Senna siamea

Scientific Name

***Senna siamea* (Lam.) Irwin & Barneby**

Synonyms

Cassia arayatensis sensu Naves, non Litv., *Cassia arborea* Macfad., *Cassia florida* Vahl, *Cassia gigantea* DC., *Cassia siamea* Lam., *Cassia siamea* Lam. var. *puberula* Kurz , *Cassia sumatrana* DC., *Cassia sumatrana* Roxb., *Chamaefistula gigantea* G. Don, *Sciacassia siamea* (Lam.) Britt. ex Britt. & Rose, *Senna sumatrana* Roxb.

Family

Fabaceae, also placed in Caesalpiniaceae

Common/English Names

Blackwood Cassia, Bombay Blackwood, Cassod, Cassod Tree, Iron Wood, Kassod Tree, Pheasant Wood, Siamese Cassia, Siamese Senna, Siamese Shower, Thai Cassia, Thai Copper Pod, Thailand Shower, Yellow Cassia

Vernacular Names

Amharic: Yeferenji Digita
Bangladesh: Minjiri
Brazil: Cássia-Do-Sião, Cássia-Siâmica, Cássia-Siamesa (Portuguese)
Burmese: Mezali
Chinese: Guo Mai Xi Li, Tie Do Mu
Creole: Kasya
French: Bois Perdrix, Casse Du Siam
German: Kassodbaum
India: Seemia, Kassod (Hindi), Hiretangedi, Motovolanyaro, Sima Tangedu (Kannada), Manjakonna, Manjakonnei (Malayalam), Kassod (Marathi) Sima Tangedu, Tangedu (Telugu), Mancal Konrai, Manjal Konrai, Manje-Konne, Celumalarkkonrai, Cimaiyaviri, Cuvarnakam, Karunkonnai, Karunkonrai, Kotakkini, Macantakatukkai, Makaraciya, Mampalakkonrai, Mancalkonrai, Mancatkonrai, Manga Konnei, Mulateciyam, Perumalarkkonrai, Pirampukkonnai, Ponnavirai, Vakai, Visakkini, (Tamil), Kurumbi, Sima Tangedu (Telugu)
Indonesia: Bujak, Dulang, Johar, Juhar, Juwar (Javanese), Jnar, Johor, Juwah (Sumatra)
Ivory Coast: Ando, Akassia
Japanese: Tagayasan
Khmer: Ângkanh
Laotian: Khi ‘Lek, ‘Khi:Z Hlek
Malaysia: Busok-Busok, Guah Hitam, Jaha, Jahor, Jeragor, Johor, Jual, Petai Belalang, Sebusok
Nepal: Casia
Pakistan: Minjri
Philippines: Robles
Sierra Leone: Mende Sheku Turay
Spanish: Flamboyán Amarillo

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Sri Lanka: Aramana, Wa (Sinhala), Manga Konnei, Vakai (Tamil)
Swahili: Mjohoro
Taiwan: Tie Dao Mu
Thai: Khi Lek, Khi Lek Ban, Khi Lek Kaen, Khi Lek Luang, Khi Lek Yai, Phak Chili
Tongan: Kasia
Vietnamese: Muồng Đen, Muồng Xiêm

Origin/Distribution

The species is native to South and Southeast Asia from India through to Malaysia and much of Malesia. It has been introduced to other humid tropical countries.

Agroecology

S. siamea will grow in a range of climatic conditions but is particularly adapted to the warm lowland tropics with a monsoon climate, with mean annual temperatures of 20–31°C and mean annual rainfall of 500–2,800 mm. It is found growing from sea level to 1,000 m altitude. It does not grow well in at altitudes above 1,300 m and will not survive in areas where the temperate falls below 10 °C. It tolerates seasonal flooding and exposure to strong winds but is cold, drought and salinity intolerant. It thrives on deep, well-drained soil rich in organic matter but will grow on degraded lateritic soils provided drainage is not impeded.

Edible Plant Parts and Uses

The young leaves have a bitter taste; young tender pods and inflorescences (buds/open flowers) are edible (Facciola 1990; Padumanonda and Gritsanapan 2006; Maisuthisakul et al. 2008; Kaisoon et al. 2011). The young leafy shoots (Plate 3) and young inflorescences are bundled and sold in markets as vegetables (Jacquat 1990). The leaves and flowers are popularly used in soups and in the Thai curry dish known as 'kaeng khi-lek' which is prepared with and without coconut milk (Monkheang et al. 2011). The fresh young leaves are boiled with water 2–3 times to get rid of the bitterness and to reduce the toxic barakol content before the boiled mush is used for curry. They are also pickled in brine. In Sri Lanka, the flowers and young fruits are used in curries.

