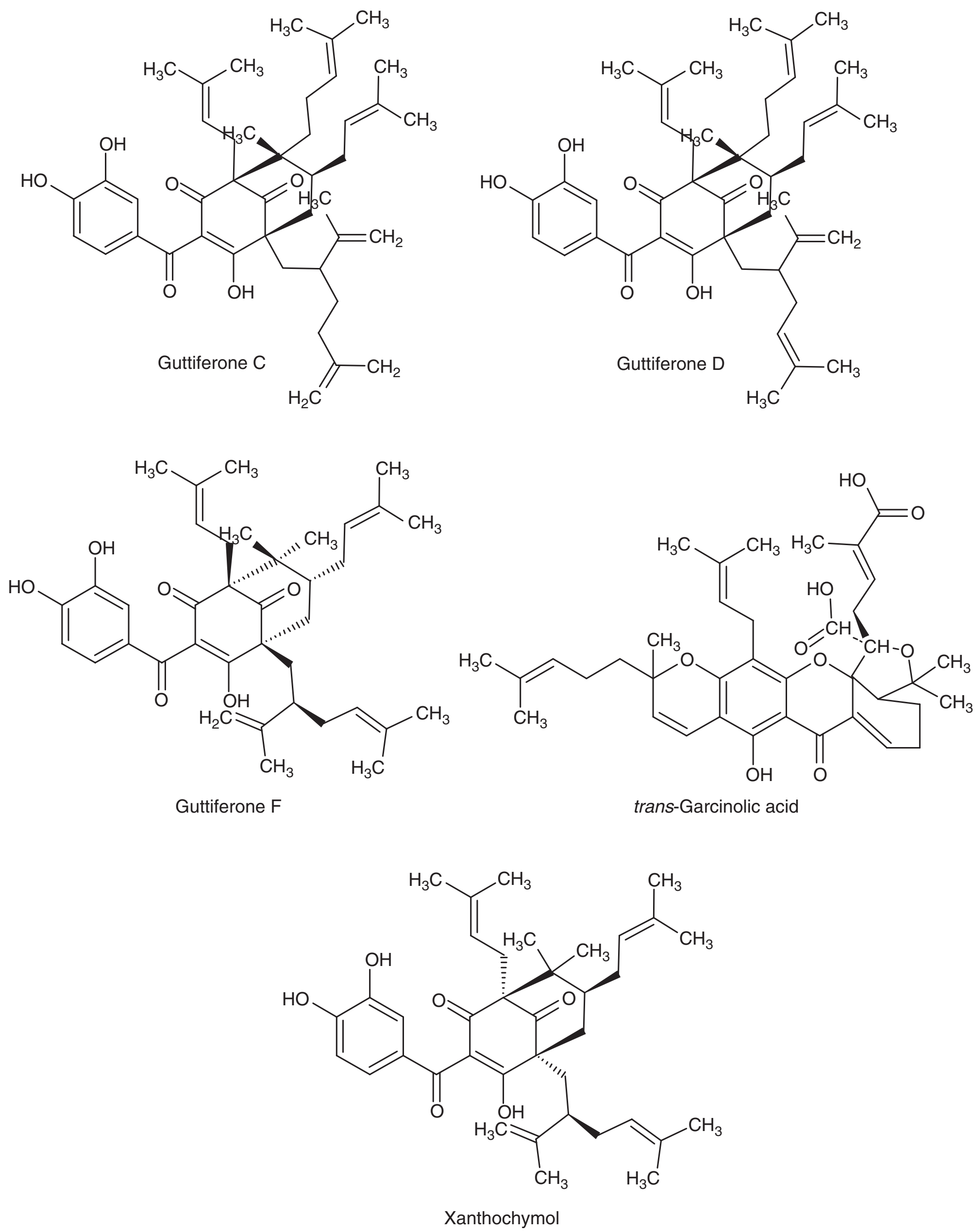


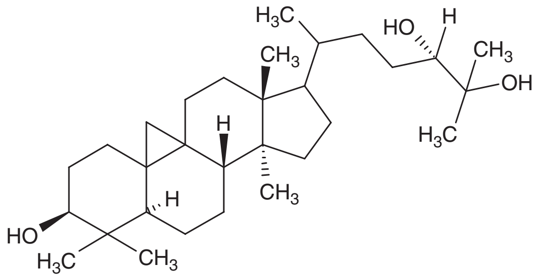
Fig. 19.2. *Continued*

xanthone and norcowanin (Pattalung *et al.*, 1994).

