Mesua ferrea

Scientific Name

***Mesua ferrea* L.**

Synonyms

Calophyllum nagassarium Burm. f., *Mesua nagassarium* (Burm. f.) Kosterm

Family

Calophyllaceae

Common/English Names

Ceylon Ironwood, Cobra's Saffron, Indian Rose Chestnut, Ironwood, Ironwood Tree, Ironwood Of Assam, Mesua, Poached Egg Tree, Sembawang Tree

Vernacular Names

Arabic: Narae-Kaisar
Bangladesh: Nageshwar
Burmese: Gungen, Kenga
Chinese: Tie Li Mu
Dutch: Ijzerhout
French: Arbe De Fer, Bois D'anis, Bois De Fer
German: Eisenholzbaum, Nagasbaum, Nagassamen
India: Nahar, Nahor, Nageshwar, Negeshvar, Nokte (Assamese), Nagesvara, Nagkesar, Punnaga (Bengali), Nagachampa, Nagkesara, Nagchampa, Pilunagkesar, Sachunagkeshara, Tamranagkesar (Gujarati), Nagakeshara, Nagchampa, Nagesar, Naghesar, Nagkesara, Nahar, Narmishka, Pila Nagkesara (Hindi), Nagakesari, Nagasampige (Kannada), Nagkesarah (Kashmiri), Churuli, Nagppu, Nagappovu, Nangaa, Nauga, Peri, Vainav, Veluthapalau (Malayalam), Nageshor (Manipuri), Nagakesara Nagchampa, Thorlachampa (Marathi), Nahar, Herhse (Mizo), Nageswar (Oriya), Nageswar (Punjabi), Champeryah, Gajakesara, Hema, Kesara, Naga, Nagakesara, Nagakeshara, Nagkesar, Nagakesarah, Nagkeshara, Nagkeshwar, Nagpushpa, Nagapuspah (Sanskrit), Charu-Nagapu, Nagappu, Nakecuram, Naugu, Naugaliral, Nagachampakam, Sirunagappoo, Tadinangu, Veillutta Champakam (Tamil), Kesaramu, Nagachampakamu, Nagakesaramu, Nagashappu (Telugu), Nagkesar, Narmishka, Narmushk (Urdu)
Indonesia: Nagasari Gede, Nagasari
Italian: Croco Di Cobra
Japanese: Tagayasan
Khmer: Bosneak
Laotian: May Lek, Ka Thang
Malaysia: Langapus, Lagggapus, Matopus, Mentepus, Naga Sari, Penaga, Penaga Kunyit, Penaga Lilin, Penaga Putih, Penaga Sabut, Penaga Suga, Tapis

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Nepalese: Nagesvar Campa, Nagesvari, Nagkesar, Narisal, Potal, Ruk Keshar
Persian: Naz Mushik
Philippines: Kaliuas (Tagalog)
Russian: Indiiskoe Zheleznoe Derevo, Mezua Zheleznaia, Mezuia Zheleznaia, Нагакешара Nagakeshara, Zheleznoe Derevo
Sri Lanka: Na, Naa-Gaha, Naaga, Naaga-Dru, Naaga-Keasara, Naaga-Kignjalka (Sinhala)
Thai: Bhra Na Kaw, Bun Nak, Boon Naak, Ka Ko (Karen), Gaa Gaaw Gam Gaaw, Kam Ko (Shan), Saan Phee Daawy, Saraphi Doi (Chiang Mai)
Vietnamese: Vắp, Vếp

Origin/Distribution

Mesua ferrea is indigenous to the wet, tropical parts of Sri Lanka, India, southern Nepal, Burma, Thailand, Indochina, the Philippines, Malaysia and Sumatra.

Agroecology

In its native range, it occurs from near sea level to 2,300 m, as a canopy component in lowland evergreen forest, especially in river valleys, but also commonly features as an understory tree in montane evergreen or semievergreen forest. In Borneo, the species is associated with dipterocarps. It thrives best in a well-drained, moist, fairly fertile soil.