Botany

A medium-sized, evergreen, much-branched perennial tree to 30 m tall with a straight trunk of 30 cm diameter with gray bark and a spreading crown of dense foliage (Plate 1). The leaves are alternate and pinnate, 23–33 cm long, and made up of 5–14 pairs of lanceolate, oblong or ovate-elliptic leaflets (Plates 1, 2 and 3), 3–7 cm long and 12–20 mm wide, abaxially finely pubescent, adaxially smooth and glabrous, base rounded and apex obtuse, borne on 25–40 mm long, terete petioles with caducous, minute subulate stipules.

Plate 1 Flowers, leaves and pods

Plate 2 Pinnate leaves

Plate 3 Tender leafy shoots sold as vegetables

Flowers occur in many-flowered, axillary or terminal, 40 cm long, racemose panicles (Plate 1). Flower 3 cm across, pedicellate, bisexual, zygomorphic, pentamerous, hypogynous; sepals imbricate, suborbicular, obtuse at the apex, pubescent outside; petals subequal, broadly obovate, bright yellow, shortly clawed; stamens 10, 7 fertile, accrescent towards the abaxial side of the flower, anther with apical pores; ovary superior, sessile, pubescent, linear and slightly curved. The fruits are pendant, linear, flat and often slightly curved legumes, 5–30 cm long, 12–20 mm wide, coriaceous or subwoody, and dark brown and dehiscent when ripe. Each fruit contains about 25 subglobose to ovate and laterally flattened seeds with a glossy, smooth, dark-brown testa.

Nutritive/Medicinal Properties

Flower Nutrient/Phytochemicals

Proximate nutrient composition of the edible flowers was reported in g/100 g edible portion as moisture 74.8 %, ash 5.6 g, protein 19.4 g, fat 1.6 g, carbohydrate 34.9 g, energy 231.7 kcal, dietary fibre 38.5 g, Ca 55.6 mg, Fe 6.93 mg and vitamin C483.3 mg (Maisuthisakul et al. 2008). Antioxidant activity (DPPH radical scavenging activity) was 2.4 ($1/EC_{50}$), total phenolics 51.5 mg GAE/g dry basis (db) and total flavonoids 24.8 mg RE/g db. The soluble phenol acids (per g dry weight) identified in *Cassia siamea* flower extract were gallic acid 30.3 µg, protocatechuic acid 638.4 µg, *p*-hydroxy benzoic acid 29.4 µg, vanillic acid 4.2 µg, chlorogenic acid 20.64 µg, caffeic acid 14.93 µg, syringic acid 16.0 µg, *p*-coumaric acid 17.5 µg, ferulic acid 11.6 µg, sinapic acid 10.4 µg and total phenolic acids 793.3 µg (Kaisoon et al. 2011). The flowers contained 455.5 µg total bound phenolic acids made up of *p*-hydroxy benzoic acid 8.8 µg, vanillic acid 3.4 µg, syringic acids 4.7 µg, *p*-coumaric acid 93.3 µg, ferulic acid 128.6 µg and sinapic acid 216.8 µg. The flowers contained 133.7 µg total soluble flavonoid made up of rutin 64 µg, myricetin 4.56 µg, quercetin 61.9 µg and kaempferol 3.21 µg and bound flavonoid 52.9 µg made up of rutin 32 µg, quercetin 10.9 µg and apigenin 10 µg. The DPPH radical scavenging activity (% inhibition) of soluble and bound phenolic fraction of the flower was 97.64 and 38.30 %, respectively. Bound phenolics exhibited lower antioxidant activity than soluble ones. The reducing potential of the soluble and bound phenolic fraction of the flower as evaluated by FRAP (ferric reducing antioxidant power) assay (mmol $FeSO_4$/100 g dry weight) was 7.30 and 26.6 mmol, respectively.

A chromone named chromone 1 was isolated from the flowers (Arora et al. 1971). Cassiadinine, a chromone alkaloid, and (+)-6-hydroxy-mellein, a dihydroisocoumarin, were isolated from the flowers (Biswas and Mallik 1986). Three new alkaloids, cassiarins C–E, and a new chromone, 10,11-dihydroanhydrobarakol, were isolated from the flowers (Oshimi et al. 2009). Cassiarin D was a dimeric compound consisting of 5-acetonyl-7-hydroxy-2-methylchromone and cassiarin C, and cassiarin E was a dimer of cassiarins A and C. The alkaloid cassiarin F was isolated from the flowers (Deguchi et al. 2011).