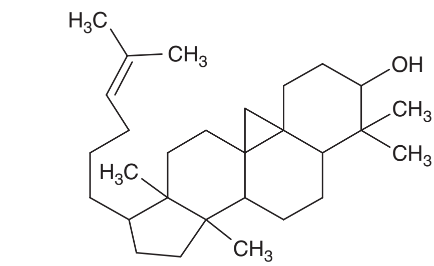
Stem: 1,3,6-trihydroxy-7-methoxy-8-(3,7-dimethyl-2,6-octadienylxanthone (Lee and Chan, 1977).

Stem bark: new xanthone, 7-*O*-methylgarcinone E (Likhitwitayawuid *et al.*, 1997).

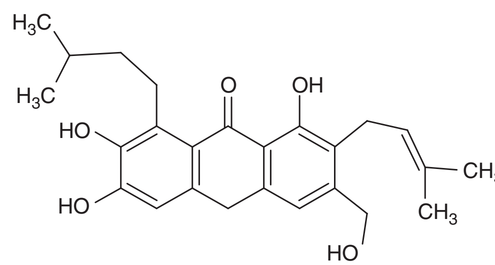
Fruit: tetraoxygenated xanthones, cowaxanthones A–E, together with ten previ-



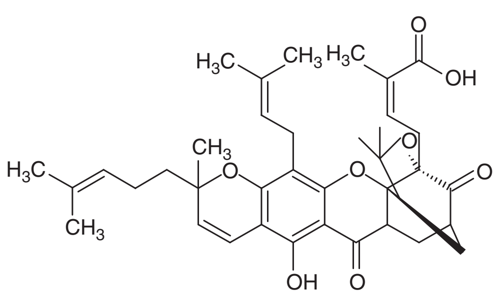
Cycloartane



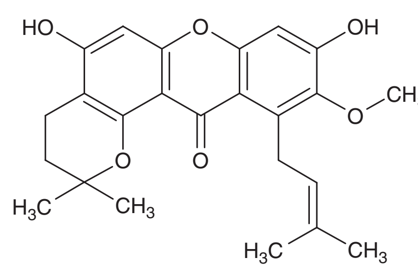
Cycloartenol



γ-Mangostin



Gambogic acid



Isomangostin

Fig. 19.2. *Continued*

ously reported tetraoxygenated xanthones (Panthong *et al.*, 2006).

G. ATROVIRIDIS Fruit: atrovirisidone, naringenin and 3,8 binaringenin (Permana et al., 2005), 2-(butoxy carbonyl methyl)-3-butoxy carbonyl-2-hydroxy-3-propanolide and 1′,1″-dibutyl methyl hydroxycitrate (Mackeen et al., 2002).

Roots: benzoquinone atrovirinone and the depsidone atrovirisidone (Permana *et al.*, 2001).

Stem bark: a new xanthone, atroviridin (Kosin *et al.*, 1998).

G. SUBELLIPTICA Root bark: subelliptinones E and F, 1,5-dihydroxy-3-methoxy xanthone (Iinuma *et al.*, 1995a). Subelliptenone H and I (with 1,1-dimethylallyl group) (Iinuma *et al.*, 1995b).

Wood: *Garcinia*xanthone D and 1,4,5-trihydroxyxanthone (Minami *et al.*, 1995). 2,5-Dihydroxy-1-methoxyl xanthone, 1-*o*-methylsympho-xanthone, *Garcinia*xanthone E, symphoxanthone and subelliptenone A (Minami *et al.*, 1996). A new benzophenone derivative, 2′,3′,6-trihydroxy-2,4-dimethoxy-benzo-phenone and a new xanthone, 1,6-*O*-

dimethylsymphoxanthone (Minami *et al.*, 1998). Four new phloroglucinol derivatives, named garsubellins B–E (Fukuyama *et al.*, 1998). Subellinone, a novel polyisoprenylated phloroglucinol (Fukuyama *et al.*, 1993).