Edible Plant Parts and Uses

The ripe fruit (surli nuts) is edible, reddish and wrinkled when ripe and resembles chestnut in size, shape, rind, substance and taste. The oily seeds are edible when well cooked but unpleasant and not suitable as a cooking oil (Pongpangan and Poobrasert 1985). Young, tender leaves have a sour astringent taste and can be eaten raw. The flowers are edible and eaten in Thailand (Wessapan et al. 2007; Wetwitayaklung et al. 2008).

Botany

A medium to tall, evergreen, perennial tree growing 20 m to over 30 m high (Plate 1) with a buttressed base, smooth or weakly scaly, dark ash grey with a red-brown blaze bark and a trunk up to 2 m in diameter. Leaves are simple, opposite, narrow, oblong to lanceolate, blue-grey to dark green, 7–15 cm long and 1.5–3.5 cm wide, with a whitish underside (Plates 2 and 4). Juvenile leaves are reddish-yellowish pink. Flowers are terminal or axillary, fragrant, usually solitary, 4–7.5 cm across and borne on pedicels with small paired bracts. Flowers are bisexual with four white petals and a centre of numerous yellow stamens, free or connate only at the base (Plate 3). The ovary is superior with 1–2 axillary ovules, with a slender style and peltate to 4-lobed stigma. Fruit is an ovoid to subglobose, dehiscent capsule (Plate 4), often beaked, thinly woody containing 1–2 seeds.

Plate 1 Habit of tree

Plate 2 Flower buds and leaves

Plate 3 Flowers in bloom (HF Chin)

Nutritive/Medicinal Properties

Between 32 and 50 components were identified in the oils from the bark, leaves, buds and flowers (full bloom) of *Mesua ferrea*, accounting for

Plate 4 Fruits

82–97 % of the total yields (Choudhury et al. 1998). The bark oil was rich in (*E*)-α-bisabolene (31.3 %) and α-selinene (12.2 %). The predominant components in the oils of tender and mature leaves were α-copaene (19.3 and 99 %) and β-caryophyllene (18.8 and 26.0 %). The bud and flower oils also contained α-copaene (28.7 and 20.2 %) and in addition germacrene D (190 and 16.1 %).

Flower Phytochemicals

Mesuaferrone-b, a new biflavanone, was isolated from *Mesua ferrea* stamens (Raju et al. 1976). Petrol extracts of the stamens of *Mesua ferrea* afforded β-amyrin, β-sitosterol and a new cyclohexadione compound named mesuaferrol (Dennis et al. 1988).

A series of 4-alkyl and 4-phenyl 5,7-dihydroxycoumarins were extracted from *Mesua ferrea* blossoms (Verotta et al. 2004). The nine compounds were 5,7-dihydroxy-6-(isobutyryl)-8-(3-methylbut-2-enyl)-4-phenyl-2H-chromen-2-one (mesuol) (1); 5,7-dihydroxy-6-(2-methylbutanoyl)-8-(3-methylbut-2-enyl)-4-phenyl-2H-chromen-2-one (mammea A/AB) (1a); 5,7-dihydroxy-6-(3-methylbutanoyl)-8-(3-methylbut-2-enyl)-4-phenyl-2H-chromen-2-one (mammea A/AA) (mammeisin) (1b); 5,7-dihydroxy-6-(2-methylbutanoyl)-8-[(*E*)-3,7-dimethylocta-2,6-dienyl]-4-phenyl-2H-chromen-2-one (2); 5,7-dihydroxy-

