T. K. Lim

Edible Medicinal and Non-Medicinal Plants

Volume 2, Fruits

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Introduction

This book continues as volume 2 of a multi-compendium on *Edible Medicinal and Non-Medicinal Plants*. It covers edible fruits and seeds used fresh, cooked or processed into other by-products, or used as vegetables, spices, stimulants, edible oils and beverages. It encompasses species from the following families: Clusiaceae, Combretaceae, Cucurbitaceae, Dilleniaceae, Ebenaceae, Euphorbiaceae, Ericaceae and Fabaceae. However, not all the edible species in these families are included for want of coloured illustrations. The edible species dealt with in this work include to a larger extent lesser-known, wild and underutilized crops and also common and widely grown crops.

As in the first volume, topics covered include: taxonomy (botanical name and synonyms); common English and vernacular names; origin and distribution; agro-ecological requirements; edible plant parts 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.

Clusiaceae

Most of the edible species in the family Clusiaceae (or Guttiferae) belonged to the *Garcinia* genus. The genus *Garcinia* is pantropical, comprising more than 250 species of evergreen, lactiferous, dioecious trees and shrubs that are a common flora of the moist, lowland tropical forests (Stevens 2007; Sweeney 2008). Centres of diversity of the genus have been reported to be in southeast Asia and Madagascar, and in the Guyana Highlands of the neotropics. Many species of *Rheedia* have been subsumed under *Garcinia*. Robson (1958) discussed the logical error in maintaining *Rheedia* separate from *Garcinia* asserting there is no basis in keeping them apart. Features thought to differentiate *Rheedia* from *Garcinia* such as the number of perianth parts and degree of fusion of the stamens are not constant in nor unique to *Rheedia* and occur in both genera (Hammel 1989; Adams 1970). Robson (1958) and later Adams (1970) argued for the inclusion of *Rheedia* in *Garcinia*, and this circumscription has been adopted in recent treatments.

One unique feature of plants in Clusiaceae is the presence of natural, secondary metabolites called xanthones. Xanthones is a family of three-membered ring phenolic compounds containing oxygen, with a yellow coloration and all of them have dibenzo-γ-pyrone or diphenylene ketone oxide, as the basic skeleton (Diderot et al. 2006; Na 2009) with the molecular formula $C_{13}H_8O_2$. Vieira and Kijjoa (2005) in their review of naturally occurring xanthones from January 2000 to December 2004, found among 515 xanthones reported during this period, of which 278 were new natural xanthones. These xanthones have been identified from 20 families of higher plants (122 species in 44 genera), fungi (19 species) and lichens (3 species). Since 1937 to 2009, 100 xanthones have been identified from Guttiferae (Han and Xu 2009), among which more than 40 are

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found in *Garcinia mangostana.* Xanthones are endowed with potent bioactivities, and provide a promising pharmacology for drug design and development (Chantarasriwong et al. 2010). Xanthones are potent antioxidants, substances that inhibit oxidation process during metabolism. Oxidation releases free radicals which are unstable molecules that cause damage to cell membranes and DNA leading to diseases like cancer, cardiovascular diseases, aging and more. Thus antioxidants scavenge these free radicals and protect cells from damage by them. Helping to fight cancer is just one of the many properties that different xanthones perform. In addition, some xanthones have shown significant antimicrobial, anti-inflammatory, antimicrobial, anti-hypercholesterolemic (cholesterol lowering), antithrombotic, immunopharmacological, antiviral, antimalarial, and antihypertensive biological profiles.

Of the edible *Garcinia* species, most notable ones from an economic standpoint are *Garcinia mangostana,* dubbed the Queen of fruits, and *Garcinia gummi-gutta,* source of hydroxycitric for weight loss. Both are rich in xanthones and also have other phytochemical such as flavonoids, tripenoid saponins and tannins and have potent bioactivities. Other lesser known edible *Garcinia* species covered in this volume also have pharmacologically active constituents but have been little exploited commercially as a fruit crop or for medicinal purposes. Among this group, *Garcina humilis,* known as Achacha or Bolivian mangosteen, has good commercial potential as a dessert fruit. Achacha has been introduced into Australia and is being cultivated commercially; the fruits are available in markets around Australia.

Combretaceae

Members of the Combretaceae family are widespread in the warm tropics and subtropics. This family comprises about 20 genera and 600 species of evergreen or deciduous trees, shrubs and woody lianas. Members of this family provide very valuable timber. Among the species that provides edible fruit noteworthy of mention are *Terminalia ferdinandiana, Terminalia kaernbachii* and *Terminalia catappa*. *Terminalia ferdinandiana is* most noted for its rich vitamin C content, containing around 5% vitamin C by weight, 50 times the concentration found in oranges. *Terminalia kaernbachii,* okari nut, an occasional timber species has potential as a high-value nut species. *Terminalia catappa,* Indian almond, possesses many bioactive metabolites that include flavonoids, triterpenoids and tannins that exhibit many pharmacological properties such as antinociceptive, antimicrobial, anti-diabetic, anticancer, and hepatoprotective, to mention some.

Cucurbitaceae

Cucurbitaceae is a major family for economically important species, particularly those with edible fruit such as cucumber, melon, gourds, pumpkin, zucchini, luffa and squashes. The family comprises 90 genera, 700 species, primarily in tropical and subtropical regions with a few representatives in temperate and cooler climates. The Cucurbitaceae are mostly prostrate or climbing, herbaceous annuals with characteristically coiled tendrils and five-angled stems. Some of the major edible species domesticated as food plants covered in this volume include *Citrullus lanatus* (watermelon), *Cucumis sativus* (cucumber), *Cucumis melo* (honey-dew melon, musk melon, cantaloupe), *Cucumis metuliferus* (African horned cucumber), *Cucurbita moschata* (pumpkin, butternut squash, squash), *Cucurbit pepo* (squash, pumpkin, zucchini), *Cucurbita filicifolia* (fig leaf gourd), *Momordica charantia* (bitter melon), spiny bitter gourd (*Momordica cochinchinensis), Sechium edule* (chayote), *Luffa acutangula, Luffa aegyptiaca* (luffa), *Lagenaria siceraria* (bottle gourd), *Benincasa hispida* (wax gourd), *Trichosanthes cucumerina* (snake gourd), *Coccinia grandis* (ivy gourd) and *Siraitia grosvenorii* (Arhat fruit, Buddha fruit, Luo han guo). Of these, three are more well known for their medicinal value: *Momordica charantia* (bitter melon), *Momordica cochinchinensis* (gac) and *Siraitia grosvenorii* (luo han guo). Luo Han Guo is rich in mogrosides, a group of triterpene glycosides. Mogroside V, the major constituent in the fruit extract is more than 400 times as sweet as sucrose and is extremely low in calories. This fruit and mogroside V will be valuable as an advanced food ingredient and a natural sweetener substitute for sucrose in the near future, and might be valuable as a source of the chemopreventive agents in chemical carcinogenesis (Konoshima and Takasaki 2002). Gac fruit contains by far the highest content of β-carotene and lycopene of any known fruit or vegetable. The concentration of lycopene in the gac seed membrane has been reported to be about ten-times higher than that in known lycopene-rich fruit and vegetables. Gac also has other carotenoids like zeaxanthin and β-cryptoxanthin. Research has confirmed that the β-carotene (vitamin A) in gac fruit is highly bioavailable. Bitter melon contains bioactive compounds such as momordicins, cucubitacins, glycosides, terpenoid compounds and cytotoxic ribosome-inactivating proteins (RIPs). Together these compounds have shown various pharmacological and biological activities including antidiabetic, antiobesity, anticancer, antimicrobial, anti-HIV, antifeedant and antioviposition activities.