Pericarp: garcinielliptone FA, benzoylphloroglucinol, garcinielliptone FB (Wu *et al.*, 2005).

Heartwood: two new prenylated xanthones, *Garcinia*xanthones A and B (Fukuyama *et al.*, 1991).

G. HANBURYI Latex: 11 cytotoxic xanthones, e.g. gambogin, morellin dimethyl acetal, isomoreollin B, moreollic acid, gambogenic acid, gambogenin, isogambogenin, desoxygambogenia, gambogenin dimethyl acetal, gambogellic acid, hanburin and gambogic acid, isomorellin, morellic acid, desoxymorellin (Asano *et al.*, 1996).

G. DULCIS Bark: a new xanthone dulciol A, 12b-hydroxydes-D-garcigerin and toxyloxanthone B (Iinuma *et al.*, 1996).

Roots: four novel xanthones with a 1,1-dimethyl allyl group (dulciols B–E) (Iinuma *et al.*, 1996).

Leaves: pyranoxanthone, dulxanthone E (5,9,10,12-tetramethoxy-2,2-dimethyl-2H-pyrano[5,6-b]xanthen-6-one) (Kosela *et al.*, 1999a).

Green fruits: dulcinoside, dulcisisoflavone, dulcisxanthone A and sphaerobioside acetate (Deachathai *et al.*, 2005).

Ripe fruits: dulcisflavan, dulcisxanthone B and isonormangostin (Deachathai *et al.*, 2005).

G. FUSCA Stem bark: fusca xanthones A–H (Ito et al., 2003b).

G. XANTHOCHYMUS Wood: two prenylated-xanthones 1,4,5,6-tetrahydroxy-7,8-di(3-methylbut-2-enyl) xanthone and 1,2,6-trihydroxy-5-methoxy-7-(3-methylbut-2-enyl) xanthone (Chanmahasathien et al., 2003).

G. CUNEIFOLIA Stem bark: a new xanthone cuneifolin (Ee *et al.*, 2003).

G. ASSUGU Two new benzo phenones corresponding to the 13-*O*-methyl ethers of isogarcinol and garcinol (Ito *et al.*, 2003a).

G. SPECIOSA Bark and stems: protostane triterpenes (Rukachaisirikul *et al.*, 2003c).

Bark: four 17,14-friedolanostanes and five lanostanes, as well as friedelin (Vieira *et al.*, 2004).

G. NIGROLINEATA Leaves: ten new 1,3,5-trioxygenated xanthones and one new quinone derivative, nigrolineaquinone A (Rukachaisirikul *et al.*, 2003a).

Bark: nine xanthones, nigrolineaxanthones A–I and nine known xanthones (Rukachaisirikul *et al.*, 2003b).

G. SCORTECHINII Fruits: four caged tetraprenylated xanthones (scortechinones Q-T, 1–4), four rearranged xanthones (scortechinones U-X, 5–8), two sesquiterpene derivatives, two triflavanoids and 11 caged polyprenylated compounds (Sukpondma *et al.*, 2005).

G. SMEATHMANNII Bark: smeathxanthone A and B (Komguem *et al.*, 2005).

G. HUMILIS Bark: guttiferone I (Herath *et al.*, 2005).

G. CAMBOGIA Fruit rind: hydroxy citric acid (Jayaprakasha and Sakariah, 1998).

Root: a new xanthone, garbogiol (Iinuma *et al.*, 1998).

Bark: known xanthone (rheediaxanthone A) and two known benzophenones (garcinol and isogarcinol) (Iinuma *et al.*, 1998).

G. VIEILLARDII Stem bark: 6-*O*-methyl-2-deprenylrheediaxanthone B and vieillardixanthone (Hay *et al.*, 2004a). 1,6-Dihydroxyxanthone pancixanthone A, isocudraniaxanthone B, isocudraniaxanthone A, 2-deprenylrheediaxanthone B and 1,4,5-trihydroxyxanthone (Hay *et al.*, 2004b).