Seed/Fruit Phytochemicals

A water-soluble polysaccharide composed of D-galactose, D-mannose and D-xylose in a molar ratio 3:6:2 was isolated from *C. siamea* seeds (Khare et al. 1980). Hydrolysis of the methylated polysaccharide furnished five methylated sugars (I) 2, 3 di-*O*-methyl D-xylose, (II) 2, 3 di-0-methyl

D-mannose, (111)2, 3, 4-tri-0-methyl D-galactose, (IV) 2, 3, 6-tri-0-methyl D-mannose and (V) 2, 3, 4, 6-tetra-0-methyl D-galactose in the molar ratio 4:4:2:8:4, while partial acidic hydrolysis yielded five oligosaccharides (I) epimelibiose, (II) mannobiose, (III) mannotriose, (IV) mannosylgalactobiose and (V) xylotetraose. *Cassia siamea* seed oil was found to be a minor source of vernolic and cyclopropenoid fatty acids; it contained palmitic (19.0 %), stearic (7.6 %), oleic (11.6 %), linoleic (42.7 %), malvalic (2.0 %), sterculic (3.1 %) and vernolic (14.0 %) acids (Daulatabad et al. 1988).

A sodium salt of a natural 2-methylchromone was isolated from pods of *C. siamea* (Reddy et al. 1976). An anthraquinone, 1-desmethylchrysoobtusin-2-*O*-glucoside, was isolated from the fruit (Abdallah et al. 1994).

Leaf Nutrients/Phytochemicals

Leaves of *Cassia siamea* together with leaves of 3 other species out of 127 species were classified in the very high class group for both TEAC (Trolox equivalent antioxidant capacity) and SOS (superoxide scavenging) activity. TEAC values on a dry weight basis ranged from 0 to 2,105 μmol TE/g, and SOS values ranged from 0 to 6,206 μmol ascorbate equivalent (AE)/g (Yang et al. 2006). Kuo (2002) reported the young leafy shoot of *C. siamea* to have 20 g dry matter, 1.29 g fibre, 0.92 g sugar, 5.92 g protein, 3.48 mg vitamin C, 97 mg β-carotene, 26 mg Ca and 1.26 mg Fe. The proximate nutrient composition of cassod leaves was reported as follows: moisture content 46.01 %, protein 4.01 %, crude fibre 12.36 %, ash 17.93 %, carbohydrate 7.67 %, crude fat 12.02 % and minerals in ppm, potassium 812, calcium 932, sodium 612, magnesium 876, manganese 35.10, phosphorus 10.84, iron 112, copper 0.84 and lead 0.34 ppm (Smith 2009). Saponins, anthraquinones, phlobatannins and alkaloids were detected in the ethanol leaf extract and also present were antinutrients phytate, tannin and oxalate in trace amounts.

A dioxaphenalene derivative was isolated from *Cassia siamea* leaves and named barakol and its structure determined as 3α,4-dihydro-3α,8-dihydroxy-2,5-dimethyl-1,4-dioxaphenalene (Hassanali et al. 1968). From the leaves were isolated β-sitosterol, cassiamin A, physcion, chrysophanol, *p*-coumaric acid, apigenin-7-*O*-galactoside (thalictiin), and a new chromone cassiachromone with the structure 2-methyl-5-acetonyl-7-hydroxy-chromone (Wagner et al. 1978). Barakol, apigenin and β-sitosterol were isolated from the leaves (Krishna Rao and Murthy 1978). Isoquinoline alkaloids, siamine and siaminines A, B and C, were isolated from the leaves (El-Sayyad et al. 1984). An isoflavone glycoside 2′,4′,5,7-tetrahydroxy-8-*C*-glucosylisoflavone (2′-hydroxygenistein 9-*C*-glucoside) was isolated from the leaves (Shafiullah et al. 1995).

Luteolin; cassia chromone (5-acetonyl-7-hydroxy-2-methylchromone);5-acetonyl-7-hydroxy-2-hydroxymethyl-chromone; 4-(*trans*)-acetyl-3,6,8-trihydroxy-3-methyldihydronaphthalenone; and 4-(*cis*)-acetyl-3,6,8-trihydroxy-3-methyl-dihydronaphthalenone were isolated from the leaves (Ingkaninan et al. 2000). Two alkaloids cassiarins A and B were isolated from the leaves (Morita et al. 2007). Chrobisiamone A, a new bischromone, was isolated from the leaves (Oshimi et al. 2008). Cyclization of 5-acetonyl-7-hydroxy-2-methylchromone in the presence of ammonium acetate resulted in generation of cassiarin A. Six compounds were isolated from the leaves and identified as 2-methyl-5-acetonyl-7-hydroxy-chromone (1), 4-*cis*-acetyl-3,6,8-trihydroxy-3-methyl-dihydronaphthalenone (2), emodin (3), physcion (4), β-amyrin (5) and β-sitosterol (6) (Xue et al. 2010). A triterpene, lup-20(29)-en-1β-3β-diol, was isolated from the plant (Tripathi et al. 1992).

