T. K. Lim

Edible Medicinal and Non-Medicinal Plants

Volume 6, Fruits

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Contents

Introduction

This book continues as volume 6 of a multi-compendium on *Edible Medicinal and Non-Medicinal Plants.* It covers edible fruits/seeds used fresh, cooked or processed into other by-products, or as vegetables, cereals, spices, stimulant, edible oils and beverages. It covers selected species from the following families: Sapindaceae, Sapotaceae, Schisandraceae, Solanaceae, Thymelaeaceae, Urticaceae, Vitaceae and Winteraceae. However, not all the edible species in these families are included. The edible species dealt with in this work include to a larger extent lesser-known, wild and underutilized crops and also common and widely grown crops.

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

Sapindaceae, the soapberry family, under the order sapindales, contains about 124 genera with 1,478 acceptable species name (The Plant List 2010). The largest genera are *Serjania*, *Paullinia*, *Acer* and *Allophylus.* The family occurs mainly in tropical and subtropical regions especially in Malesia and South America but may also be found in temperate areas. The species consist of trees, shrubs and climbers, rarely herbaceous and contain milky sap. Many species may contain mildly toxic saponin in the bark, twigs, leaves, seeds or roots that is used as a foaming agent and as a fish poison. Several yield valuable timber; many species yield edible fruit, such as the better known lychee (*Litchi chinensis*) longan (*Dimocarpus longan* subsp. *longan* var. *longan*) and the rambutan (*Nephelium lappaceum*). Other lesser-known species with edible fruit include *Nephelium ramboutan-ake* (pulasan), *Nephelium maingayi* (serait), *Nephelium cuspidatum* var. *robustu*m (giant rambutan), *Dimocarpus longan* subsp. *malesianus* var. *malesianus* (mata kucing, isau, kakus, sau), *Dimocarpus longan* subsp. *malesianus* var. *echinatus* (spiny longan), *Dimocarpus fumatus* (Blume) Leenh. subsp. *fumatus* (green mata kucing), *Blighia sapida* (akee), *Lepisanthes alata and L. fruticosa.* All these edible fruit species together with *Paullinia cupan*a (guarana), a caffeine rich fruit, used in energy drinks, are covered in this volume.

Sapotaceae is a family of evergreen flowering plants, belonging to order Ericales with 58 genera and 1,271 accepted species name (The Plant List 2010). The family is pantropical and comprises shrubs or trees with milky sap and are often further characterized by the presence of reddish-brown hairs on the leaf undersides and other plant surfaces. Economic species include species' of *Palaquium* in particular *P. gutta* that produces an important latex with industrial uses, *Vitellaria paradoxa* (African shea tree) that produces shea butter from itsoil-rich nuts and *Argania*

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spinosa, the seeds of which yield an edible oil and is traditionally harvested in Morocco. Species that produce edible fruits include *Chrysophyllum cainito* (starapple), *Chrysophyllum oliviforme, Manilkara jaimiqui, Manilkara kauki, Manilkara zapota* (sapodilla, chiku), *Mimusops elengi* (Spanish cherry), *Pouteria caimito* (abiu), *Pouteria campechiana* (canistel, egg fruit), *Pouteria sapota* (mamey sapote), *Pouteria viridis* (green sapote) and *Synsepalum dulcificum*, also known as miracle fruit that produces that produces a glycoprotetin compound called miraculin that can alter the perceived sweetness of sour food. All the above mentioned species with edible fruit are treated in this volume.

Schindraceae is a recognised family under the modern molecular-based APG II system, (Angiosperm Phylogeny Group II system) of plant classification of 2003. The family is placed under the order Austrobaileyales, APG II assumes Schisandraceae sensu lato to be a family of three genera, *Illicium, Kadsura and Schisandra*. The Plant List (2010) also accepted these 3 genera and listed 181 species name out of which 81were accepted, 81 were synonyms and 29 unassessed. The family consists of woody shrubs or small trees containing essential oils and found in tropical to temperate regions of East and Southeast Asia and the Caribbean. The species, *Illicium verum* with edible fruit and seeds used as a spice is treated in this volume. Its fruit contain catechins, protoanthocyanidin, shikimic acid, volatile oil, fixed oil and other phytochemicals like and its pharmacology includes anticancer, antiviral, antimicrobial, antiinflammatory, anticholinesterase and analgesic attributes.

Solanaceae is a large family of angiosperms with 105 genera and 2,030 accepted plant species out of a list of 8,216 scientific plant names of species rank (The Plant List 2010). The family comprise herb, shrubs or small trees, or rarely woody vines; spines present or absent . The family is ubiquitous in tropical and temperate zones, chiefly native of Central and south America. The family contains many ornamental plant species *Browallia, Brunfelsia, Cestrum, Datura, Lycium, Nicotiana, Nierembergia, Petunia, Physalis, Salpiglossis, Schizanthus, Solanum, Solandra* and *Streptosolen.* Several genera like N*icotiana* species, Deadly Nightshade (*Atropa belladonna*), thornapples (*Datura* species) are poisonous or have medicinal or narcotic properties. The family also contain many food plants whose fruit are eaten as fruits or eaten as vegetables (usually cooked); all these are covered in this volume. The fruit group includes Cape gooseberry (*Physalis peruviana*), *Physalis angulata* (wild gooseberry), *Solanum betaceum* (tamarrilo), *Solanum muricatum* (pepino), *Solanum quitoense* (naranjilla), and *Solanum sessiliflorum* (cocona). The vegetable group include eggplant *(Solanum melongena*), capsicum, chili and peppers (*Capsicum annuum, Capsicum baccatum, Capsicum chinense, Capsicum frustescens*), potato (*Solanum tuberosum*) and tomato (*Solanum lycopersicon*), *Lycium barbarum* and *L. chinense* (Goji berry), *Solanum americanum, Solanum lasiocarpum, Solanum linearifolium, Solanum macrocarpon, Solanum mammosum, Solanum nigrum* and *Solanum torvum.*

Thymelaeaceae is a family of dicotyledonous flowering plants with 898 species in 50 genera under the order Malvales. The family is cosmopolitan with greater diversity in the southern hemisphere, in Australia and Africa, than in the north. The species are shrubs, trees, or lianas. One species with edible fruit *Phaleria capitata* is covered in this volume.