G. GAUDICHAUDII Leaf: cytotoxic gaudichaudiones A–D (penta-cyclic tetra-isoprenylated xanthonoids) (Cao *et al.*, 1998a). Fifteen novel cytotoxic compounds, gaudichaudiones A–H and gaudichaudiic acids A–E, including the known morellic acid and forbesione (Cao *et al.*, 1998b).

Bark: gaudispirolactone and 7-isoprenylmorellic acid (Wu *et al.*, 2001).

G. FORBESII Branch: a new chromenoxanthone, forbexanthone, as well as the known compounds pyranojacareubin and 1,3,7-trihydroxy-2,3-methylbut-2-enyl-xanthone (Harrison *et al.*, 1993).

G. VOLKENSII Heartwood: known biflavonoids GB-1a, GB-2a and morelloflavone and a new flavanone, volkensiflavone, whose constituent units are naringenin and apigenin (Herbin *et al.*, 1970).

G. ANDAMANICA Leaves: sorbifolin 6-galactoside and scutellarein 7-diglucoside (Alam *et al.*, 1986). A new flavone glycoside 4′-hydroxywogonin 7-neohesperidoside (Alam *et al.*, 1987).

G. NERVOSA; G. POLYANTHA; G. PYRIFERA Stem bark: isocowanin (8-geranyl-4-(3,3-dimethylallyl)-7-methoxy-1,3,6-trihydroxyxanthone), isocowanol (8-geranyl-4-(3-hydroxymethyl-3-methyl-allyl)-7-methoxy-1,3,6-trihydroxy-xanthone) and nervosaxanthone (4,8-di(3,3-dimethylallyl)-2-(1,1-dimethyl-allyl)-1,3,5,6-tetrahydroxyxanthone) (Ampofo and Waterman, 1986).

G. THWAITESII *β*-Amyrin and tirucallol, four biflavonoids and a new xanthone, 2,5-dihydroxy-1,6-dimethoxyxanthone (Gunatilaka *et al.*, 1983).

G. DENSIVENIA Stem bark: 1,3,5,6-tetraoxygenated xanthone pyranojacareubin (1,5-dihydroxy-6′,6′-dimethylpyrano (2′,3′:3,2)-6″,6″-dimethylpyrano (2″,3″:6,7)-xanthone) and the biflavonoids morelloflavone and *O*-methyl fukugetin (Waterman and Crichton, 1980b).

G. PEDUNCULATA Heartwood: 2,4,6,3′,5′-pentahydroxybenzophenone and 1,3,5,7-tetrahydroxyxanthone (Rama Rao *et al.*, 1974).

G. LIVINGSTONII Heartwood, bark and leaves: moarelloflavone (BGH-II) and a new biflavonyl, BGH-111, along with optically active amentoflavone and podocarpusflavone A (Pelter *et al.*, 1971).

Root bark: five prenylated xanthones (Diserens *et al.*, 1992a). Three xanthone dimers garcilivin A–C that are structurally related to 1,4,5-trihydroxy-3-(3-methylbut-2-enyl)-9*H*-xanthen-9-one (Diserens *et al.*, 1992b).

G. NERVOSA Leaves: I-5,II-5,I-7,II-7,I-3′,I-4′,II-4′-hepta-hydroxy-[I-3, II-8]-flavanonylflavone (Babu *et al.*, 1988). A new isoflavone, 5,7,4′-trihydroxy-2′,3′,6′-trimethoxyisoflavone, nervosin, along with two known isoflavones, irigenin (5,7,3′-trihydroxy-6,4′,5′-trimethoxyisoflavone) and 7-methyltectorigenin(5,4′-dihydroxy-6,7-di-methoxyisoflavone) (Ilyas *et al.*, 1994).

G. PSEUDOGUTTIFERA Heartwood: benzophenones, e.g. 6-hydroxy-2,4-dimethoxy-3,5-*bis*(3-methyl-2-butenyl)benzophenone (myrtiaphenone-A); 2,2-dimethyl-8-benzoyl-7-hydroxy-5-methoxy-6-(3-methyl-2-butenyl)benzopyran (myrtiaphenone-B); 2,6-dihydroxy-4-methoxy-3,5-*bis*(3-methyl-2-butenyl)benzophenone (vismiaphenone-C) and a new benzophenone, 2,2-dimethyl-8-benzoyl-3,7-dihydroxy-5-methoxy-6-(3-methyl-2-butenyl)-3,4-dihydrobenzopyran (pseudoguttiaphenone-A) and a triterpene, eupha-8,24-dien-3*β*-ol (Ali *et al.*, 2000).