Fresh young leaves of *S. siamea* contained 0.4035 % w/w barakol (Padumanonda and Gritsanapan 2006). Barakol was extracted as pure lemon-yellow crystals from young *S. siamea* leaves with 0.1 % yield (Padumanonda et al. 2007). Barakol content in young leaves, mature leaves and young flowers were 1.67, 0.78 and 1.43 % dry weight, respectively. Total anthraquinone glycosides and total anthraquinones, calculated as rhein, in the fresh young leaves were

0.0523 and 0.0910 % w/w, respectively (Sakulpanich and Gritsanapan 2009). The first and second boiled filtrates contained total anthraquinone glycosides 0.0334 and 0.0031 % fresh weight, respectively. The first boiled leaves contained 0.0161 % fresh weight, and the second boiled leaves contained non-detected amount. Total anthraquinone contents in the first and second filtrates and the first and second boiled leaves were found to be 0.0721, 0.0069, 0.0167 % fresh weight and non-detected amount, respectively. Four new alkaloids, cassiarins G, H, J and K (1–4), were isolated from the leaves, (Deguchi et al. 2012).

Stem/Wood Phytochemicals

From heartwood, a new bianthraquinone, 4,4′-bis(1,3-dihydroxy-2-methyl-6,8-dimethoxy anthraquinone), along with 1,1′-bis(4,5-dihydroxy-2-methyl anthraquinone), chrysophanol and emodin were isolated (Singh et al. 1992). From the stem bark, 19α, 24-dihydroxyurs-12-ene-28-oic acid- 3-*O*-β-D-xylopyra-noside along with anthraquinones, namely, chrysophanol and physcion, were isolated (Singh and Agrawal 1994).

From the stem, three anthraquinone compounds were isolated and identified as chrysophanol, chrysophanol-1-*O*-β-D-glucopyranoside and 1-[(β-D-glucopyranosyl-(1→6)-0-β-D-glucopyranosyl) oxy]-8-hydroxyl-3-methy-9,10-anthraquinone (Lü et al. 2001b), and a chromone glycoside, 2-methyl-5-propyl-7, 12-dihydroxy chromone-12-*O*-β-D-glucopyranoside (Lü et al. 2001b). Five additional compounds were isolated from the stem and identified as β-sitosterol, sucrose, *n*-octacosanol, 2-methyl-5-(2′-hydroxypropyl)-7-hydroxy-chromone-2′-*O*-β-D-glucopyranoside and piceatannol (Lü et al. 2003). Emodin and lupeol were isolated from the ethyl acetate fraction of the stem bark extract (Ajaiyeoba et al. 2008). Triterpenes (lupeol, oleanolic acid, ursolic acid, friedelin, betulin), flavonoids (apigenin, kaempferol, luteolin), anthraquinones (emodin) and phytosterols (stigmasterol, β-sitosterol) were reported in the stem bark (Nsonde Ntandou et al. 2010).

Root Phytochemicals

Anthraquinones, chrysophanol, emodin, and two bianthraquinones, cassiamin A and cassiamin B (Koyama et al. 2002a), another two bianthraquinones(1,1′,3,8,8′-pentahydroxy-3′,6-dimethyl[2,2′-bianthracene]-9,9′,10,10′-tetrone and 7-chloro-1,1′,6,8,8′-pentahydroxy-3,3′-dimethyl[2,2′-bianthracene]-9,9′,10,10′-tetrone, respectively (Koyama et al. 2001a), were isolated from the root bark.

Antioxidant Activity

The alcoholic flower extract of *C. siamea* was found to contain a large amount of polyphenols and also exhibited an immense reducing ability (Kaur et al. 2006). At a concentration of 250 µg/mL, 96 % of DPPH radicals and at 500 µg/mL, 42.7, 32.7 and 64.5 % of O^{2-}, H_2O_2 and NO, respectively, were scavenged by the extract. The extract also inhibited OH radical-induced oxidation of protein (bovine serum albumin) and lipid peroxidation in murine hepatic microsomes. The extract displayed significant antioxidant activity in acute oxidative tissue injury animal model caused by CCl_4-induced hepatotoxicity. Oral administration of the extract at a dose of 50–150 mg/kg of body weight significantly protected from CCl_4-induced elevation in aspartate aminotransaminase (AST) and alanine aminotransaminase (ALT), in the serum; elevation in hepatic lipid peroxidation; depletion of hepatic glutathione (GSH); and decrease in the activities of hepatic antioxidant enzymes: superoxide dismutase (SOD), glutathione peroxidase (GPX) and catalase (CAT). The extract also protected against histopathological changes produced by CCl_4 such as necrosis, fatty changes and ballooning degeneration. The findings suggested that the alcoholic extract of *C. siamea* flowers had potent antioxidant activity against free radicals, prevented oxidative damage to major biomolecules and afforded significant protection against oxidative damage in the liver.