Urticaceae, the nettle family of flowering plant comprises 52 genera with 1,303 accepted species name, under the order Rosales. The family is cosmopolitan apart from the polar regions and occurs mainly in the tropical and subtropical regions. Species are shrubs (e.g. *Pilea*),, lianas, herbs (e.g. *Urtica*, *Parietaria*), or, rarely, trees (*Dendrocnide*, *Cecropia, Pourouma).* Economically the Urticaceae are most important for their fibres (e.g. ramie, *Boehmeria nivea*). They can be troublesome weeds (*Urtica* and *Parietaria* spp.), pot herbs (*Pilea* spp. in the tropics; *Urtica* spp. in temperate zones), and frequently cultivated ornamentals (*Pilea* spp). One species with edible fruit, *Pourouma cecropiaefolia* is treated in this volume.

Vitaceae is a family of woody or herbaceous climbing, deciduous or evergreen dicotyledonous flowering plants. It encompasses about 700 species in 12 genera, mainly in tropical and subtropical regions. It has one economically important edible species grapes, *Vitis vinifera,* cultivated for wine and table grapes, is treated in this volume. Besides vitamins, proteins, carbohydrates and minerals, grapes have phenolic compounds including phenolic acids, bisphenols including stilbenes (*cis*- and *trans*-piceid, *cis*- and *trans*-resveratrol), tricyclic phenols (flavonoids) and their subclasses, and oligomeric and polymeric species, the proanthocyanidins and anthocyanidins (Sovak 2001) imparting many beneficial pharmacological activities.

Winteraceae, a mostly southern-hemisphere family associated with the Antarctic flora, is found tropical to temperate climate regions of Malesia, Oceania, Eastern Australia, New Zealand, Madagascar and the Neotropics. The family is traditionally regarded as the least-specialized descendents of the first flowering plants, based largely on their lack of xylem vessels (Feild et al. 2002, 2012). Since vessels have been viewed as a key innovation for angiosperm diversification, Winteraceae have been portrayed as declining relicts, limited to wet forest habitats where their tracheid-based wood does not impose a significant hydraulic constraints .e.g. *Tasmannia cordata*. Many species are fragrant and yield essential oil. Two species with edible seeds used as condiment and spice, *T. lanceolata* (Tasmanina pepper) and *T. insipida* (pepper tree) are covered in this volume.

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Blighia sapida

Scientific Name

Blighia sapida **Koenig.**

Synonyms

Cupania akeesia Spach, *Cupania edulis* Schumach, *Cupania sapida* Voight.

Family

Sapindaceae

Common/English Names

Ackee, Akee, Akee Apple, Aki, Savory Akee Tree, Vegetable Brain.

Vernacular Names

Benin: Diremou (Baatonu (language), Batombou (ethnic group)), Moufodom (Ditammari, Otamari), Lissetin, sissitin (Fongbe/Mahi, Fon), Ichin, Iguchin (Nagot/Idatcha, Yoruba), Foulama (Nateni, Natmeba);
Colombia: Bien Me Sabe, Pan Y Quesito;
Costa Rica: Akí;
Cuba: Arbol De Seso, Palo De Seso;
Czech: Mýdelník Obvejčitý;
Danish: Aki;
Eastonian: Maitsev Akipuu;
French: Akée, Arbre Fricassee, Blighia Savoureuse, Fausse Anacarde, Fisanier, Pommier D'aki, Ris De Veau Végétal;
Guatemala: Huevo Vegetal, Fruto De Huevo
German: Akibaum, Aki-Pflaume;
Guinea: Finsan (Manding-Bambara);
Guinea-Bissau: Otau (Bidyogo), Feso (Fula-Pulaar);
Haiti: Arbre Fricassé, Arbre A Fricasser (French);
Ivory Coast: Kaka, Finzan;
Martinique: Yeux De Crabe, Ris De Veau;
Mexico: Arbor Del Huevo, Pera Roja;
Nigeria: Akee, Ishin;
Panama: Huevo Vegetal, Fruto De Huevo;
Portuguese: Castanha, Castanheiro De Africa, Castanheiro-Da-África;
Senegal: Finza (Manding-Bambara);
Sierra Leone: Maiyosundo, Sundo (Kisssi), Muŋgσpo (Kono),
Spanish: Akí, Arbol De Seso, Huevo Vegetal, Seso Vegetal;
Sudan: Finza;
Surin am: Akie;
Venezuela: Merey Del Diablo;
West Africa: Akye, Akyen, Finzan, Ishin, Kaka.

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Origin/Distribution

The akee is indigenous to the forests of the Ivory Coast and Gold Coast of West tropical Africa. It is now widespread in tropical and subtropical environments and is the national fruit of Jamaica. It has also been introduced into Australia.

Agroecology

The akee tree is tropical to subtropical; flourishes from sea-level to an elevation of 900 m and is frost sensitive. The tree thrives in full sun or partial shade on deep, fertile loamy soils with abundant moisture, but makes satisfactory growth on shallow sandy soils or calcareous soils.

Edible Plant Parts and Uses

The akee fruit must be allowed to open fully (ripe) before it is detached from the tree. The fleshy arils from fully ripe fruits are eaten fresh or used for many dishes after parboiling, cooking or frying. Arils of the ripe fruit are nutty-flavoured, and cooked arils have texture of scrambled eggs. The seeds are discarded and the arils, while still fresh and firm are best parboiled in salted water or milk and then lightly fried in butter. In Jamaica, they are often cooked with codfish, onions and tomatoes. After parboiling, they are added to a stew of beef, salt-pork and scallions, thyme and other seasonings. Sometimes they are curried and eaten with rice. They are served, not only in the home, but also in hotel dining rooms and other restaurants. The fleshy arils are also processed in brine, canned and exported.