G. POLYANTHA Stem bark: bangangxanthone A [1,5,8-trihydroxy-6′-methyl-6′-(4-methylpent-3-enyl)-pyrano[2′,3′:3,4]xanthone] and B [1,4,8-trihydroxy-2-prenylxanthone], along with two known xanthones, 1,5-dihydroxyxanthone, 2-hydroxy-1,7-dimethoxyxanthone and the pentacyclic triterpenoids, friedelin, oleanolic acid and lupeol (Lannang *et al.*, 2005).

G. VIRGATA Stem bark: two prenylated xanthones and two formyl-*δ*-tocotrienol derivatives (Merza *et al.*, 2004).

G. XANTHOCHYMUS Wood: two prenylated xanthones, 1,4,5,6-tetrahydroxy-7,8-di(3-methylbut-2-enyl)xanthone and 1,2,6-trihydroxy-5-methoxy-7-(3-methylbut-2-enyl)xanthone and a known xanthone, 12b-hydroxy-des-D-garcigerrin A (Chanmahasathien *et al.*, 2003).

G. MERGUENSIS Bark: xanthones, e.g. merguenone, 1,5-dihydroxy-6′-methyl-6′-(4-methyl-3-pentenyl)-pyrano(2′,3′:3,2)-xanthone, subelliptenone H, 8-deoxygartanin, rheediaxanthone A, morusignin G, 6-deoxyjacareubin, 1,3,5-trihydroxy-4,8-di(3-methylbut-2-enyl)-xanthone, rheediachromenoxanthone and 6-deoxyisojacareubin (Nguyen *et al.*, 2003).

G. VILERSIANA Bark: four triterpenoids (olean-12-ene-3β,11α-diol, lupeol, β-amyrin and oleanolic acid) and six xanthones (globuxanthone, subelliptenone H, subelliptenone B, 12b-hydroxy-des-D-garcigerrin A, 1-*O*-methylglobu-xanthone and symphoxanthone) (Nguyen and Harrison, 2000).

G. CONRAUANA Stem bark: 3-(3,3″-dimethylallyl)-conrauanalactone [4-hydroxy-3-(3″, 3″-dimethylallyl)-6-pentadecylpyran-2-one] (Hussain and Waterman, 1982). Bark: conrauanalactone (4-hydroxy-6-pentadecyl-2-pyrone),5,7-dihydroxychromone and eriodictyol (Waterman and Crichton, 1980a).

G. LATERIFLORA Lateriflorone, a cytotoxic natural product with spiroxalactone skeleton (Kosela *et al.*, 1999b).

G. QUADRIFARIA Stem bark: xanthone 1,3,5-trihydroxy-4,8-di(3,3-dimethylallyl)xanthone and the biflavonoids, *O*-methylfukugetin and morelloflavone (Waterman and Hussain, 1982).

G. STAUDTII Stem bark: rheedia xanthone-A and xanthochymol (Waterman and Hussain, 1982).

G. MANNII Stem bark: a new biflavanone, I-3′-II-3,3′-I-4′-II-4′-I-5-II-5-I-7-II-7-nonahydroxy-I-3-II-8-biflavanone (Crichton and Waterman, 1979).

G. OPACA Leaf: macluraxanthone, 1,3,5-trihydroxy-6′,6′-dimethylpyrano-(2′,3′:6,7)-4-(1,1-dimethylprop-2-enyl)xanthone and two new prenylated xanthones, 1,3,5-trihydroxy-6′,6′-dimethylpyrano-(2′,3′:6,7)-2-(3-methylbut-2-enyl)-4-(1,1-dimethylprop-2-enyl)xanthone and 4″,5″-dihydro-1,5-dihydro-1,5-dihy-droxy-6′,6′-dimethylpyrano(2′,3′:6,7)-2-(3-methylbut-2-enyl)-4″,4″,5″-trimethylfurano(2″,3″:3,4) xanthone (Goh *et al.*, 1992).