Antitumour Activity

Anthraquinone monomers isolated from *Cassia siamea* showed higher antitumour-promoting activity than that of bianthraquinones in inhibiting Epstein–Barr virus activation (Koyama et al. 2001b). Emodin and cassiamin B, isolated from *Cassia siamea,* exhibited marked antitumour-promoting effect on two-stage carcinogenesis test of mouse skin tumours induced by 7,12-dimethylbenz[*a*]anthracene as an initiator and 12-*O*-tetradecanoylphorbol-13-acetate (TPA) as a promoter by topical application (Koyama et al. 2002b). In addition, emodin exhibited potent inhibitory activity on two-stage carcinogenesis test of mouse skin tumours induced by nitric oxide donor, (+/−)-(*E*)-methyl-2-[(*E*)-hydroxyimino]-5-nitro-6-methoxy-3-hexeneamide as an initiator and TPA as a promoter.

Antiplasmodial Activity

Crude hot water extracts of *Cassia siamea*, *Jatropha gossypifolia* and *Pavetta crassipes* exhibited 100 % inhibition in vitro against *Plasmodium falciparum* (Gbeassor et al. 1989). Two alkaloids cassiarins A and B isolated from the leaves showed antiplasmodial activity; cassiarin A showed potent activity (Morita et al. 2007). Cassiarin A isolated from *C. siamea* leaves exhibited potent antimalarial activity against *Plasmodium falciparum* in vitro as well as *P. berghei* in vivo (Morita et al. 2009). Based on the premise that interactions of parasitized red blood cells (pRBCs) with endothelium in aorta were especially important in the processes involved in the pathogenesis of severe malaria, they found that cassiarin A showed vasorelaxation activity against rat aortic ring, which may be related with nitric oxide (NO) production. NO had been reported to reduce cytoadherence of pRBC to vascular endothelium. Similarly, a series of a hydroxyl and a nitrogen-substituted derivatives and a dehydroxy derivative of cassiarin A having potent antimalarials against *P. falciparum* with vasodilator activity reduced cytoadherence of pRBC to vascular endothelium. These derivatives showed more potent vasorelaxant activity but not higher inhibition of *P. falciparum* in vitro. The results suggested that cassiarin derivatives may be promising candidates as antimalarials with different mode of actions.

Emodin and lupeol, isolated from the stem bark, were found to be the active principles responsible for the antiplasmodial property with IC_{50} values of 5 μg/mL, respectively, against the multi-resistant strain of *Plasmodium falciparum* (K1) (Ajaiyeoba et al. 2008). Chrobisiamone A, a new bischromone isolated from the leaves, exhibited antiplasmodial activity (Oshimi et al. 2008). Three new alkaloids, cassiarins C–E (1–3), and a new chromone, 10,11-dihydroanhydrobarakol (4) isolated from the flowers, showed moderate antiplasmodial activity against *Plasmodium falciparum* 3D7 (Oshimi et al. 2009). The alkaloid cassiarin F from the flowers showed antiplasmodial activity against *Plasmodium falciparum* (Deguchi et al. 2011). Four new alkaloids, cassiarins G, H, J and K (1–4), isolated from the leaves, showed moderate antiplasmodial activity against *Plasmodium falciparum* 3D7 (Deguchi et al. 2012).

Cardioprotective Activity

Pretreatment with barakol (10 mg/kg i.v.) from *C. siamea* leaves reduced the incidence of aconitine-induced ventricular fibrillation (VF) and ventricular tachycardia (VT) as well as mortality of rats (Chen et al. 1999). It was found that the mechanisms of the protective effects of barakol on aconitine-induced cardiac toxicity may relate to the prevention of intracellular Na + accumulation.

Vasodilating Activity

In rings cut from rat superior mesenteric arteries precontracted with phenylephrine, cassiarin A from *C. siamea*, induced a concentration-dependent relaxation (Matsumoto et al. 2010).

It was found that that the vasodilating effect of cassiarin A may be mediated by endothelial nitric oxide and may occur partly via BK(Ca)-channel activation.