In Africa, they may be eaten raw or in soup, or after frying in oil. In Benin, ripe arils are consumed directly fresh, added to sauce to replace sesame seeds or peanuts, or grounded into powder and added to the sauce. Arils are also fried in peanut oil or palm oil. (Ekué et al. 2010). In Benin, the ethnic group, Natemba, use the young leaves as vegetables.

Botany

A perennial evergreen tree, growing to 10–12 m with a short trunk of 1.8 m circumference and grey, smooth bark and a dense crown of spreading branches. The leaves are alternate, pinnately compound with 3–5 pairs of oblong, obovate-oblong, or elliptic leaflets, 15–30 cm long, with obtuse base and acuminate apex, glossy bright-green on the upper surface (Plate 1), dull and paler and finely hairy on the prominently raised lateral veins on the under side (Plate 2). Flowers are bisexual and male borne together in simple racemes 7.5–17.5 cm long, fragrant, 5-merous, greenish-white and pubescent. The fruit is a leathery, pear shaped, more or less distinctly 3–4 lobed capsule (Plates 1–3), 7–10 cm long, yellow with splashes of bright-scarlet. When fully mature, it splits open revealing 3 cream-colored, fleshy, glossy, crisp arils attached to the large, black, nearly round, smooth, hard, shining seeds (Plate 4) – normally 3; often 1 or 2 may be aborted. The base of each aril is attached

Plate 1 Dark green glossy leaves and fruit of Ackee

Plate 2 Pale green and raised veins of the lower leaf surface and 3–4 lobed ackee fruit

Plate 3 Cluster of ackee fruits

Plate 4 White edible arils and black glossy seeds

to the inside of the stem-end of the "jacket" by pink or orange-red membranes.

Nutritive/Medicinal Properties

The fruit was reported to contain significant amount of protein, fibre and potassium. The fruit pulp contained higher percentages of crude fat, crude protein, total ash and moisture than the seed (Akintayo et al. 2002). The most abundant mineral was potassium, in both. The reddish-coloured oil obtained from *B. sapida* had an acid value of 14.2 mg KOH/g, specific gravity of 0.9510, refractive index of 1.462, and saponification value of 177. Protein solubility studies showed that both seed and pulp protein were soluble at acidic and basic pH regions, indicating that they may be useful in formulating acid foods, such as meat and milk analogue products and protein-rich beverages. The protein solubility curves showed that two different fractions might be recovered from pulp at pH 4.0 and 10.0 and from the seed at pH 3.0 and 7.0. Their relatively high emulsion and oil absorption capacities facilate their use in the production of sausages, soups and cakes with improved flavour-retaining capacities and mouth-feel. *B. sapida* fruit oil yield was found to be 20.02% (Oladiji et al. 2009). The oil consisted of 22.22% saturated, 56.43% monounsaturated, and 21.35% polyunsaturated fatty acids. It was richer than soybean oil in behenic, palmitoleic, oleic, gadoleic, erucic, and 9,12-eicosanoic acids by 15.70, 0.89, 7.22, 12.05, 8.27, and 21.35%, respectively. The smoke, flash, and fire points as well as peroxide, iodine, and acid values of the fruit oil were significantly lower, whereas the specific gravity, relative density, saponification, and ester values compared well with soybean oil.

Proximate composition of dried akee aril was reported as: moisture 6.84%, crude fat 45.32%, protein 11.99%, carbohydrate 4.13%, crude fibre 3.21%, total soluble sugar 3.31%, reducing sugar 1.52%, ash 4.90%, K 1503.30 mg/100 g, Mg 53.17 mg/100 g, Ca 139.67 mg/100 g, Na 53.17 mg/100 g, Fe 17.33 mg/100 g, Zn 4 mg/100 g (Howélé et al. 2010). The oil from the dried aril was yellowish in colour with a specific gravity of 0.933, refractive index of 1.48, acid value of 7.38, peroxide value of 174.44, iodine value of 56.26 and saponification value of 188.40. The results indicated dried ackee aril to be nutritionally rich with high oil and carbohydrate content, but its protein content was found to be lower than that recommended by the Food and Agriculture Organisation. The extracted aril oil contained low unsaturated fatty acid, with a low deteriorating rate and can therefore be stored for a relatively long time. It is a non drying oil, edible and may be suitable for soap making. It can also serve to make margarine. In another study, ackee seed oil was found to have a saponification value of 145 and an iodine value of 66, consistent with the high mono-unsaturated fatty acids content (63.8 wt%) (Djenontin et al. 2009). The oil had a prominent concentration of eicosenoic acid (48.4 wt%). Arachidic acid being the main component within the saturated group, the C20 fatty acids fraction accounted for 68.4wt%. Among the unsaponifiable fraction (2.4wt%), the major sterol was stigmasterol (54.6wt%), surpassing β-sitosterol. Tocols (338ppm) comprised mainly α- and γ-tocopherol. The defatted cake contained high starch content and a noticeable amount of proteins and fibres (44.2, 22.4, 15.6 wt%, respectively). Seventeen amino acids were identified together with valuable minerals (total ashes 3.5 wt%).

The phytochemical screening of extracts of *Blighia sapida* showed the presence of some groups of phytochemicals such as saponins, reducing sugar, phytosterols, and polyamide (Antwi et al. 2009). Pure (2S, 1′ S, 2′ S)-2-(2′-carboxycyclo-propyl)glycine was isolated from *Blighia sapida* (Natalini et al. 2000).