G. QUAESITA Bark: hermonionic acid and a new phenol, quaesitol (Gunatilaka *et al.*, 1984).
A new method based on reversed-phase high-performance liquid chromatography with photodiode array detector (LC–PDA) enabled simultaneous analysis of six naturally occurring xanthones (3-isomangostin, 8-desoxygartanin, gartanin, α-mangostin, 9-hydroxycalabaxanthone and β-mangostin). Separation was performed on a Phenomenex Luna C18 (2) (150 mm × 3 mm, 5 μm) column. The xanthones were identified by retention time, ultraviolet (UV) spectra and quantified by LC–PDA at 320 nm. The precision of the method was confirmed by the relative standard deviation (RSD), which was ≤ 4.6%. The recovery was in the range of 96.58–113.45%. A good linear relationship was established in over two orders of magnitude range. The limits of detection (LOD) for six xanthone compounds were ≤ 0.248 μg/ml. The identity of the peaks was further confirmed by high-performance liquid chromatography with time-of-flight mass spectrometry (LC–TOF MS) system coupled with electrospray ionization (ESI) interface. The developed methods were applied to the determination of six xanthones in *G. mangostana* products. The methods also are effective for the analysis of real samples (Ji *et al.*, 2006).

A sensitive liquid chromatography/electrospray ionization tandem mass spectrometrical (LC/ESI–MS/MS) method was developed for the identification and quantification of two polyisoprenylated benzophenones, xanthochymol and isoxanthochymol, in the extracts of the fruit rinds, stem bark, seed pericarps and leaves of *G. indica* and in the fruit rinds of *G. cambogia* (Chattopadhyay and Kumar, 2006).

A recycling counter-current chromatographic system was first set up with a high-speed counter-current chromatography instrument coupled with a column-switching valve. This system was first applied successfully to the preparative separation of epimers, gambogic acid and epigambogic acid from *G. hanburyi* using *n*-hexane:methanol: water (5:4:1, v/v/v) as the two-phase solvent system (Han *et al.*, 2006).

19.5. Medicinal and Pharmacological Uses

Traditionally, *Garcinia* species have been used as anti-inflammatory, anti-immunosuppressive, antiprotozoal and antimicrobial agents. The various medicinal properties attributed to *Garcinia* are:

- Antioxidant
- Anti-inflammatory agent
- Analgesic
- Astringent
- Hepatotic tonic
- Cancer suppressant
- Anti-HIV agent
- Antibacterial agent
- Antiobesity factor
- Veterinary medicine
- Other medicinal uses.

Antioxidant

Kolaviron isolated from *G. kola* seed extract appears to act as an *in vivo* natural antioxidant and an effective hepatoprotective agent and is as effective as butylated hydroxyanisole (Farombi *et al.*, 2000). The *G. indica* extract which contains garcinol has both antifungal and antioxidant properties and has potential for use as a biopreservative in food applications and nutraceuticals (Selvi *et al.*, 2003). The growth of *Aspergillus flavus* was inhibited completely by the hexane and chloroform extracts from *G. cowa* and the chloroform extract from *G. pedunculata*. The antiaflatoxigenic activities of the extracts from *G. cowa* and *G. pedunculata* may be due to their effective antioxidative properties, which could suppress the biosynthesis of aflatoxin (Joseph *et al.*, 2005). Superoxide anions in xanthine and xanthine oxidase systems were scavenged by the xanthones isolated from *G. subelliptica* (Minami *et al.*, 1995). Xanthone present in the hulls of *G. mangostana* exhibits a potent radical scavenging activity (Yoshikawa *et al.*, 1994).

Anti-inflammatory agent

G. mangostana fruit hulls are used as an anti-inflammatory agent (Chairungsrilerd *et al.*, 1996). In Thai medicine, the fruit hull is used to heal skin infections and wounds (Parveen *et al.*, 1991; Yaacob and Tindall, 1995; Ohizumi, 1999). The rind is also used to treat respiratory disorders (Wahyuono *et al.*, 1999).

Analgesic

A decoction from the leaves and roots of *G. atroviridis* is used in the treatment of earache (CSIR, 1956). A decoction of the fruit rind of *G. cambogia* is given for rheumatism and bowel complaints (Jena *et al.*, 2002).