CNS (Anti-insomnia, Analgesic, Anxiolytic) Activities

Animal studies showed that barakol, active compound from *S. siamea*, had anxiolytic properties similar to diazepam but differed from diazepam in that it also increased exploratory and locomotor behaviour, as shown by the number of rears and total arm entries in the elevated plus-maze test (Thongsaard et al. 1996). However, studies by Fiorino et al. (1998) found that barakol (0–20 mg/kg) exhibited no evidence of its anxiolytic effects in either of two pharmacologically validated tests of rat anxiety: the plus-maze or shock-probe burying tests.

Luteolin from *Senna siamea* was found to be an antagonist at the adenosine A(1) receptor binding activity with a *K*(i) value in the low micromolar range (Ingkaninan et al. 2000). Abundant evidence showed that the sleep-inducing effects were mediated locally in the basal forebrain through the adenosine A1 receptor (Alanko et al. 2004). They found that G-protein activity was increased in the cortex but not in the basal forebrain during the first hours of sleep deprivation, suggesting different A1 receptor-mediated responses to increasing adenosine concentrations in different brain areas.

Studies showed that barakol, from *C. siamea*, reduced spontaneous locomotor activity, increased the number of sleeping mice and prolonged the thiopental-induced sleeping time, indicating a sedative effect (Sukma et al. 2002). At a high dose (100 mg/kg, i.p.), barakol slightly prolonged the latency of clonic convulsion induced by the convulsant, picrotoxin, suggesting that the sedative effect may not be induced via the GABA or glycine systems. There was no evidence of an anxiolytic effect of barakol in the plus-maze test. However, barakol (25–100 mg/kg, i.p.) could suppress methamphetamine (1 mg/kg, i.p.)-induced hyperlocomotor activity in a dose-dependent manner, indicating an effect on the dopaminergic system. The results indicated that the CNS inhibitory effect of barakol on dopamine release may account for the blocking effect of barakol on the striatum-related behaviour induced by methamphetamine. Acute and chronic oral administration of barakol (10, 30 and 100 mg/kg, p.o.) had no anxiolytic and locomotor effects on male Wistar rats (Deachapunya and Thongsaard 2009). However, it exerted a sedative effect as shown by a reduction in the directed exploratory behaviours.

Studies showed that intraperitoneal administration of low-dose (25 mg/kg) and high-dose (100 mg/kg) barakol resulted in sleeping behaviour in Long-Evans hooded rats, substantiating the use of the cassod leaves for insomnia commonly prescribed in Thai traditional medicine (Bulyalert 2011). The acetic acid-induced writhing test in mice showed that ethanol leaf extract of *Senna siamea* at the dose of 500 mg/kg exhibited significant inhibition of writhing reflex by 61.98 % while the standard drug diclofenac Na inhibition was found to be 85.95 % at a dose of 25 mg/kg body weight (Momin et al. 2012).

Antiinflammatory and Analgesic Activity

At the doses used (100, 200 and 400 mg/kg), ethanol and water extracts of *Cassia siamea* stem bark showed significant and dose-dependent analgesic and antiinflammatory effects in the hot-plate test, paw pressure and carrageenan-induced paw oedema tests (Nsonde Ntandou et al. 2010). None of the extracts had cytotoxic activity on KB and Vero cell lines, and the most active extracts (CSE3 and CSE4) had no acute toxicity. These activities were attributed to the presence of triterpenes (lupeol, oleanolic acid, ursolic acid, friedelin, betulin), flavonoids (apigenin, kaempferol, luteolin), anthraquinones (emodin) and phytosterols (stigmasterol, β-sitosterol) in the stem bark.

Antiviral Activity

Seven new chromones, siamchromones A–G (1–7), and 12 known chromones (8–19) were isolated from *Cassia siamea* stems (Hu et al. 2012). Compound 6 showed anti-tobacco mosaic virus (anti-TMV) activity with an inhibition rate of 35.3 % and IC_{50} value of 31.2 μM, which was higher than that of the positive control, ningnamycin. Compounds 1, 10, 13 and 16 showed anti-TMV activities with inhibition rates above 10 %. Compounds 4, 6, 13 and 19 showed anti-HIV-1 (anti-human immunodeficiency virus-1) activities with therapeutic index values above 50.