Dilleniaceae

The family Dilleniaceae comprises 10–12 genera with 400 species distributed in the tropical and subtropical regions in Asia to temperate Australia and Oceania. The genus *Dillenia* has about 100 species of which several have edible fruits. Of the *Dillenia* species with edible fruits, *Dillenia indica, D. serrata* and *D. philippinensis* have been used in traditional folkloric medicine in south and southeast Asia. Various plants parts of *D. indica* have exhibited antimicrobial, antidiarrhoeal, antiinflammatory and anticancer properties. *D. serrata* is also an important timber species.

Ebenaceae

Ebenaceae is a family of flowering plants, which includes ebony, a valuable timber species, and persimmon, a nutritious and economically-important fruit. The family comprises approximately 500 species of trees and erect shrubs in two genera, *Diospyros* and *Euclea*. The species are mostly evergreen and native to the warm tropics and subtropics, with a few deciduous species indigenous to temperate regions. *Diospyros* contains 450–500 species and has a pantropical distribution, with the greatest diversity of species in the Indo-Malayan region (Bakhuizen van den Brink 1936–1941; Kostermans 1977). Persimmon, *Diospyros kaki*, beside providing a nutritious and delicious fruit, also contain many bioactive phytochemicals that include tannins, proanthcyanidins, and flavoniods which impart a diverse array of pharmacological properties such as antioxidant activity, anticancer, antihypercholesterolemic, antidiabetic, cardioprotective, neuroprotective, antihypertensive, anti-skin whitening, and anti-aging activities.

Ericaceae

Ericaceae, the heather family, comprises about 125 genera and 4,000 species. The species are widely distributed in temperate and subarctic regions, and also found at high elevations in tropical regions. Plants are usually herbaceous or woody. Several genera and many species are ornamental viz. rhododendrons, azaleas and heathers. Edible berries are produced by some species in the genera: *Arctostaphylos, Gaylussacia* and *Vaccinium*. Within *Vaccinium*, the edible berries are: cranberry (sometimes called bearberry), blueberry, whortleberry, bilberry and huckleberry. Two species are covered in this volume, *Arbutus unedo* and *Vaccinium corymbosa*, blueberries. Blueberries are very nutritious and have many beneficial health attributes. Blueberries contain anthocyanins, potent antioxidant pigments, and various phytochemicals possibly having a role in reducing risks of some diseases, including inflammation, cardiovascular and certain cancers. *Arbutus unedo* also produces edible fruit but is more well-known as an ornamental species.

Euphorbiaceae

The Euphorbiaceae, the spurge family, occurs mainly in the tropical Indo-Malayan region followed by tropical America. This one large family has been split or segregated into 14 families: Androstachydaceae, Antidesmataceae, Bischofiaceae, Hymenocardiaceae, Phyllanthaceae, Pedilanthaceae, Picrodendraceae, Porantheraceae, Putranjivaceae, Icinocarpaceae, Scepaceae, Stilaginaceae, Trewiaceae, and Uapacaceae. The Pandanaceae and Buxaceae, formerly included under Euphorbiaceae, are now well established as separate families. Many members of this family are economically important such as *Hevea brasiliensis* that produces rubber latex; *Ricinus communis* that provides castor oil; *Aleurites moluccana* candle nut; and *Manihot esculenta* whose tuberous roots are staple food in many tropical countries. Members of the families also include many ornamental species and weeds. Four species with edible fruit and medicinal properties, namely *Aleurites moluccana*, *Elateriospermum tapos*, *Hevea brasiliensis* and *Ricinus communis* are covered in this volume.

Fabaceae

Fabaceae or Leguminosae is the third largest family of flowering plants with 730 genera and over 19,400 species. It is commonly known as the legume family, pea family, bean family or pulse family. It consists of trees, shrubs or herbs, sometimes climbing or trailing species widespread throughout the tropics and temperate zone. Taxonomically, Fabaceae has been traditionally divided into three subfamilies, the Caesalpinioideae, Mimosoideae, and Papilionoideae. However, many scientists have ranked them as separate families, as in Caesalpiniaceae, Mimosaceae, and Papilionaceae. However, Lewis et al. (2005) maintained that there is increasing body of evidence from morphology, and molecular phylogenetic studies to support the legumes as being one monophyletic family. This view has been strengthened by the degree of interrelatedness of taxonomic groups within the legumes compared to that between legumes and its relatives, and also by recent molecular phylogenetic studies (Doyle et al. 2000; Kajita et al. 2001; Wojciechowski 2003; Wojciechowski et al. 2004). Such evidence has provided strong support for Fabaceae as a monophyletic family that is more closely linked to Polygalaceae, Surianaceae, and Quillajaceae, which together form the order Fabales (APG 2003).

Fabaceae is an economically important plant family. Legumes contribute significantly to the world's economy – through food and drink, pharmaceuticals and medicine, biotechnology, building and construction, textiles, furniture, horticulture, paper and pulp, fertilizers, chemicals, animal feed, timber, biodiesel, pest control, environmental management and ecotourism. There is a vast array of agricultural important plants, noteworthy of mention are: *Glycine max* (soybean), *Phaseolus* and *Vigna* spp. (various beans), *Pisum sativum* (pea), *Cicer arietinum* (chickpeas), *Medicago sativa* (alfalfa), *Arachis hypogaea* (peanut), *Lens culinaris* (lentils), *Lupinus* spp. (lupins), *Ceratonia siliqua* (carob), *Glycyrrhiza glabra* (licorice) and *Tamarindus indica* (tamarind). According to Graham and Vance (2003), grain legumes alone contribute 33% of the dietary protein nitrogen needs of humans, while soybeans and peanut provide more than 35% of the world's processed vegetable oil and a rich source of dietary protein for the poultry and pork industries. Except for alfafa, licorice and carob, the rest of the aforementioned are covered in this volume together with numerous lesser known legume species with edible fruit/seeds and some with medicinal value.

Health-wise, legumes are excellent sources of high quality proteins, low-glycemic index carbohydrates, essential minerals, dietary fibre and other bioactive phytochemicals. Soybeans have attracted the most scientific interest, mainly because they are a unique source of phytoestrogens known as isoflavones. Soyfoods and isoflavones have received much attention for their potential role in preventing and treating cancer and osteoporosis (Messina 1999). Both beans and soybeans have reported protective and therapeutic effects that include lowering cholesterol levels, ameliorating diabetic state, and providing metabolic benefits that aid in weight control (Anderson et al. 1999).