Astringent

G. mangostana fruit hulls are used as an astringent and to treat diarrhoea (Chairungsrilerd *et al.*, 1996). The bark and leaves are also used as an astringent for the cure of aphtha or thrush (Coronel, 1983).

Hepatotic tonic

Syrup from the juice of *G. indica* fruit is given in bilious infections (Jena *et al.*, 2002). *G. kola* extracts are used extensively in traditional

African medicine for the treatment of coughs, inflammation of the respiratory tract and liver cirrhosis (Iwu *et al.*, 1990).

Cancer suppressant

Among the nine Thai medicinal plants tested for antiproliferative activity against SKBR3 human breast adenocarcinoma cell line using MTT assay, ethanolic extracts of *G. mangostana* had strong antiproliferation, potent antioxidation and induction of apoptosis (Moongkarndi *et al.*, 2004b). Thus, this indicates that this substance can show different activities and has potential for cancer chemoprevention which is dose-dependent as well as exposure time-dependent (Moongkarndi *et al.*, 2004a). Investigations on the induction of apoptosis in human leukaemia HL-60 cells, the inhibition of NO generation and the inhibition of LPS-induced iNOS gene expression by Western blot analysis suggest the possible chemopreventive ability of garcinol (purified from *G. indica* fruit rind) and its oxidation products (Sang *et al.*, 2002). Dietary administration of garcinol inhibited 4-NQO-induced tongue carcinogenesis through suppression of increased cell proliferation activity in the target tissues and/or COX-2 expression in tongue lesions (Yoshida *et al.*, 2005).

Human telomerase reverse transcriptase gene expression was inhibited by gambogic acid in human hepatoma SMMC-7721 cells, indicating the gambogic acid's potent anticancer activity (Guo *et al.*, 2006). The high potency of gambogic acid, a natural product isolated from the resin of the *G. hurburyi* tree as an inducer of apoptosis, its novel mechanism of action, easy isolation and abundant supply, as well as the fact that it is amenable to chemical modification, makes gambogic acid an attractive molecule for the development of anticancer agents (Zhang *et al.*, 2004). A new benzoylphosphoglucinol, garcinielliptone FB, isolated from the pericarp of *G. subelliptica,* exhibited cytotoxic activity against several human cancer cells (Wu *et al.*, 2005). Atrovirisidone B isolated from *G. atroviridis* showed cytotoxic activity against human breast, prostate and large cells. Cancer chemopreventive activity was exhibited by *G. assugu* plants (Ito *et al.*, 2003a) and also by *G. fusca* plants (Ito *et al.*, 2003b).

Anti-HIV agent

Ethanol extract of the fruit peel of *G. mangostana* showed potent inhibiting activity against HIV-1 protease; the compound responsible was isolated and established as mangostin (Chen *et al.*, 1996). Protostane triterpenes, e.g. garciosaterpenes A, B and C, obtained from methanol extracts of bark and stems of *G. speciosa*, showed anti-HIV-1 activity (Rukachaisirikul *et al.*, 2003c).

Antibacterial agent

The polyoxygenated xanthones present in the rind of *G. mangostana* act as antibacterial agents. Antibacterial biphenyl derivatives have been isolated from *G. bancana* (Rukachaisirikul *et al.*, 2005). Nigrolineaxanthone N isolated from the leaves of *G. nigrolineata* showed significant antibacterial activity against methicillin-resistant *Staphylococcus aureus* (Rukachaisirikul *et al.*, 2003a). α-Mangostin alone or in combination with gentamicin against vancomycin-resistant enterococci (VRE) and in combination with VCM (vancomycin hydrochloride) against methicillin-resistant *S. aureus* (MRSA) might be useful in controlling VRE and MRSA infections (Sakagami *et al.*, 2005). GBI, a hydroxybiflavanol present in the seed extract of *G. kola*, exhibited activity against Gram-positive and Gram-negative bacteria, C*andida albicans* and *A. flavus* (Madubunyi, 1995). Cowanol and cowaxanthone from *G. cowa* also have moderate antibacterial activity against *S. aureus* (Pattalung *et al.*, 1994). Compounds extracted from the roots of *G. atroviridis* showed mild inhibitory activity towards *Bacillus cereus* and *S. aureus* (Permana *et al.*, 2001).