Two toxic, non-proteinogenic amino acids, hypoglycin A and B were isolated from the seeds of unripe ackee fruit and hypoglycin A from the unripe fruit arils (Hassall et al. 1954; Hassall and Reyle 1955). Another non-proteinogenic amino acid (2S, 1′S, 2′S)-2-(2′-carboxycyclopropyl) glycine (CCG 1), was isolated from ackee fruit with a structure similar to hypoglycin A with respect to the presence of a cycopropane ring structure (Natalini et al. 2000). Blighinone, a sparingly soluble quinone was isolated from the aril of ackee fruit (Garg and Mitra 1976). Vomifoliol was isolated from the leaves and stems of *B. sapida* and had been implicated in the endogenous regulation of stomatal aperture (Stuart et al. 1976).

Antioxidant Activity

The IC_{50} value of the H2O:MeOH Diaion HP-20SS fractions of *B. sapida* fruit in the DPPH radical scavenging assay was 6.6 μg/mL (Einbond et al. 2004). *B. sapida* not known for a high sugar content, eluted 43% w/w of the semi-purified aqueous fraction in the Diaion HP-20SS H_2O fraction.

Antidiarrhoeal Activity

Administration of ethanolic and aqueous stem bark extracts of *Blighia sapida* before castor oil challenge caused significant dose-dependent inhibitions of the castor oil-induced diarrhoea (39.7–93.2%) and intestinal motility (31.9–77.5%) with the highest dose (1,060 mg/kg) showing inhibitions (70.4–93.2%) comparable to loperamide (89–100%) and atropine (72.8–100%), respectively (Antwi et al. 2009). Castor oil-induced enteropooling was significantly inhibited by the ethanolic and aqueous extracts in rats (23.8–25.9%) and mice (58.4–59.0%) at the highest dose compared to 41.6–46.8% for loperamide. The results indicated that there were no significant differences between the ethanolic and aqueous extracts of *B. sapida* in the reduction or prevention of castor oil-induced diarrhoea and that *B. sapida* may act through the inhibitions of intestinal motility and enteropooling.

Hypocholesterolemic Activity

Daily administration of the aqueous and ethanolic ackee leaf extracts (50 and 100 mg/kg body weight) for 21 days significantly reduced the levels of total cholesterol, triglycerides and LDL-cholesterol in all extract treated rats compared with the control (Owolabi et al. 2010). For the atherogenic indices, there was a significant increase in HDL-cholesterol/Total cholesterol ratio, while LDL-cholesterol/HDL-cholesterol and log (TG/HDLCH) ratio showed a significant decrease in extract treated groups compared to the control group.

The liver- and kidney-body weight ratios as well as the serum concentrations of cholesterol and high-density lipoprotein cholesterol of the rats maintained on diet formulated with the oil from the fruit of *B. sapida* increased significantly, but the triglyceride and atherogenic index decreased (Oladiji et al. 2009). The low-density lipoprotein cholesterol concentration and the heart-body weight ratio of the rats fed with the fruit oil diet compared well with those on soybean oil-based diet. Animals fed with the fruit oil-based diet had their activities of liver glutamate oxaloacetate transaminase and glutamate pyruvate transaminase as well as alkaline phosphatase activities of the liver and kidney decreased with corresponding increase in the serum enzymes. The oil is also unlikely to predispose the animals to cardiovascular risk, but may labilize the plasma membrane of the hepatocytes and nephrons. It may also have a negative effect on the metabolism and regulation of amino acid in the animals. Therefore, the oil from *B. sapida* fruit may not be completely safe for consumption (Oladiji et al. 2009).

Miscellaneous Pharmacological Activity

Aqueous and lipid extracts of the unripe fruit of *Blighia sapida* were reported to significantly lower neutrophil and platelet counts in treated mice (Gardner et al. 1996). The percentage reduction in neutrophil and platelet counts relative to the controls for the aqueous and lipid (data in parentheses) extracts were 63.4% (59.3%) and 37.46% (32.44%) respectively after 6 weeks of treatment. The significant reduction in neutrophil and platelet numbers suggested that these extracts may be useful in disease conditions where these two blood parameters were elevated, for example chronic myeloid leukaemia, essential thrombocythaemia and polycythaemia.

Adverse Toxic Effects

Scott (1917) first associated Jamaican vomiting sickness with ingestion of unripe ackee fruit. The fatal disorder was characterised by vomiting, severe hypoglycaemia and depletion of liver glvcogen (Hill and Bras 1953; Jellife and Stuart 1954). Two hypoglycemic non proteinogenic amino acids were isolated from the seeds of unripe ackees and named hvpoglycin A and B as they induced severe hypoglycaemia (Hassall et al. 1954). Hypoglycin A was also isolated from the aril of unripe fruit but not hypoglycin B (Hassall and Reyle 1955). Hypoglycin A is found predominantly in the immature ackee fruit. Concentrations within the arilli were found to range from over 1,000 ppm in the immature fruit to less than 0.1 ppm in the fully mature fruit (i.e., pod coloured up, split and opened fully) (Brown et al. 1991). At all stages the seed contained considerable hypoglycin A, about 1,000 ppm, and the membrane mirrored aril levels. These analyses supported earlier observations that unopened or partially opened ackee should not be consumed, whereas fruit which open naturally to >15 mm lobe separation pose little health hazard, provided that all seed and membrane portions are removed. Chase et al. (1990) also determined that hypoglycin-A concentrations in the unripe ackee fruit components to be 939 mg, 711 mg and 41.6 mg/100 g of seed, aril and husk components respectively Analysis of the ripe fruit components showed that hypoglycin-A in the seed decreased to 269 mg/100 g and remained unchanged in the husk while the concentrations in the edible ripe aril decreased below the detection limit of 1.2 mg/100 g. Hypoglycin A was also detected in canned ackee fruit. Unripe akee fruit samples were found to contain significantly higher quantities of hypoglycin A when compared with ripe fruit samples (Golden et al. 2002). Uncooked unripe fruit was found to contain 124.4 mg/100 g fresh weight and uncooked ripe fruit 6.4 mg/100 g fresh weight. The seed of the uncooked unripe fruit was found to contain 142.8 mg/100 g fresh weight, and the seed of uncooked ripe fruit has 106.0 mg/100 g fresh weight. Boiling fruit in water for approximately 30 min was efficient in removing hypoglycin A from the edible arils; however, low levels of 0.54 mg/200 ml were detected in the water that was used to cook the ripe fruit. Kean and Hare (1980) found that γ-glutamyl transpeptidase catalyzed the formation of hypoglycin A from hypoglycin B and glutathione at pH 9.5 following a 5 h incubation. Within ackee plants, the highest level of enzymatic activity (per mg of protein in a crude extract) was found to occur in young and unripe seeds, followed by leaf, and pericarp tissues. The lowest levels of activity were found in the arillus regardless of developmental stage. The average percent recovery of hypoglycin A was 80.34%. As the fruit matures, the concentration of hypoglycin B increased from 0.4 mg/g to 3.3 mg/g (Kean and Hare 1980). Hypoglycin B was only found in the seeds of the fruit. It also possessed hypoglycemic activity but was less potent than hypoglycin A. Recent studies by Bowen-Forbes and Minott (2011) found that hypoglycin A decreased from about 8,000 mg/kg in the green arilli and seeds to 271 and 1,451 mg/kg, respectively, in the ripe fruit whereas hypoglycin B levels in the seeds increased from 1,629 to 11,774 mg/kg. The strong inverse relationship demonstrated that hypoglycin B in the seeds served as a sink for hypoglycin A from the ripening arilli and was thereby involved in the detoxification mechanism of the fruit.