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Calophyllum inophyllum

Scientific Name

***Calophyllum inophyllum* L.**

Synonyms

Balsaminaria inophyllum (L.) Lour., *Calophyllum bitangor* Roxb., *Calophyllum blumei* Wight, *Calophyllum calaba* Lam non L., *Calophyllum ovatifolium* Nor., *Calophyllum spurium* Choisy.

Family

Clusiaceae

Common/English Names

Alexandrian Laurel, Ball Nut, Ball Nut Tree, Beach Callophyllum, Beauty Leaf, Borneo Mahogany, Indian Laurel, India-Oil Nut, Laurelwood, Mastwood, Oi Nut Tree, Portia Tree, Poon, Poonay Oil Plant, Satin Touraga, Sweet-Scented Calophyllum

Vernacular Names

Burmese: Ponnyet, Ph'ong;
Chinese: Hai-Tang-Guo, Hong Hou Ke, Hu Tong;
Chuk: Rakich;
Cook Islands: Tamanu;
Fiji: Dilo;
French: Bintangor, Vintanina;
German: Alexandrischer Lorbeer, Rosenholz, Südsee-Eisenholz;
Guam: Daog, Daok;
Hawaiian: Kamani, Foraha, Tamanu;
India: Sultana-Champa, Sultanachampa, Sultanah-Champa, Sultanchampa, Surpan, Surpunika, Surpunka, Undi (Hindu), Hona, Honne, Honne Kaayi Mara, Honnu, Hoo Home, Hoo Honne, Huhome, Huhonne, Kallu Honne, Koove Mara, Mara, Naameru Mara, Namaeru, Nameru, Nameyru Mara, Ooma Mara, Pinekai, Pinnai, Pinnaykai, Ponneda, Ponnekayi, Srihonne, Suraganne-Mara, Suragonne, Sura Honne, Surahonnae Ponne, Surahonne, Surhonne, Sudaabu Mara, Voma, Uma, Vuma, Wuma (Kannada), Betan, Cerupunna, Ceruppuna, Cherupinna, Cherupuna, Cherupunna, Pine, Ponna, Ponnakam, Ponnakum, Pouna, Punna (Malayalam), Nagchampa, Pumag, Surangi, Undag, Undela, Undi, Ungam, Wundi (Marathi), Tungakesara (Oriya), Namaeruak, Panchakaeshera, Punnaga, Punnagah, Punnagavrikshaha, Punnaman, Tunga (Sanskrit), Arttakecam, Cayantakam, Cayantakamaram, Cimmantacikam, Culetam, Culetamaram, Curalam, Cuvetputpakam, Kecaram, Kopikakitam, Kopikakitamaram, Koppika, Koppikamaram, Kukattal, Kuruntutikam, Kuruntutikamaram, Macarrapattiram, Makapucurapi, Makapucurpimaram, Matukatitam, Matukatitamaram, Murunkai, Nagam, Nakam, Nameru, Narruti, Patalatturumam,

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Patumakecaram, Pillaicceti, Pinnai, Pitataru, Pitatarumaram, Punnacam, Punnacamaram, Punnagam, Punnai, Punnai-Maram, Pinmai, Punnakam, Punnagum, Punnaivirai, Pinnay Unnay, Pinnai, Purusa Akacciyam, Purusam, Purutaki, Purutakimaram, Purutam, Tamalai, Tankakecaram, Tevali, Tevalimaram, Vacanaikkenti, Viranankalkustampokki (Tamil), Naameru, Nameru, Ponna,Ponna Chettu, Ponna-Chettu, Ponnachettu, Ponna Vithulu, Ponnavittulu, Poona, Poonas, Poone, Pouna, Pumagamu, Puna, Punas, Punna, Punnaga, Punnagamu, Punnaagamu (Telugu);
Indonesia: Nyamplung (Java), Dingkaran (Sulawesi), Nyamplung (Sundanese), Punaga, Penago (Sumatra);
Kampuchea: Khtung, Kchyong;
Kiribati: Te Itai;
Kosrae: Eet;
Madagascar: Vintanina;
Malaysia: Bentagor Bunga, Bintagor, Bintangor Laut, Penaga, Penaga Laut, Penaga Air, Pudek, Senaga (Iban);
Maldives: Funa;
Marquesas: Tamanu;
Marshall Islands: Lukwej, Lueg;
Niuē: Fetau;
N. Marianas: Daog, Daok;
Palau: Btaches;
Papua New Guinea: Beach Calophyllum;
Philippines: Dagkaan (Bagobo), Dangkalan, Dingkalan (Bikol), Butalau (Cebu Bisaya), Bitaog, Pamitaogen (Iloko), Vutalau (Ivatan), Dangkalan, Langkagan (Maguindanao), Butalau (Manobo), Bitaog (Pampangan), Dangkalan (Panay Bisaya), Bitaoi (Pangasinan), Butulau (Samar-Leyte Bisaya), Bitaog (Sambali), Palo Maria De La Playa (Spanish), Palo Maria De La Playa (Sulu), Bitaog, Bitok, Bitong, Butulau, Dagkalan, Dangkalan, Dingkalan, Palo Maria De La Playa (Tagalog);
Pohnpei: Isou;
Portuguese: Loureiro De Alexandria;
Samoa: Fetau;
Society Islands: Tamnu;
Solomon Islands: Koila;
Spanish: Palo De Santa María, Palo María, Undi;
Sri Lanka: Domba-Gass;
Swahili: Motondoo, Mtondoo, Mkanja;
Tahiti: Ati, Tamanu;
Thailand: Kating, Kra Thing (General), Saraphee Naen (Northern), Naowakan (Nan);
Tonga: Feta U, Tamanu;
Vanuatu: Nambagura;
Vietnamese: Cong, Mù U;
Yap: Biyuch.

Origin/Distribution

Calophyllum inophyllum is a native of the old world tropics from East Africa, southern coastal India to Malesia, northern Australia and the Pacific islands. The species is widespread along the coasts of eastern Africa (from Kenya to northern Mozambique), Madagascar and other Indian Ocean islands, tropical Asia, northern Australia and the islands of the Pacific Ocean. Although it is considered wild in most of this area, it is often unclear where it is truly wild or a relict of former cultivation. In Réunion and Mauritius it has possibly been introduced. In Africa, it is locally planted outside the natural distribution area, e.g. in Guinea, Sierra Leone, Côte d'Ivoire, Ghana, Nigeria, Cameroon and Gabon, where seemingly wild trees and seedlings can be found near beaches. The species is also planted in southern China.

Agroecology

Calophyllum inophyllum occurs in maritime, littoral and riparian areas in the warm tropics and sub-tropics. It thrives in areas with mean annual temperature of 18–33°C, mean maximum temperatures of 22–37°C mean minimum temperatures of 12–17°C and mean annual rainfall of 1,000–5,000 mm occurring seasonally in winter or summer or uniformly throughout the year. It grows naturally on rocky and sandy sea shores, usually just above the high-tide mark and has also been cultivated successfully in inland areas at elevation from 0 to 800 m elevation. It is not suited to higher elevations. It grows best in full sun but will tolerate light shade. It is a hardy robust tree that tolerates strong wind, salt spray, drought, and brief periods of waterlogged conditions but is susceptible to natural bush fires, cold weather (below 10°C) and frost. It occurs on a wide range of soils including clays, loams, calcareous, rocky and gravelly soils but performs best on well-drained, sandy soils. It is also tolerant of saline soils. A pH range of 4.4–7.4 is suitable for the tree.