Antiobesity factor

(–)-Hydroxycitric acid (HCA) is found in the fruit rinds of certain species of *Garcinia*, including *G. cambogia*, *G. indica* and *G. atroviridis*. These are in great demand by health practitioners, as HCA is known to induce weight loss (Jena *et al.*, 2002). Preliminary research based on laboratory and animal experiments suggests that (–)-HCA may be a useful weight-loss aid (Lowenstein, 1971; Triscari and Sullivan, 1977). Animal research also indicated that (–)-HCA suppressed appetite and food intake to induce weight loss (Greenwood *et al.*, 1981; Rao and Sakariah, 1988). Heymsfield *et al.* (1998) noted that, although (–)-HCA appeared to be a promising experimental weight control agent, studies in humans were limited (Thom, 1996; Rothacker and Waitman, 1997) and results have been contradictory. Supporting evidence of human (–)-HCA efficacy for weight control is based largely on studies with small sample sizes. Their study failed to detect either the weight-loss or fat-mobilizing effects of (–)-HCA. (–)-Hydroxycitric acid (HCA-SX) and, to a greater degree, the combination of HCA-SX, niacin-bound chromium and *Gymnema sylvestre,* can serve as safe weight management supplements (Preuss *et al.*, 2004). HCA from *G. cambogia* resulted in a reduction in body weight but did not cause any changes in major organs or in the haematology, clinical chemistry and histopathology in rats (Shara *et al.*, 2004). *G. cambogia* extracts containing a high concentration of hydroxycitric acid were effective in suppressing fat accumulation in developing male Zucker obese rats, but were highly toxic to the testis (Saito *et al.*, 2005). Burdock *et al.* (2005) expressed that the toxicity, as reported by Saito *et al.* (2005), was misleading and was dependent on other factors such as dose, frequency of administration, etc.

Veterinary medicine

A decoction of the fruit rind of *G. cambogia* is employed in veterinary medicine as a rinse for diseases of the mouth in cattle (Jena *et al.*, 2002). Gamboge resin extracted from *G. Morella* is used as a strong purgative in veterinary medicine and gamboges from *G. hanburyi* is also used similarly in Indochina (Howes, 1949; Dastur, 1964).

Other medicinal uses

The fruit of *G. indica* is anthelmintic and useful in piles, dysentery, tumour, pain and heart complaints (Jena *et al.*, 2002). *G. dulcis* is used in traditional medicine to treat lymphatitis, parotitis and struma (Iinuma *et al.*, 1996). *G. kola* also is used in traditional medicine to treat a variety of ailments (Madubunyi, 1995). In Nigerian medicine, *G. kola* is used to treat hepatitis, laryngitis and gastroenteritis (Braide, 1993). The latex of *G. cowa* is used in Thai folk medicine as an antifever agent (Pattalung *et al.*, 1994). The bark of *G. lucida* is used by traditional healers in Cameroon to treat gastric infections and as an antidote against poison (Nyemba *et al.*, 1990). The seeds of *G. kola* enjoy a folk reputation in Africa as a poison antidote (Iwu *et al.*, 1987). *G. mangostana* rind is used as a cure for dysentery and chronic intestinal catarrh (Coronel, 1983) and is used as a lotion and medicine for menstruation (Burkill, 1966). The stem bark of *G. epunctata* has medicinal value in Cameroon (Mbafor *et al.*, 1989).

19.6. Conclusion

The major flavouring compound in *G. cambogia*, *G. indica* and *G. atroviridis* is (–)-hydroxycitric acid. Though this is emerging as a handy tool to treat obesity, more evidence needs to be gathered to prove its potential as an antiobesity factor satisfactorily. The various naturally occurring xanthones in different species of *Garcinia* also have medicinal use as radical scavenging agents and also are employed to treat infections and some respiratory disorders. Anti-HIV, anticancer and antibacterial activities have been reported from some species of *Garcinia*. Strong systematic research including clinical trials is needed to prove the reported claims, though, traditionally, *Garcinia* species have been used to treat all kinds of ailments.

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