The chemical structure of hypoglycin A was subsequently elucidated as L-α-amino-β-methylene cyclopropane propionic acid by Carbon et al. (1958) who determined that causative agent of Jamaican vomiting sickness was a metabolite of hypoglycin A called methylenecyclopropane acetyl CoA (MCPA-CoA). Hypo-glycin A was found to transaminate to methylenecyclopropyl-alanine (MCPA) and subsequently underwent oxidative decarboxylation to form MCPA-CoA (Von Holt 1966). MCPA-CoA exerted its effect by inhibiting several coenzyme A dehydrogenases which were essential for gluconeogenesis (Von holt et al. 1966). Depletion of glucose reserves and the inability of cells to regenerate glucose led to hypoglycaemia. Two hypoglycin metabolites methylenecyclopropanepyruvate and methylenecyclopropaneacetate were formed in the rat's liver (Von Holt et al. 1966). Methylenecyclopropanepyruvate slightly inhibited the decarboxylation of 1-14C pyruvate in mitochondria whereas methylenecyclopropaneacetate did not affect the oxidation of 2-14C pyruvate. Methylenecyclopropaneacetate inhibited in the mitochondria the oxidation of C12- to C18-fatty acids but not that of C4- to C10-fatty acids. Also oxidative phosphorylation in mitochondria was uncoupled and respiration inhibited by methylenecyclopropaneacetate. The data suggested that hypoglycin toxicity was due to the formation of its metabolite methylenecyclopropaneacetate which inhibited the oxidation of long-chain fatty acids, uncoupling oxidative phosphorylation, and interfering with gluconeogenesis.

Minor direct effect of hypoglycin was observed on glucose metabolism, either on glucose oxidation to respiratory CO^2 or on conversion of glucose to liver lipid or muscle glycogen. Synthesis of glycogen from glucose in diaphragm muscle was inhibited by hypoglycin without altering glucose uptake (Mckerns et al. 1960). The major effects of hypoglycin were those concerned with fatty acid metabolism. The administration of hypoglycin to rats caused an increase in the level of non-esterified fatty acids in the serum, an increase in the total lipids of the liver and a significant inhibition in the conversion of butyrate or stearate to respiratory CO^2. Liver mitochondria isolated from hypoglycin-treated rats showed an impaired ability to form high energy phosphate bonds associated with the oxidation of pyruvate and malate. Since hypoglycin lowered blood glucose level only after 3 or 4 h, the active compound may be a metabolite or the effects on blood sugar may be secondary to some primary metabolic block. Methylenecyclopropanepyruvic acid and methylenecyclo-propaneacetic acid, both likely metabolites, did produce hypoglycemia. Hypoglycin and hypoglycin-like compounds were found to cause profound hypoglycemia which may be largely attributed to their effects on gluconeogenesis (Bressler et al. 1969). Their toxicity was attributed to their capacity to become activated to acyl CoA derivatives whose further oxidation was impaired.

Hypoglycin toxicity in rats was found to cause changes in hepatic ultrastructure such as progressive mitochondrial swelling in the hepatocytes with loss of granules and pallor of the matrix, followed by incorporation into autophagic vacuoles (Brooks and Audretsch 1970). Kean (1972) found that liver of rats administered hypoglycin exhibited drastically reduced levels of acyl-CoA dehydrogenase activity with butyryl-CoA as substrate and less so with palmitoyl-CoA as substrate. The observed effect was consistent with quite general inhibition of fatty acid β-oxidation by hypoglycin. Studies by Lai et al. (1991, 1993) found that (methylenecyclopropyl)acetyl-CoA (MCPA-CoA), a metabolite of hypoglycin A, inactivated medium-chain acyl-CoA dehydrogenase, a FAD (flavin adenine dinucleotide)-dependent enzyme that catalyzed the first step of the fatty acid oxidation cycle. When General acyl-CoA dehydrogenase was exposed to (methylenecyclopropyl)acetyl-CoA (MCPA-CoA), time-dependent inhibition occurred with concomitant bleaching of the active-site FAD.