Plate 1 Bark, leaves and fruits

Edible Plant Parts and Uses

Only the endospermum of the immature, unripe fruit is safe to be eaten. In Indonesia, the half-ripe fruit are sometimes pickled but only the endosperm is eaten (Burkill 1966); but caution is needed as toxic compounds may be present in the fruit and seeds. In Sabah, young sour fruit is pickled in sugar and eaten (Lee and Gibot 1986). The seed oil has also been reported to be edible after refinement and detoxification. Unlike most vegetable oils, Tamanu oil is not contained in fresh ripe fruits. It forms in the course of the nuts' desiccation.

Studies conducted by Venkatesan and Rege (1973) reported the possibility of using the meal remaining after defatting *Calophyllum inophyllum* seeds as a potential protein source in foods and feeds. Reasonably good correlation between chemical data and biological performance had been observed in case of undi (*C. inophyllum*) meal. The meal, when made nutritionally adequate by supplementation, was found capable of supporting normal growth rate in animal studies. Fat-free meal from undi and mowra (*Bassia latifolia*) seeds provided 25% or 50%, casein the remainder, of the dietary protein of rats. The undi meal was poor in methionine. The protein efficiency ratio of undi meal at the 50% level, alone or supplemented with histidine 0.09, lysine 0.14 and methionine 0.21% of diet, was 78.2, 91.3 and at the 25% level, without or with 1% methionine, was 98.1%, 100.6%, respectively, with 100% for the control diet of casein.

Botany

A medium to large, lowly branched evergreen, tree with a broad, spreading to irregular crown, gray bark and fissured trunk (Plate 1) and reaching heights of 8–30 m. It has milky white sap. Leaves are opposite, deep glossy green, glabrous, simple, coriaceous with broadly elliptic or obovate-elliptic lamina 10–20 cm long by 6–9 cm wide, rounded or emarginate apex, rounded or cuneate base, entire margin (Plate 1) and distinct parallel lateral veins, perpendicular to the mid rib. Flowers are white, fragrant, bisexual, 2.5 cm across and 8–14 mm long on sturdy pedicels and borne in racemose or paniculate, axillary inflorescences of 4–15 flowers. Flower has 8 white, suborbicular to obovate tepals, numerous (200 to >300) free stamens, superior, subglobose ovary with joined carpels, one locule and one solitary, peltate style. Fruit is globose to subglobose, 2.5–4 cm across, indehiscent drupe, light green (Plate 1) turning yellow to purplish brown and wrinkled when ripe and is found in clusters. The seed is large, brown 2–4 cm across and surrounded by a corky shell and thin pulp.

Nutritive/Medicinal Properties

Calophyllum inophyllum possess more significance as a timber tree with manifold medicinal attributes rather than for its infrequently eaten fruit. As such, no nutritive information has been published on the nutrient value of the fruit.

The physico-chemical properties and fatty acid composition of the kernel oils of *Calophyllum calaba* L. and *Calophyllum inophyllum* were reported by Crane et al. (2005). Oleic acid C18:1 (39.1–50%) was the predominant fatty acid followed by linoleic acid C18:2 (21.7–31.1%). Stearic C18:0 (13.4–14.3%) and palmitic C16:0 (11–13.7%) acids were the major saturates. The oils contained an appreciable amount of unsaturated fatty acids (70.8–73.10%). Most of the fatty acids were present as triacylglycerol (76.7–84%), 21 triacylglycerols were detected with predominantly unsaturated triacylglycerols. In both species, analysis of the unsaponifiable fractions revealed the preponderance of phytosterols, mainly stigmasterol (35.8–45.1%) and β-sitosterol (41.1–43.1%). Variations existed among the eight tocopherols and tocotrienols present in the two species; α-tocopherol (183 mg/kg) was the major tocopherol in *Calophyllum calaba* and δ-tocotrienol (236 mg/kg) was the dominant tocotrienol in *Calophyllum inophyllum*.

Total kernel lipids extracted from *Calophyllum inophyllum*, amounted to 60.1% of the dry kernel (Hemavathy and Prabhakar 1990). The total lipids consisted of 92.0% of neutral lipids, 6.4% glycolipids and 1.6% phospholipids. Neutral lipids consisted of triacylglycerols (82.3%), free fatty acids (7.4%) and small quantities of diacylglycerols, monoacylglycerols and sterols. At least four glycolipids and five phospholipids were identified. Acylmonogalactosyldiacylglycerol and monogalactosylmonoacylglycerol were the main glycolipids; while an acylated sterolglucoside and monogalactosyldiacylglycerol was present in small amounts. The phospholipids consisted of phosphatidylethanolamine and phosphatidylcholine as major phospholipids, and minor amounts of phosphatidic acid, phosphatidylserine and lysophosphatidylcholine.

Seventeen components out of 25 were identified in the pale yellow oil steam-distilled from *C. inophyllum* flowers (Samsudin et al. 1998). The major constituent of the oil was found to be a naphthalene derivative, 1,2,3,4,4α,7-hexahydro-1,6-dimethyl-4-(1 -methylethyl)naphthalene, which accounted for 24.50% of the oil. Other components identified were α-cubebene (6.83%), β-farnesene (6.53%), calerene (6.44%), β-selinene (5.28%), δ-cadinene (4.74%), α-farnesene (3.76%), β-bourbonene (3.01%), farnesol (2.59%), hexadecane (2.18%), β-sesquiphellandrene (2.12%), octadecanal (2.02%), nerolidol (0.95%), α-murelene (0.82%), copaene (0.77%) and zingiberene (0.46%).

Reviews reported by Su et al. (2008); Cechinel Filho et al. (2009) on *Calophyllum inophyllum*, revealed that various parts of the tree contained bioactive phytochemicals which included xanthones, coumarins, chromanones (flavonoids, biflavonoids), tripenes, tripenoids and steroids. Many of these compounds possessed biological activities that included anticancer (cytoxtoicity, antitumorous), antimicrobial, antimalarial, inhibition of HIV-1 reverse transcriptase, antisecretory and cytoprotective properties, inhibition of multidrug transport of P glycoproteins, inhibition of sulfotranferases, antinociceptive, molluscicidal and etc.