6-(3-methylbutanoyl)-8-[(*E*)-3,7-dimethylocta-2,6-dienyl]-4-phenyl-2H-chromen-2-one (2a); 5,7-dihydroxy-8-(2-methylbutanoyl)-6-(3-methylbut-2-enyl)-4-phenyl-2H-chromen-2-one (mammea A/BB) (isomammeisin) (3); 5,7-dihydroxy-8-(3-methylbutanoyl)-6-(3-methylbut-2-enyl)-4-phenyl-2H-chromen-2-one (mammea A/BA) (3a); 5,7-dihydroxy-8-(2-methylbutanoyl)-6-[(*E*)-3,7-dimethylocta-2,6-dienyl]-4-phenyl-2H-chromen-2-one (4); 5,7-dihydroxy-8-(3-methylbutanoyl)-6-[(*E*)-3,7-dimethylocta-2,6-dienyl]-4-phenyl-2H-chromen-2-one (4a); 8,9-dihydro-5-hydroxy-8-(2-hydroxypropan-2-yl)-6-(2-methylbutanoyl)-4-phenylfuro[2,3-h]chromen-2-one (mammea A/AB cyclo F) (5a); 8,9-dihydro-5-hydroxy-8-(2-hydroxypropan-2-yl)-6-isobutyryl-4-phenylfuro[2,3-h]chromen-2-one (mammea a/AD ciclo F) (5); 8,9-dihydro-5-hydroxy-8-(2-hydroxypropan-2-yl)-6-(3-methylbutanoyl)-4-phenylfuro[2,3-h]chromen-2-one (mammea A/AA ciclo F) (5b); 5,7-dihydroxy-4-(1-hydroxypropyl)-8-(2-methylbutanoyl)-6-(3-methylbut-2-enyl)-2H-chromen-2-one (assamene) (6); 5,7-dihydroxy-4-(1-hydroxypropyl)-8-(2-methylbutanoyl)-6-[(*E*)-3,7-dimethylocta-2,6-dienyl]-2H-chromen-2-one (surangin C) (6a); 8,9-dihydro-5-hydroxy-6-(2-methylbutanoyl)-4-phenyl-8-(prop-1-en-2-yl)furo[2,3-h]chromen-2-one (7); 8,9-dihydro-5-hydroxy-6-(3-methylbutanoyl)-4-phenyl-8-(prop-1-en-2-yl) furo[2,3-h]chromen-2-one (7a); 5-hydroxy-6-isobutyryl-8,8-dimethyl-4-phenyl-2H-pyrano[2,3-h]chromen-2-one (mammea A/AD cyclo D) (mesuagin) (8); 5-hydroxy-8,8-dimethyl-6-(2-methylbutanoyl)-4-phenyl-2H-pyrano[2,3-h]chromen-2-one (mammea A/AB cyclo D) (mammeigin) (8a); 5-hydroxy-8,8-dimethyl-6-(3-methylbutanoyl)-4-phenyl-2H-pyrano[2,3-h]chromen-2-one (mammea A/AA cyclo D) (8b); 5-hydroxy-6-isobutyryl–8-methyl-8-(4-methylpent-3-enyl)-4-phenyl-2H-pyrano[2,3-h]chromen-2-one (9); and 5-hydroxy-8-methyl-6-(2-methylbutanoyl)-8-(4-methylpent-3-enyl)-4-phenyl-2H-pyrano[2,3-h] chromen-2-one (9a). Fourteen major volatile components of the methanol flower extract of *Mesua ferrea* (Nordin et al. 2004).

Seed Phytochemicals

Two different samples of *Mesua ferrea* seed oil yielded coumarins mammeigin and mesuol as the main phenolic components (Bala and Seshadri 1971). The synthesis of mammeisin and mammeigin and also the conversion of mesuol into mesuagin were carried out.

Mesua ferrea seeds were found to contain total lipid (66.91–70.23 g %), moisture (4.02–5.05 g %), ash (1.46–1.50 g %), total protein (6.99–7.19 g %), water-soluble protein (2.98–3.11 g %), starch (5.51–5.85 g %), crude fibre (1.22–1.98 g %), carbohydrate (15.88–18.68 g %) and energy value (700.55–724.15 kcal/100 g) (Abu Sayeed et al. 2004).

Mesua ferrea seed oils were found to have the following physicochemical characteristics: specific gravity (0.9287–09312), refractive index (1.4690–1.4739), solidification point [−4.0–(−4.3)], pour point [−1.0–(−1.3)], cloud point (5.5–6.0), flashpoint (90–98), fire point (110–116), smoke point (44–47), iodine value (89.17–93.01), saponification value (199.03–206.40), saponification equivalent (271.80–281.86), acid value (9.64–11.87), free fatty acid (4.85–5.96), ester value (188.95–1.95.44), unsaponifiable matter (1.44–1.50), acetyl value (2.70–2.84), peroxide value (3.58–3.64), Reichert–Meissl value (5.852–6.031) and Polenske number (0.7891–0.8401) (Abu Sayeed et al. 2004). Glyceride classes were estimated to be monoglycerides (1.05–1.35 %), diglycerides (2.12–2.32 %) and triglycerides (87.65–89.50 %), whereas total lipid extracts were fractionated into neutral lipid (89.83–92.18 %), glycolipid (3.65–4.15 %) and phospholipid (1.98–2.68 %). Saturated and unsaturated fatty acids present in the oils were separated and amounted to be (27.40–29.11 %) and (65.85–68.31 %), respectively. The oil contained the highest amount of oleic acid 55.93 %, while linoleic acid, stearic acid and palmitic acid contents were found to be 13.68, 14.19 and 10.87 %, respectively. The oil also contained small amount of myristic acid (2.13 %) and arachidic acid (2.92 %). Konwer et al. (1989) found *M. ferrea* seed oil consisted of triglycerides of linoleic, oleic, palmitic and stearic acids.