Hypoglycin A was more potent than B and had been reported in the literature as the causative agent in incidences of acute toxicity termed Jamaican vomiting sickness or toxic hypoglycemic syndrome (Blake et al. 2006). The toxic peptide compounds of *Blighia sapida fruit*, hypoglycin A and B had been shown to induce hypoglycemia in rabbits, monkeys, rats and mice upon intravenous injection (Chen et al. 1957). Administration of hypoglycin A to animals caused drowsiness progressing to coma, and when large doses were given the animals died (Feng and Patrick 1958). For the rat, the oral and intraperitoneal LD_{50} values were 98 and 97 mg/kg respectively. The most outstanding biochemical change produced by hypoglycin-A was a delayed hypoglycaemia, the depth of which was related to the dose. The hypoglycaemia was preceded by exhaustion of liver glycogen. There were also smaller decreases in the glycogen stores of the heart, skeletal muscle and kidney, without any increase in blood pyruvate or lactate. Hypoglycin-A lessened the effect of adrenaline on blood glucose and decreased both glucose tolerance and insulin sensitivity. Hypoglycin-A also decreased oxygen consumption and carbon dioxide production of the intact rat. All these effects were consistent with the hypothesis that the primary action of hypoglycin-A was the interference with glycogen production by the liver.

Hypoglycin A, the causative agent of the Jamaican vomiting sickness, produced a marked increase in concentration of isovaleric acid in the plasma of rats, when administered in a single dose (Tanaka et al. 1972). α-methylbutyric acid, a position isomer, also accumulated. The use of hypoglycin A reproduced some features of human isovaleric acidemia. Accumulation of these branched pentanoic acids may be another factor contributing to the pathogenesis of the Jamaican vomiting sickness.

Subacute intraperitoneal administration of the lipid portion of the unripe ackee aril (ackee oil) in rats resulted in marked neutropenia and increase in platelets without anaemia (Singh et al. 1992). Blood urea, sodium and aspartate aminotransferase levels were significantly decreased but glucose and bilirubin levels were similar to those of controls. The lungs showed areas of petechial haemorrhages and a dose-related perivascular and peribronchial mononuclear cell infiltration. The pulmonary toxicity may be interpreted as a hypersensitive reaction to ackee oil.

In Jamaica, ackee consumption was highest in the lower socio-economic group, particularly in children (Blake et al. 2004). Hypoglycin occurrence levels in typical ackee diets ranged from 1.21 to 89.28 μg hypoglycin/g ackee. Animal feeding studies showed that the acute toxic dose for male and female rats was 231.19 mg hypoglycin A/kgBW and 215.99 mg hypoglycin A/kgBW, respectively (Blake et al. 2006). This was considerably greater than the dose of 100 mg hypoglycin/kg BW reported in a previous study when aqueous hypoglycin was administered orally. The maximum tolerated dose of hypoglycin A in both male and female rats was 1.50 mg hypoglycinA/kg BW/day. These findings suggested that the form in which hypoglycin in ackee was administered could affect the toxicological properties it exhibited.

Hypoglycin Toxicity Treatment

The administration of riboflavin and glycine had been reported to reverse the effects of hypoglycin A intoxication (Duff et al. 1980; Brooks and Audretsch 1971). It was believed that riboflavin stimulated the de novo synthesis of acyl-CoA dehydrogenases while glycine conjugated with excess dicarboxylic acids produced due to impaired lipid metabolism (Al-Bassam and Sherratt 1981). Study by Brooks and Audretsch (1971) found that mitochondrial swelling was reduced in rats given riboflavin prior to hypoglycin, compared with rats given hypoglycin alone. Riboflavin appeared less effective if given 10 min after hypoglycin.

Studies in mice showed that as a treatment for ackee poisoning, glucose was more effective than methylene blue and elicited the same survival as methylene blue in conditions of early treatment (Barennes et al. 2004). Methylene blue must be given in multiple doses and the first administration should be performed early, at least within 3 h of poisoning, which may decrease the practical value of methylene blue in the field.

Traditional Medicinal Uses

Various parts of the plant have been used in folkloric medicine in many tropical countries (Irvin 1965; Morton 1987; Asamoah et al. 2010; Ekué et al. 2010). In Brazil, repeated small doses of an aqueous extract of the seed has been administered to expel parasites. The treatment is followed by a saline or oily purgative. In Colombia, the leaves and bark are regarded stomachic. Various preparations are made for treatment of epilepsy and yellow fever. Cubans blend the ripe arils with sugar and cinnamon and give the mixture as a febrifuge and as a treatment for dysentery.

In Ghana, the bark is mixed with pungent spices (*Capsicum* pepper) in an ointment applied to relieve pain. The crushed new foliage is applied on the forehead to relieve severe headache. The seeds are ingested to treat nausea and vomiting. In Côte d'Ivoire and Nigeria, the leaves, crushed with salt, are poulticed on ulcers and yaws. In Côte d'Ivoire, *finsan* is widely used for the treatment of yellow fever, epilepsy and oedema, and as a laxative and diuretic. The leaf juice is employed as eye drop in ophthalmia and conjunctivitis. The bark pulp is used as liniment for oedema intercostals pains. In Benin, leaves are employed for the therapy of fever and vertigo, and twigs for hepatitis, cirrhosis and amygdalitis. In Togo, decoctions of bark or fruit walls are applied to wounds, and the fruit pulp to treat whitlow. Pounded bark is administered as an antidote to snake, stings and scorpion bites, and pounded seeds to treat stomach complaints.