Phytochemicals in the Leaves

The following xanthones: inophyxanthone A [1, 3, 5-trihydroxy-2-(1, 1-dimethylallyl)xanthone], pancixanthone A, gerontoxanthone B, jacareubin and pyranojacareubin were isolated from *C. inophyllum* leaves (Li et al. 2009). Three new friedelane-type triterpenoids, 3,4-secofriedelan-3,28-dioic acid, 27-hydroxyacetate canophyllic acid and 3-oxo-27-hydroxyacetate friedelan-28-oic acid, were isolated from the leaves of *Calophyllum inophyllum* (Laure et al. 2005). Various pyranocoumarins, calophyllolide, inophyllums B, inophyllum C, inophyllum G(1), inophyllum G(2) and inophyllum P, were isolated from the leaves (Laure et al. 2008). Nine compounds were isolated from stems and leaves of *Calophyllum inophyllum*: 2-hydroxyxanthone; 4-hydroxyxanthone; 1, 5-dihydroxyxanthone; 1, 7-dihydroxyxanthone; 1, 3, 5-trihydroxy-2-methoxyxanthone; 6-deoxyjacareubin; flavonoids amentoflavone; kaempferol-3-O-α-L-rhamnoside; and quercetin-3-O-α-L-rhamnoside (Li et al. 2007). Two isomeric benzodipyranone (chromone) derivatives: (2*S*,3*R*)-2,3-dihydro-5-

hydroxy-2,3,8,8-tetramethyl-6-(1-phenylethenyl)-4H,8H-benzo [1,2-*b*:3,4-*b*′] dipyran-4-one along with (2*R*,3*R*)-2,3-dihydro-5-hydroxy-2,3,8,8-tetramethyl-6-(1-phenylethenyl)-4H,8H-benzo [1,2-*b*:3,4-*b*′] dipyran-4-one were isolated from the leaves of *Calophyllum inophyllum* (Khan et al. 1996). The chromone flavonoid epimers, inophynone and isoinophynone were isolated from leaves together with the sterol: cholesterol, triterpenes: friedelin, canophyllol and canophyllic acid (Ali et al. 1999); triterpenes friedelin, canophyllal, canophyllol and canophyllic acid (Govindachari et al. 1967).

The following pyranocoumarins: inophyllum A, inophyllum B, inophyllum C, and inophyllum E; and calophyllolide 1a, calophyllolide 2a, calophyllolide 3a, calophyllolide 3b, and calophyllolide 6, were isolated in considerably high yield in addition to a novel enantiomer of soulattrolide, inophyllum P (2a 2b), and two other novel compounds, inophyllums G-1 and G-2 from the leaves (Patil et al. 1993).

Phytochemicals in the Seeds

Fractionation of the ethanolic extract of the seeds of *Calophyllum inophyllum* resulted in the isolation of four novel pyranocoumarin derivatives, designated as inocalophyllin A, inocalophyllin B and their methyl esters in addition to the known calophyllolide (Shen et al. 2003). Bhushan et al. (1975) recorded calaustralin, a new 4-phenylcoumarin from the seed oil of *Calophyllum inophyllum*. Three new pyranocoumarin derivatives, tamanolide, tamanolide D and tamanolide P, were isolated from the seeds (Leu et al. 2009). Costatolide and inophyllum (Spino et al. 1998) and 5,7-dihydroxy-6-(2-methylbutyryl)-4-phenylcoumarin (Ravelonjato et al. 1992) were isolated from the seeds.

Phtyochemicals in the Wood, Bark and Root

The following xanthones were isolated from the heart wood: 2-(3-hydroxy-3-methylbutyl)-1,3,5,6-tetrahydroxyxanthone, jacareubin, 6-deoxyjacareubin, 2-(3-methylbut-2-enyl)-1,3,5,6-tetrahydroxyxanthone and 2-(3-methylbut-2-enyl)-1,3,5-trihydroxyxanthone (Goh and Jantan 1991); jacareubin, 1,7-dihydroxyxanthone (euxanthone), 1,5,6-trihydroxyxanthone, 1,6-dihydroxy-5-methoxyxanthone (buchanaxanthone), 6-desoxyjacareubin, 2-(3,3-dimethylallyl)-1,3,5-trihydroxyxanthone and 2-(3,3-dimethylallyl)-1,3,5,6-tetrahydroxyxanthone (the latter two isolated as their methyl ether derivatives) (Al-Jeboury and Locksley 1971). The following were also isolated from the heart wood: mesuaxanthone B and calophyllin B (Govindachari et al. 1968); 6-desoxyjacareubin, 2-(3,3-dimethylallyl)-1,3,5,6-tetrahydroxyxanthone, and jacareubin (Jackson et al. 1969); jacareubin; 1,7-dihydroxy-3,6-dimethoxyxanthone; 6-desoxyjacareubin; 6(3-methyl-2-butenyl)-1,5-dihydroxyxanthone (Kumar et al. 1976). Xanthones isolated from root bark and wood included: caloxanthones A and B, macluraxanthone and 1,5-dihydroxyxanthone (Iinuma et al. 1994b); caloxanthone D, caloxanthone E, 1,3,8-trihydroxy-7-methoxy-xanthone, 1,3-dihydroxy-7,8-methoxy-xanthone, 1,3,5-trihydroxy-2-methoxy-xanthone and 6-hydroxy-1,5-dimethoxy-xanthone (Iinuma et al. 1995). Chemical investigations on the root bark extracts of *Calophyllum inophyllum* yielded two new xanthones, inophyllin A and inophyllin B, three known xanthones, brasilixanthone B, tovopyrifolin C, caloxanthone B, one triterpene, friedelin and one triterpenoid, β-sitosterol (Ee et al. 2004, 2006, 2009).

From the root bark, a new xanthone named caloxanthone C and 4-hydroxyxanthone were isolated, and from the heartwood, a new xanthone 1-hydroxy-2-methoxyxanthone in addition to three known xanthones 1,2-dimethoxy-xanthone, 2-hydroxy- 1-methoxy-xanthone, and 6-deoxyjacareubin (Iinuma et al. 1994a); a polyphenolic compound flavanoid (−)-epicatechin was also isolated (Iinuma et al. 1994a). The study of the chemical constituents of the root bark and the nut of *Calophyllum inophyllum* resulted in the isolation and characterization of a xanthone derivative, named inoxanthone, together with 12 known compounds: caloxanthones A, and B, macluraxanthone, 1,5-dihydroxyxanthone, calophynic acid (dihydro coumarin), brasiliensic acid, inophylloidic acid, friedelan-3-one, calaustralin (4-phenyl coumarin), calophyllolide, inophyllum C and inophyllum E (Yimdjo et al. 2004).

Two new prenylated xanthones, caloxanthone O and caloxanthone P were isolated from the twigs (Dai et al. 2010).

Biological activities of the phytochemicals from various parts of the tree include:

Antivira Activity

From a methanol/methylene chloride extract of *C. inophyllum*, inophyllums A, B, C, and E and calophyllolide (1a, 2a, 3a, 3b, and 6), in considerably greater yield were isolated in addition to a novel enantiomer of soulattrolide (4), inophyllum P (2b), and two other novel compounds, inophyllums G-1 (7) and G-2 (8) (Patil et al. 1993). Inophyllums B and P (2a and 2b) were found to inhibit HIV reverse transcriptase with IC_{50} values of 38 and 130 nM, respectively, and both were active against HIV-1 in cell culture (IC_{50} of 1.4 and 1.6 μM). Closely related inophyllums A, C, D, and E, including calophyllic acids, were significantly less active or totally inactive, indicating certain structural requirements in the chromanol ring. Altogether, 11 compounds of the inophyllum class were isolated from *C. inophyllum* and were described together with the SAR (structure-activity relationship) of these novel anti-HIV compounds. The seeds of *Calophyllum cerasiferum* and *Calophyllum inophyllum* were found to contain several known coumarins, among which were the potent HIV reverse transcriptase inhibitors costatolide and inophyllum (Spino et al. 1998).