Antimicrobial Activity

The ethanol extracts of *C. siamea*, *Syzygium jambolanum* and alga *Caulerpa scalpelliformis* exhibited antifungal activity at 100 mg/mL against *Candida albicans*, *Candida glabrata*, *Candida tropicalis*, *Candida krusei*, *Candida parapsilosis* and *Candida guilliermondii* (Prabhakar et al. 2008). The ethanol leaf extracts showed the highest activity at 40 mg/mL concentration against *Salmonella typhi* followed by acetone extracts, while the aqueous extracts showed the lowest activity (Doughari and Okafor 2008). The MIC and MBC values of the crude extracts (1–3 mg/mL) were comparable to those of the tested antibiotics (ampicillin, chloramphenicol, cotrimoxazole and ciprofloxacin). Purification of the ethanol extract showed that the ethyl acetate fraction possessed the highest activity followed by *n*-butanol fraction while the chloroform fraction did not show any activity at 20 mg/mL. The ethanol leaf extract of *Senna siamea* exhibited antibacterial activity against *Pseudomonas aeruginosa* at concentration of 500 μg/disc in comparison with the standard kanamycin (Momin et al. 2012).

Secretagogue Activity

Studies demonstrated that barakol stimulated bumetanide-sensitive chloride secretion in rat colon (Deachapunya et al. 2005a). The effect of barakol was partly mediated by the stimulation of submucosal nerves and through the release of cyclooxygenase metabolites. The results elucidated the underlying mechanism of barakol as a secretagogue in mammalian colon.

Purgative Activity

Barakol was found to have purgative effects (Deachapunya et al. 2005b). Barakol extract increased the force of spontaneous muscle contractions in the rat ileum in a concentration-dependent manner. Pretreatment of muscle strips with barakol (1 mM) significantly decreased the inhibitory effect of norepinephrine by 60 %, but not that of dopamine. Its ability to potentiate atropine- and saxitoxin-sensitive contractions and inhibit the antimotility actions of norepinephrine suggested that barakol may increase longitudinal smooth muscle contractions by decreasing the inhibitory effect of norepinephrine on excitatory cholinergic motor neurons. The authors concluded that barakol may produce a purgative action in small intestine which may be clinically important in patients with intestinal hypomotility disorders.

Antidiabetic Activity

Oral administration of cassod leaf extracts at doses of 250 and 500 mg/kg for 3 weeks significantly improved blood glucose levels and body weights in normal and streptozotocin-induced diabetic rats (Kumar et al. 2010). Daily oral treatment with the extract also resulted in significantly reduction of serum cholesterol and triglycerides and improvement in HDL cholesterol level.

Mosquitocidal Activity

The leaf methanol extract of *C. siamea* exhibited 100 % mortality against *Anopheles stephensi* (malaria vector) and *Culex quinquefasciatus*

(filariasis vector) after 48-hour exposure, suggesting that the extract has the potential to be used as an ideal eco-friendly approach for the control of both mosquito vectors (Kamaraj et al. 2011).

Laxative Activity

Studies showed that the process of preparation of Khi Lek curry by boiling *S. siamea* young leaves twice with water reduced total anthraquinone glycosides content by more than 75 %, confirming the traditional use of Khi Lek curry as a very mild laxative drug (Sakulpanich and Gritsanapan 2009). The fresh or dried leaves are used traditionally for constipation in Thailand (Monkheang et al. 2011).

Barakol Toxicity Studies

Studies showed that the process of preparation of Khi Lek curry by boiling *S. siamea* young leaves twice with water was found to reduce barakol content up to 90 % and thus lowering the tendency to cause liver toxicity (Padumanonda and Gritsanapan 2006). Fresh young leaves contained 0.4035 % w/w barakol. The contents of barakol in the first and second boiled filtrates were 0.2052 and 0.1079 % fresh weight, while the first and second boiled leaves samples were 0.1408 and 0.0414 % fresh weight, respectively. This may explain the reason why Thai Khi Lek curry had not caused hepatotoxicity, unlike *S. siamea* leaves consumed as a powdered capsule.

Hongsirinirachorn et al. (2003) studied the adverse effects of barakol in 12 healthy Thai patients, aged 29–81 years (mean 52.5) with neither a history of chronic liver disease nor known hepatotoxic substance ingestion, who took barakol for 3–180 days (mean 76.9). Eight of them were admitted with the first episode of anorexia and jaundice for 4–60 days after taking 20–40 mg/day (2–4 tablets) of barakol. The mean total bilirubin was 5.7 mg/dL, and liver function test revealed moderate to severe hepatitis (aspartate amino transferase (AST) range 111–1,473 U/L: mean = 692). Histopathological findings were in accord with interface hepatitis. Their symptoms and liver function completely improved within 2–20 weeks (mean 5.9) after barakol abstinence.