In Benin, 22 ailments have been reported to be healed with ackee (Ekué et al. 2010). To treat whitlow, ackee bark is crushed with common bean or cowpea and salt and applied to the finger; or crushed roasted seeds added to palm oil and similarly applied; or a mixture off ackee seeds and cashew nuts is incinerated and the ash applied to the finger. To treat head lice the fruit capsule is incinerated and the ashes are used to wash the head. To treat dental decay, the crushed seeds and salt is applied on the decaying teeth or crushed dried bark is placed on the hole of the decaying teeth. For apparition of the first children's teeth, a decoction of leaves and bark is drank. To treat child fever, the child is washed with a root infusion or with a water decoction of pounded leaves. To treat fever, pounded leaves of ackee and teak or pounded leaves of ackee and mango are used. To treat yellow fever powdered dried bark and salt is added to porridge and ingested, or crush bark and African locust bean (*Parkia biglobosa*) are eaten. For eye problems, a bark solution is used to wash the eyes. To treat malaria, a bark infusion; decoction of dried bark; an infusion of the bark plus green pepper seeds (*Capsicum anuum*) and soyabean leaves; an infusion of ackee and papaya leaves or a leaf decoction is taken. Powdered dried bark and salt is applied on wounds caused by scorpion and snake bites. Powdered seed or bark; or crushed, roasted seed and pal moil is used to heal wounds. Crushed bark plus cowpea or common bean is applied on abscesses. Juice from crushed bark and honey is applied on burns. To treat cutaneous infections, buttons on the body, a shower is taken with an infusion of leaves and bark. Macerated leaves are used as a massage for fractured limbs. To treat internal haemorrhage crush dried bark is taken with porridge. To treat pregnant women blood flow, macerated leaves previously exposed to the dew plus limestone is drunk. A bark decoction is taken for constipation; root decoction for anemia, leaf decoction for vomiting and decoction of leaves of akee and shea butter (*Vitellaria paradoxa*) is taken for dysentery. To treat Guinea worn infection, crushed dried bark plus shea butter (*Vitellaria paradoxa*) and potash are applied on the skin.

Other Uses

The fruit of *Blighia sapida* has molluscicidal activity. An extract prepared from freeze-dried, semi-ripe fruits of *B. sapida*, resulted in a mortality of 95% mortality of the snails after an exposure for 24 h (LC95) were at concentrations of 232.7 and 161.2 ppm for the juveniles and adults of *Bulinus globosus* and 187.6 and 140.2 ppm for the juveniles and adults of *Bulinus truncatus* (Anto et al. 2005). Oil from *B. sapida* fruit could be edible and may be explored as raw materials in the paint, margarine, and soap industries (Oladiji et al. 2009).

Feed intake and digestibility studies in Nigeria showed that *Bligha sapida leaves* could be a very good feed resource for West African dwarf goats especially in the dry season (Aderinola et al. 2007). Ackee leaves had the highest value for feed intake and nutrient digestibility.

The ethnic groups, Otamari and Natemba, located in the North-West of Benin use powdered bark, seeds and capsule to poison fish rendering them easier to catch. ackee soap is mainly produced and commercialized by women from the ethnic groups Otamari (63.3%), Batombu (57.5%) and Natemba (50%) (Ekué et al. 2010). The soap is valued mainly for its medicinal and esthetical properties. In the Pobè region (South-East Benin), the whole immature fruits are cut into small pieces and plunged into water for washing clothes. in the region of N'Dali (North-East Benin) the ash from calcined capsules is used as a repellent for some insect pest in cowpea (*Vigna unguiculata*) or common bean (*Phaseolus vulgaris*). In Boukoumbe, thed dried, crushed bark is mixed with seeds of pearl millet (*Pennisetum glaucum*) and African finger millet (*Eleusine coracana* ssp. *africana*) before sowing to thwart insects' attacks.

In Cuba, an extract of the flowers is appreciated as cologne.

The sapwood is white or light greenish-brown. The heartwood is reddish-brown, hard, coarse-grained, durable and immune to termites. It is used locally for light construction and pilings, building materials, carpentry and related applications, farming, forestry, hunting and fishing apparatus and has been recommended for railway sleepers. It is also fashioned into boxes, oars, tool handles, mortars, handicraft, carvings, paddles and casks. In the timber trade, the wood is marketed as *achin or tsana*. The wood is also used for fuel and lighting.

Comments

Ackee can be readily and successfully propagated from seeds, stem cuttings, grafting or air layering.

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Dimocarpus fumatus subsp. fumatus

Scientific Name

Dimocarpus fumatus **(Blume) Leenh. subsp.** ***fumatus.***

Synonyms

Nephelium fumatum Blume, *Pseudonephelium fumatum* (Blume) Radlk. p.p. nom. illeg.

Family

Sapindaceae

Common/English Names

Green Cat's Eye, Green Mata Kucing.

Vernacular Names

Borneo: Katumbar, Mambuakat, Merakiang; ***Sabah***: Kekucing;

Origin/Distribution

This subspecies is found throughout Borneo Island and perhaps also in Peninsular Malaysia. The species *Dimocarpus fumatus* is found in Southern China, Indo-China, Thailand, Peninsular Malaysia, Sumatra, Java, Borneo (throughout the island) and the Philippines.

Agroecology

This subspecies is found in primary forests, mainly on the flat lowland as well as hill slopes or hill tops or along river banks, at altitudes mostly below 100 m, up to 1,200(−1,350) m altitude. It is usually found on sandy soils.

Edible Plant Parts and Uses

The arillode of ripe fruit is sweet and edible fresh.

Botany

Mid-canopy tree up to 27 m high, dbh up to 1 m, sometimes with buttresses. Twigs terete, rarely less than 3 mm in diameter, dark to greyish brown, early glabrescent lenticels inconspicuous. Leaves (2-) 3- or 4-jugate; petiole up to 11.5 cm long. Leaflets usually subopposite to alternate, 6.5-28 by 2.8-10.5 cm, apex tapering to narrowly acuminate, base cuneate to rounded margin, entire, penniveined, glands along both mid-rib and margin, abaxial surface sparsely patent short hairy in the basal part on midrib and nerves,

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Plate 1 Tree habit

Plate 3 Globose yellowish-green fruit with translucent, juicy arillode

Plate 2 Leaf with three pairs of sub-opposite leaflets

Plate 4 Fruit with arillode and seed removed

adaxial surface glabrous, minutely punctuate (Plates 1 and 2). Inflorescences usually terminal lax up to 45 cm long, branched with many-flowered cymules, bracts subulate, pedicels 2-4 mm long. Sepals up to 1/3 connate, tomentose inside. Petals absent or rarely 1, much reduced. Stamens with glabrous filaments. Fruits globose to subglobose, 2.0-2.5 cm diameter, smooth, granular, glabrous, hardly warty, yellowish-green. Pericarp thin, arillode, fairly thick, translucent, juicy and sweet enclosing a large short-oblong seed (Plates 3 and 4).