Inophyllums isolated from *Calophyllum inophyllum* were found to be novel non-nucleoside inhibitors of human immunodeficiency virus (HIV) type 1 reverse transcriptase (Taylor et al. 1994; De Clercq 2000). Inhibition of avian myeloblastosis virus reverse transcriptase and Moloney murine leukemia virus reverse transcriptase by inophyllum B was demonstrated, suggesting that these inhibitors may be more promiscuous than other previously described non-nucleoside inhibitors. Inophyllums were active against HIV type 1 in cell culture with IC_{50} values of approximately 1.5 μM. These studies implied that the inophyllums had a novel mechanism of interaction with reverse transcriptase and as such could conceivably play a role in combination therapy.

Various pyranocoumarins, calophyllolide, inophyllums B, C, G(1), G(2) and P, from *Calophyllum inophyllum* leaves of French Polynesia (Austral, Marquesas, Society and Tuamotu archipelagos) were found to inhibit HIV-1 (Laure et al. 2008). The use of multivariate statistical analyses (PCA) showed geographical distribution of inophyllums and indicated those rich in HIV-1 active (+)-inophyllums. Inophyllum B and P contents (0.0–39.0 and 0.0–21.8 mg/kg, respectively) confirmed the chemodiversity of this species within the large area of French Polynesia. The study suggested the presence of interesting chemotypes which could be used as plant source for anti-HIV-1 drugs. A number of coumarins, xanthones and chromene acids from different *Calophyllum* species of Sri Lanka including *C. inophyllum* were found to be inactive in both the HIV-1 RT and whole virus systems (Dharmaratne et al. 2002). In contrast, cordatolide A and B demonstrated IC_{50} values of 19.3 and 11.7 μM, respectively, against HIV-1 replication in a novel green fluorescent protein (GFP)-based reporter cell assay (HOG.R5).

Anticancer Activity

Ten 4-phenylcoumarins isolated from *Calophyllum inophyllum* exhibited inhibitory activity against Epstein-Barr virus without showing any cytotoxicity (Itoigawa et al. 2001). Calocoumarin-A (5) showed more potent activity than any of the other compounds tested. Furthermore, calocoumarin-A exhibited a marked inhibitory effect on mouse skin tumour promotion in an in vivo two-stage carcinogenesis test. The results indicated that some of these 4-phenylcoumarins might be valuable as potential cancer chemopreventive agents (anti-tumour-promoters). A new friedelane-type triterpene, along with seven known triterpenoids, was isolated from the stems and leaves of *Calophyllum inophyllum* (Li et al. 2010). Their structures were established as 3β, 23-epoxy-friedelan-28-oic acid, friedelin, epifriedelanol, canophyllal, canophyllol, canophyllic acid, 3-oxo-friedelan-28-oic acid, and oleanolic acid. The growth inhibitory effects of these triterpenoids on human leukemia HL-60 cells were also determined.

A new prenylated xanthone (**1**), named caloxanthone N, together with two known constituents, gerontoxanthone C (**2**) and 2-hydroxyxanthone (**3**), were isolated from the ethanolic extract of the twigs of *Calophyllum inophyllum (*Xiao et al. 2008). Compounds **1** and **2** exhibited cytotoxicity against chronic myelogenous leukemia cell line (K562) with IC_{50} values of 7.2 and 6.3 µg/ml, respectively. Two new prenylated xanthones, caloxanthone O (1) and caloxanthone P (2) were isolated from the ethanol extract of the twigs (Dai et al. 2010). Compound 1 exhibited cytotoxicity against human gastric cancer cell line (SGC-7901), with an IC_{50} value of 22.4 µg/mL while compound 2 was inactive (IC_{50} > 100 µg/mL). Extract of *C. inophyllum* was one of 43 plant species that were found to exhibit in-vitro cell viability of a human leukaemia cell-line HL60 by more than 50% when exposed to 9.6 J/cm^2 of a broad spectrum light when tested at a concentration of 20 µg/mL (Ong et al. 2009). The results indicated that the plant extract could have potential for photodynamic therapy.

Antiplatelet Activity

Xanthone compounds isolated from *Calophyllum* and *Garcinia* species including *Calophyllum inophyllum* exhibited antagonistic activity against rabbit platelet activating factors (PAF) (Jantan et al. 2001). The compounds, 6-deoxyjacareubin, 2-(methylbut-2-enyl)-1,3,5-trihydoxyxanthone and 2-(3-methylbut-2-enyl)-1,3,5,6-tetrahydroxyxanthone isolated from *C. inophyllum* inhibited 3 H-PAF binding to rabbit platelets with IC_{50} values of 4.8, 29.0 and 44.0 µM, respectively. Calophyllolide, a nonsteroidal 1–4 phenyl coumarin isolated from *C. inophyllum* exhibited anti-blood coagulation activity (Arora et al. 1962). Xanthones from 3 Clusiaceae plants (*Hypericum patulum, Calophyllum inophyllum* and *C. austroindium*): guanandin; caloxanthone E; 1,3,5,6-tetrahydroxy-2-isoprenylxanthone; 6-deoxyjacareubin; and patulone showed strong inhibition of platelet activating factor (PAF)-induced hypotension, with inhibitory effects of more than 60% (Oku et al. 2005). Their ID_{50} values were greater than that of ginkgolide B (BN-52 021), a natural PAF-antagonist from the *Ginkgo biloba*.

Antimicrobial Activity

C. inophyllum oil exhibited antibacterial activity in-vitro against Gram negative bacteria (Bhat et al. 1954). Tamanu (*C. inophyllum*) oil demonstrated significant antimicrobial activity, as shown in antibacterial and antifungal tests (Sundaram et al. 1986; Mahmud et al. 1998). The oil was found to contain several powerful bactericide/fungicide agents, which demonstrated efficacy against various human and animal pathogens. These antimicrobial phytochemical agents included friedelin, canophyllol, canophyllic acid, and inophynone (Mahmud et al. 1998). Xanthones and coumarins in tamanu oil demonstrated anti-oxidant properties, specifically inhibiting lipid peroxidation (Mahmud et al. 1998). The antioxidant activity of tamanu oil was found to protect skin cells from damage by reactive oxygen species and other oxidative antagonists.

The following compounds from the root bark and the nut of *Calophyllum inophyllum*: a xanthone derivative, named inoxanthone, 3, together with 12 known compounds: caloxanthone A; caloxanthone B; macluraxanthone; 1,5-dihydroxyxanthone; calophynic acid; brasiliensic acid; inophylloidic acid; friedelan-3-one; calaustralin; calophyllolide; inophyllum C; and inophyllum E were evaluated for their antimicrobial activity against *Staphylococcus aureus, Vibrio anguillarium, Escherichia coli*, and *Candida tropicalis* (Yimdjo et al. 2004). Their *in vitro* cytotoxicity against the KB cell line was also evaluated. At 20 µg per disc, caloxanthone A, calophynic acid, brasiliensic acid, inophylloidic acid, calophyllolide, inophyllum C and inophyllum E inhibited the growth of *S. aureus*.