Barakol was hepatotoxic in mice, causing liver injury when administered in a single dose (100, 200, 300 and 400 mg/kg, p.o.) and repeated doses (100, 200 and 300 mg/kg/day, p.o., 28 days) for acute and subacute toxicity studies, respectively (Devakul Na Ayutthaya et al. 2005). The acute and subacute hepatotoxic findings included the increase in total bilirubin, AST and ALT concentrations and the decrease in cholesterol, triglyceride and glucose levels which corresponded to the histopathological examination showing the hydropic swelling of hepatocytes, scattered degree of necrotic cells around central vein spreading to periportal zone and finally apoptotic cell death around centrilobular zone spreading to periportal area. The degree of the severity of barakol-induced liver injury was dose and time dependent. There were signs of liver regeneration and recovery in all doses of barakol treatment. A 6-month chronic toxicity study of powdered cassod leaves in Wistar rats showed that at the doses of 200 and 2,000 mg/kg bw/day, the levels of bilirubin were significantly increased compared to control rats (Chavalittumrong et al. 2012). A dose-dependent increase of the incidence of hepatic lesion, namely, degeneration and necrosis, was found at every dose level in both male and female animals. It appeared that male rats were more susceptible to the hepatotoxic effect of cassod than female rats. Reduction of the hepatic damage of the recovery group suggested that the hepatotoxic effect of *C. siamea* was reversible when the drug was stopped for only 14 days.

Treatment with barakol decreased cell viability in a concentration- and time-dependent manner with an IC_{50} value of 1.5 mM in 24-h-treated mouse embryonal carcinoma P19 cells (Wongtongtair et al. 2011). Barakol-induced cytotoxicity was due to a significant increase in the number of apoptotic cells. The mechanism of barakol-mediated toxicity in P19 cells was mainly attributed with the ROS generation, followed by the imbalance of the Bax/Bcl-2 ratio,

and caspase-9 activation leading to apoptotic cell death. Pretreatment of cells with *N*-acetyl-l-cysteine could antagonize the toxicity produced by barakol.

Subchronic toxicity studies showed that *S. siamea* stem extract significantly increases the body weight and feed intake of the male Wistar rats but did not significantly affect haematological parameters, total protein and albumin levels, serum glucose, triglycerides, cholesterol and the markers of kidney function (creatinine, urea, potassium, sodium and chloride) (Mohammed et al. 2012). However, levels of serum liver enzymes (alkaline phosphatase (ALP), alanine aminotransaminase (ALT) and aspartate aminotransaminase (AST)) were significantly different from the normal control group. The quantitative determination of saponins, alkaloids, total polyphenolics and flavonoids in (g/g) were found to be 0.07, 0.05, 0.92 and 0.06, respectively. These results may explain the use of *S. siamea* stem bark in folk medicine due its less toxic effect.

Traditional Medicinal Uses

The plant is commonly used in traditional medicine to treat hypertension, malaria and diabetes mellitus (Mohammed et al. 2012). In Burkina Faso, a decoction of the leaves with lemon juice is used for the treatment of fevers (Fowler 2006). In northern Nigeria, the tree is very popular for its local usage in the treatment of typhoid fever. In Kampuchea, a hardwood decoction is used against scabies. The fruit and seeds have been used to treat intestinal worms. In Thailand, the leaves and flowers are used as a remedy for insomnia, as laxative for constipation and as appetite stimulant and digestive stimulant; flower and root decoctions are used to treat anxiety, nervousness and stress, and wood decoction for fever (Thongsaard et al. 1996; Sukma et al. 2002; Deachapunya et al. 2005a; Sakulpanich and Gritsanapan 2009; Bulyalert 2011; Monkheang et al. 2011). The flowers are used to treat insomnia and asthma in traditional medicine (Kaur et al. 2006).

Other Uses

Senna siamea is cultivated as windbreaks, shelterbelts, live fence, boundary markers, ornamental in parks and gardens, wayside tree and shade tree for tea, cocoa and coffee plantings. The tree is also used for erosion control, for land reclamation in former tin/aluminium mining sites and in alley cropping systems in agroforestry, largely because of its coppicing ability and high biomass production shade besides also for its nitrogen-fixing capability. In India, it is used as a host for the semiparasitic sandalwood (*Santalum* spp.). In China, it has been cultivated as fuelwood by the Dai people since 400 years ago and as a host plant for lac insects. Its foliage is rich in nitrogen and organic matter and is used as green manure. The foliage can be used as browse or fodder for cattle, sheep and goats but are toxic to poultry and swine. The flower is an important nectar source for bees.

The tree afford a hard, heavy, dense, durable, dark blackish brown and termite-resistant wood that is used in joinery, cabinet making, furniture, inlaying, tool handles, walking sticks, posts, bridges, mine poles and beams and other decorative carvings. All parts of the tree including the bark can be used for tanning.

Comments

Cassod is easily and readily propagated from seeds, although stumps can be used.

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