Nutritive/Medicinal Properties

No information on its fruit nutritive value has been published.

The ethanolic extract from *Dimocarpus fumatus* stem bark showed in-vitro cytotoxic activity against KB (human naspharynx carcinoma) cells (Voutquenne et al. 1999). Fractionation of the extract afforded compounds belonging to different classes. The two major components were identified as a benzoquinone, sargaquinone, and a chromene, sargaol. One sphingolipid, soyacerebroside I, two glycosides of sitosterol, and fatty acids were also identified. Besides these known compounds, two new glycosides of long-chain fatty alcohols were identified as 1-*O*-[α-L-rhamnopyranosyl-(1→2)-β-D- glucopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→6)-β-D- glucopyranosyl]hexadecanol and 1-*O*-[[α-L-arabinopyranosyl-(1→3)]-α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→6)-β-D- glucopyranosyl] hexadecanol, and a mixture of three new diacylglycerylglucosides were also isolated.

Mono-desmosidic and bidesmosidic saponins with haemolytic activity were isolated from five Sapindaceous species including *Dimocarpus fumatus* (Voutquenne 2001). Additionally, other metabolites were also isolated from *Dimocarpus fumatus*, including isoprenypchromenes and three new glycosides of long chain fatty alcohols. Comparison of activities of monodesmosidic and bidesmosidic saponins showed that monodesmosidic saponins were generally more activein haemolytic activity and suggest ed a polar balance between the two sugar chains at positions 3 and 28 (Voutquenne et al. 2002).

Other Uses

Parts of the plant that contain saponins can be used as fish poison and as detergent for washing clothes.

Comments

Dimocarpus fumatus subsp. *fumatus* can be differentiated from other Malesian subspecies (Adema et al. 1994) as follows:

Dimocarpus fumatus subsp. *philippinensis* (syn. *Nephelium fumatum* Radlk. pp., *Nephelium intermedium* auct. Non Radlk.) - Twigs rarely more than 3 mm in diameter glabrous; leaves 1- or 2-jugate (exceptionally 1-foliolate), leaflets opposite, glabrous, base acute; petals absent, fruits short spiny. Found in the Philippines (Luzon, Samar, Panay).

Dimocarpus fumatus subsp. *javensis* (Radlk.) Leenhout (Syn. *Pseudonephelium javanicum* Radlk.) – Twigs about 5 mm in diameter, early glabrescent; leaves 3–4 jugate, leaflets alternate base acute; inflorescence incompletely known, petals 4, reduced; fruits not observed. Found in Sumatra and Java

An article in Nature Malaysiana erroneously showed a picture of *Dimocarpus dentatus* with subglobose greenish fruit and leaflets with smooth, entire margin. *D. dentatus* has serrate-dentate leaflets and granular, aculeate (spiny) fruits.

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Dimocarpus longan subsp. *longan* var. *longan*

Scientific Name

Dimocarpus longan **Lour. subsp.** ***longan*** **Leenhout var.** ***longan*** **Leenhout.**

Synonyms

Dimocarpus longan Lour., *Euphoria echinulata* Radlk., *Euphoria longan* (Lour.) Steudel, *Euphoria longana* L., *Euphoria longana* Lamk. nom. illeg., *Euphoria sinensis* Gmel., *Nephelium bengalense* G. Don., *Nephelium didymum* Craib, *Nephelium longana* (Lam.) Cambess., *Nephelium longan* (Lour.) Hook., *Nephelium longana* Cambess., *Nephelium longana* var. *pallida* Trim., *Nephelium longana* var. *acuminata* Pierre, *Nephelium pupillum Wight*.

Family

Sapindaceae

Common/English Names

Dragon's eye, Dragon's eye fruit, Longan, Lonagn Tree, Lungan.

Vernacular Names

Brazil: Olho-De-Dragão (Portuguese);
Burmese: Kyet Mouk;
Chinese: Lóng Yăn, Longan, Lung Ngaan, Gui Yuan, Yang Yan Guo Shu, Yuan Yan;
Cuba: Mamoncillo Chino (Spanish);
Dutch: Lengkeng;
French: Longan, Longanier, Oeil De Dragon;
German: Longane, Longanbaum, Longanbeere;
India: Ash-Fol (Bengali), Kanakindeli (Kannada), Chempoovana, Chempunna, Malampoovathi, Malampuvanna, Mulei, Pasakotta, Poripuna (Malayalam), Kattupuvam Shempuvam (Tamil);
Indonesia: Kalengleng (Madurese), Lengkeng;
Japanese: Rongan, Ryugan;
Khmer: Mien,
Laos: Lam Nhai, Nam Nhai;
Malaysia: Lengkeng, Longan Lungan;
Philippines: Longan (Tagalog);
Russian: Longan, Longana;
Portuguese: Longana, Pitomba Longana;
Spanish: Longán, Mamoncillo Chino;
Sri Lanka: Mora (Sinhalese);
Thailand: Lamyai Pa, Ma Lamyai;
Vietnam: Nhãn, Long Nhãn.

Origin/Distribution

The longan is native to southern China, in the provinces of Kwangtung, Kwangsi, Schezwan and Fukien, Hainan, Yunnan, between elevations of 150–700 m. The species has also reported to be found in India, Sri Lanka, Upper Myanmar, North Thailand, Kampuchea, North Vietnam and New Guinea. The crop is mainly grown in

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