UV Protection Activity

Calophyllum inophyllum oil was found to exhibit antioxidant and cytoprotective properties, and thus to have potential as a natural UV filter in ophthalmic preparations (Said et al. 2006). The oil, even at low concentration (1/10,000, v/v), exhibited significant ultra violet (UV) absorption properties (maximum at 300 nm) and was associated with an important sun protection factor (18–22). Oil concentrations up to 1% were not cytotoxic on human conjunctival epithelial cells, and *Calophyllum inophyllum* oil appeared to act as a cytoprotective agent against oxidative stress and DNA damage (85% of the DNA damage induced by UV radiations were inhibited with 1% Calophyllum oil) and did not induce in vivo ocular irritation in rabbits.

Wound Healing Activity

Dweck and Meadows (2002) reported that there was significant improvement in scars after 6 weeks of tamanu oil use in six subjects with visually obvious scars, which continued till 9 weeks of the study. The overall size of scars gradually decreased throughout the study. Scar length decreased by an average of 0.28 cm and scar width by an average of 0.12 cm. They reported that the oil was recommended for all kinds of burns (sunburns or chemical burns), most dermatoses, postsurgical cicatrization, certain skin allergies, acne, psoriasis, herpes, chilblains, skin cracks, diabetic sores, haemorrhoids, dry skin, insomnia, hair loss, etc. In cosmetology, it is used in the preparation of regenerative creams. Calophyllic acid and a lactone was found to be endowed with antibiotic properties which contributed to the oil's amazing cicatrising power (Dweck 2003).

Central Nervous System (CNS) Depressent Activity

The xanthones of *Calophyllum inophyllum* and *Mesua ferrea* namely, dehydrocycloguanandin (DCG), calophyllin-B (CPB), jacareubin (JR), 6-desoxy jacareubin (DJR), mesuaxantbone-A (MXA), mesuaxanthone-B (MXB) and euxanthone (EX) produced varying degrees of CNS depression characterised by ptosis, sedation, decreased spontaneous motor activity, loss of muscle tone, potentiation of pentobarbitone sleeping time and ether anaesthesia in mice and rats (Gopalakrishnan et al. 1980). None of the xanthones had any analgesic, antipyretic and anticonvulsant activities. The xanthones did not produce any pharmacological effect in the cardiovascular system of frogs and dogs.

Antiinflammatory Activity

Tamanu oil demonstrated significant anti-inflammatory activity which was partially due to the 4-phenyl coumarin calophyllolide (Bhalla et al. 1980). Calophyllolide, a nonsteroidal anti-inflammatory agent, was found to be effective in reducing the increased capillary permeability induced in mice by various chemical mediators involved in the inflammatory process viz. histamine (HA), 5-hydroxytryptamine (5-HT) and bradykinin (BK) (Saxena et al. 1982). Pretreatment with calophyllolide (p. o.) afforded significant protection against induced increase in capillary permeability by HA (PD50 144.1 mg/kg), 5-HT (PD50 250.0 mg/kg) and BK (PD50 133.5 mg/kg). The xanthones of *Calophyllum inophyllum* and *Mesua ferrea* namely, dehydrocycloguanandin (DCG), calophyllin-B (CPB), jacareubin (JR), 6-desoxy jacareubin (DJR), mesuaxantbone-A (MXA), mesuaxanthone-B (MXB) and euxanthone (EX) exhibited anti inflammatory activity both by intraperitoneal and oral routes in normal and adrenalectomised rats as tested by carrageenin induced hind paw oedema, cotton pellet granuloma and granuloma pouch techniques, (Gopalakrishnan et al. 1980). The xanthones did not have any mast cell membrane stabilising effect, and the degranulating effect of compound 48/80, diazoxide and Won-X-100 on rat peritoneal mast cells in-vitro was not prevented.

Antiulcer Activity

The xanthones jacareubin and 6-desoxy jacareubin isolated from *Calophyllum inophyllum* exhibited antiulcer activity in rats (Gopalakrishnan et al. 1980).

Molluscicidal Activity

Of crude extracts of seeds, leaves and barks of *Calophyllum inophyllum*, the seed extract showed significant molluscicidal activity against *Biomphalaria glabrata* (Ravelonjato et al. 1992) . Among the coumarinic derivatives examined, 5,7-dihydroxy-6-(2-methylbutyryl)-4-phenylcoumarin presented an interesting molluscicidal activity.

Stable Fly Repellancy Activity

An enhancement in the protection time was produced by binary mixtures (PT, 2.68–2.04 h) of five essential oils (clove bud, clove leaf, thyme white, patchouli, and savory) and tamanu oil (0.25:2.0 mg/cm^2) compared with that of either the constituted essential oil or tamanu oil alone (PT, 0.56 h) in repellancy test against female stable fly, *Stomoxys calcitrans* in humans (Hieu et al. 2010b). The protection time of these binary mixtures was comparable with that of DEET the commonly used repellant. With the exception of savory essential oil, the other essential oils, tamanu oil, and binary mixtures did not induce any adverse effects on the human volunteers at 0.5 mg/cm^2. In another study, Hieu et al. (2010a) found that mixtures formulated from *Zanthoxylum piperitum* (pericarp steam distillate (ZP-SD), *Zanthoxylum armatum* seed oil (ZA-SO) and their constituents alone or in combination with *Calophyllum inophyllum* nut oil (CI-NO), or their bioactive constituents could be useful as potential repellents for the control of stable fly, *Stomoxys calcitrans* populations. The repellency of aerosols containing 2.5% ZP-SD or 2.5% ZA-SO and 2.5% CI-NO was comparable with that of 5% DEET aerosol.

Traditional Medicinal Uses

Various parts of the tree have been used in traditional herbal folk remedies in Asia and the Pacific islands (Burkill 1966; Chuah et al. 2007; CSIR 1950; Dweck and Meadows 2002; Kirtikar and Basu 1989; Lemmens 2003; Quisumbing 1978; Whistler 1992). Various parts has been reported to be used as a diuretic, for treatment of venereal disease, blood pressure, rheumatism, inflammation, eye diseases, varicose veins, haemorrhoids, chronic ulcers, skin infections and wounds (Su et al. 2008; Dai et al. 2010).

Plant

The plant is a virulent poison including the mature fruit and seed kernel. The milky juice causes blindness when brought in contact with the eyes and the sap, when brought into the circulation, causes death and is therefore used by the Samoans as an arrow poison.

Root

In Mauritius a root decoction is used to treat ulcers, boils and ophthalmia (inflamed eyes). A root infusion is used internally in conjunction with heated leaf poultice for side-stitch. The root decoction is used externally in combination with the leaf infusion taken internally for heat stroke.

Bark/Resin

Resin that oozes from the bark and bark itself have various medicinal uses. Bark can be used as analgesic, antispasmodic, depurative, diuretic, emmolient and laxative and contains tannin. In India and Indo-China the pounded bark is applied in orchitis. In Indo-China, the bark is used against dysentery and intestinal colds. In Indonesia, the bark decoction is given after childbirth for vaginal discharges, passing of blood and in gonorrhoea. The latex and pounded bark are applied externally on wounds, ulcers and to treat phthisis, orchitis and lung affections, and internally as a purgative, after childbirth and to treat gonorrhoea. The gum that oozes from wounds is astringent and used as emetic and purgative and a decoction is given for internal haemorrhage and also used for the antiseptic treatments of wounds and ulcers. The oleoresin mixed with strips of the bark and leaves, and is steeped in water; the oil which rises to the surface is used as an application to sore eyes. The resin is sudorific and is useful for chronic catarrh and as cicatrizant for wounds, indolent ulcers and sores. The resin is employed in Indonesia, Philippines and Indochina as an application on wounds and a balsamic in phthisis. The oleoresin is taken internally for affections of the lungs.

Leaves

Boiled leaves provide a wash solution for skin rash, leg swellings, leg ulcers and wounds. Heat softened leaves are applied to boils, cuts, wounds, sores, pimples and skin ulcers, also for treating ocular irritation and microbial infection. In Madagascar, Linga and Fiji, a leaf lotion is used for sore eyes. Leaf solution is used as an astringent against haemorrhoids in the Philippines. Leaf infusion is used to treat sore eyes and dysentery. Leaves are used in inhalations to treat migraine and vertigo in Cambodia. The leaf infusion is taken internally of heat stroke in conjunction with an external application of the root decoction. For side stitch, the hot leaf poultice is applied externally in combination with the root decoction taken internally.

Flower/Fruit

The flowers are used as a heart tonic. An infusion of the fruit is pectoral and stimulates the mucous membrane of the lungs.

Seed/Seed Oil

Pounded seeds are applied on the abdomen for gastric pains, indigestion and colic in the Philippines. In Indonesia, pounded seed are used for itch. In Western India, the pounded seeds are mixed with cashew nuts, borax and sparrow droppings to boils to hasten maturation. In India, the seed oil is applied as a remedy for exanthematous eruptions, and as external application for scabies, liniment for rheumatism, arthritis and gout and as a treatment for gonorrhoea and gleet. The seed oil is rubefacient, analgesic, emetic and irritant and is applied externally as an analgesic against rheumatism and sciatica, and as a medication against swellings, ulcers, scabies, ringworm, boils, sores, and itch. In Malaysia and Polynesia, the seed oil is used as an external application for indigestion and colic and rheumatism. In the Philippines, the seed oil is used as a cicatrisant and as balsamic (soothing medicine) in pulmonary complaints. In Kenya, the seed oil is applied to glandular swellings in the neck and jaws. Fijian use the seed oil to massage their bodies. In Malaysia the seed oil is also used for ringworm. The oil has various other applications: hair/tonic/alopecia, relief of neuritis, nappy rash, minor wounds (lip chaps and skin cracks, atonic wound, physical and chemical burns. The seed oil is called Donba oil in Europe and is used for the treatment of rheumatism, itch and scabies.

Other Uses

Various parts of the tree have many other non-medicinal uses (Al-Jeboury and Locksley 1971; Burkill 1966; CSIR 1950; Dweck and Meadows 2002; Friday and Okano 2006; Lemmens 2005; Lim and Lemmens 1993).

Calophyllum inophyllum is planted as a roadside tree, shade tree, in hedges and as a wind break, and landscape ornamental plant in parks, gardens and coastal areas. The tree has been regarded as sacred in some Pacific islands, where it has been planted around altars and featured in old chants. It is also a useful timber tree. It provides valued, hard and strong wood for general construction and the construction of ships, canoes and small boats, masts, keels, knees and pulley blocks, carpentry, flooring, panels, stairs, furniture and cabinet work, cart-wheel hubs, vessels, handicraft and musical instruments. . In Hawai'i it is traditionally used for food vessels and in Palau for storyboards. Latex from the cut bark can be used as a poison to kill rodents and stun fish. The bark is used as shingles/thatches for house walls in Yap. Latex from the cut bark has been made into a poison to kill rodents and stun fish. The bark contains tannins that have been used to strengthen fishing nets.

Flowers are used in leis (garlands), to scent hair, and to scent bark cloth. The mature fruit is burned for mosquito repellent. In ancient Hawai'i, a brownish-mauve dye for tapa or bark cloth (*kapa*) was made from the fruit husks. The stones (nuts) of the fruit are used as marbles. The nuts are hollowed out and the shells are used in making leis. The round thin shells are used as receptacles for 'buri sugar' a popular confection. In ancient times, whistles were made from the hollowed- out shells.

The seeds yield a thick, dark green oil for medicinal use or hair grease. The seed oil is used for illumination in oil lamps, varnishes, and as finishers for wooden bowls and wood. The purified oil can be used in soap production and as a carrier oil, skin moisturizer, skin creams and hair oil in cosmetics and also in aromatherapy.

The seed oil can be used as biodiesel. Studies conducted by Sahoo et al. (2007) in India demonstrated that non-edible filtered high viscous (72 cSt at 40°C) and high acid value (44 mg KOH/g) polanga (*Calophyllum inophyllum*) oil based mono esters (biodiesel) produced by triple stage transesterification process and blended with high speed diesel (HSD) were suitable for their use as a substitute fuel of diesel in a single cylinder diesel engine. HSD and polanga oil methyl ester (POME) fuel blends (20%, 40%, 60%, 80%, and 100%) were used for conducting the short-term engine performance tests at varying loads (0%, 20%, 40%, 60%, 80%, and 100%). The optimum engine operating condition based on lower brake specific fuel consumption and higher brake thermal efficiency was observed at 100% load for neat biodiesel. From emission point of view the neat polanga oil methyl ester was found to be the best fuel as it showed lesser exhaust emission as compared to high speed diesel. The fatty-acid methyl ester of *Calophyllum inophyllum* seed oil meets all of the major biodiesel requirements in the USA (ASTM D 6751–02, ASTM PS 121–99), Germany (DIN V 51606) and European Union (EN 14214) (Mohibbe Azam et al. 2005). The average oil yield is 11.7 kg-oil/tree or 4,680 kg-oil/ha. The yield of biodiesel from *C. inophyllum* oil using three stage process viz., pre-treatment, alkali catalyzed transesterification and post treatment and under the optimized conditions of methanol to oil molar ratio, catalyst concentration, temperature and time was found to be 89% (Venkanna and Venkataramana 2009). A two-step process was developed to produce biodiesel from *Calophyllum inophyllum* oil (Sathyaselvabala et al. 2011). This involved a pre-treatment with phosphoric acid modified β-zeolite in acid catalyzed esterification process preceded by transesterification.

C. inophyllum oil has insecticidal activity and can be used as insecticides (Pawar et al. 2004). Extracts and purified extracts of seeds of *Calophyllum inophyllum* when evaluated against the second instar larvae reared on synthetic diet, exhibited high larval mortality of *Helicoverpa armigera*, prolongation of developmental period, morphological deformities and highly significant reduction in adult emergence. The reduction in larval weights in the treatments was also highly significant.

Comments

The seeds are recalcitrant and are damaged by drying and sub-zero temperatures.

Selected References

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