Leaf Phytochemicals

Mesua ferrea leaves were found to contain total lipid (2.32–2.44 g %), moisture (65.12–72.19 g %), ash (2.60–2.71 g %), total protein (4.23–4.85 g %), water-soluble protein (1.47–2.01 g %), starch (3.06–3.27 g %), crude fibre (3.12–3.29 g %), carbohydrate (14.82–22.30 g %) and energy value (100.24–128.40 kcal/100 g) (Abu Sayeed et al. 2004).

Furano-naphthyl-hydroxy cyclohexyl type of compound was isolated from the ethyl acetate leaf extract of *Mesua ferrea* and identified as 12, 13-furano-8-hydroxy napthyl-6-0-β-2′,3′,4′,6′ tetrahydroxy-5′,5′ dimethyl cyclohexyl ether (Rahman et al. 2008).

Thirty-five components constituting 81.4 % total volatile components were obtained from *M. ferrea* leaf essential oil (Keawsaard and Kongtaweelert 2012). The oil comprised 60–7 % sesquiterpene hydrocarbons (60.7 %), diterpenes and triterpenes (0.4 %), terpene-related compounds (0.4 %), carboxylic acids (0.5 %), saturated hydrocarbons (0.3 %) and others (0.2 %). Major components were *trans*-caryophyllene (30.9 %), β-caryophyllene oxide (19.9 %), α-humulene (6 %), δ-cadinene (4.1 %), γ-muurolene (3.5 %), γ-cadinene (2.3 %), β-selinene (1.9 %), germacrene D (1.8 %) and β-bisabolene (1.6 %). Other minor components included (*Z*)-3-hexanol (0.1 %), linalool (trace), edulan I (trace), α-cubebene (0.3 %), α-ylangene (0.3 %), α-copaene (1.1 %), β-bourbonene (0.8 %), β-elemene (0.5 %), (*cis*)-caryophyllene (0.4 %), (+)-aromadendrene (0.7 %), (−)-alloaromadendrene (1.1 %), valence (1 %), α-selinene (1.1 %), α-muurolene (0.7 %), (*cis*)-calamenene (0.5 %), α-calacorene (0.3 %), caryophyllenyl alcohol (0.5 %), τ-muurolol (0.5 %), hexahydrofarnesyl acetone (0.5 %), *n*-hexadecanoic acid (0.5 %), phytol (0.2 %), 4,8,12,16-tetramethyl heptadecan-4-olide (0.1 %), hexadecanoic acid bis(2ethylhexyl) ester (0.1 %), heptacosane (0.1 %), squalene (0.2 %) and nonacosane (0.2 %).

Wood/Trunk/Root Phytochemicals

Two new yellow pigments, mesuaxanthone-A and mesuaxanthone-B, and the known euxanthone were isolated from the heartwood extracts of *Mesua ferrea* (Govindachari et al. 1967a). Mesuaxanthone-A was elucidated as 1,5-dihydroxy-3-methoxy-xanthone and mesuaxanthone-B as 1,5,6-trihydroxyxanthone. Ferruol A, C23H30O5, a new 4-alkylcoumarin isolated from the trunk bark (Govindachari et al. 1967b). The heartwood of *Mesua ferrea* was found to contain 1,5-dihydroxyxanthone (II), euxanthone 7-methyl ether (IV) and β-sitosterol, in addition to the two xanthones previously isolated (Chow and Quon 1968). The following xanthones dehydrocycloguanandin, calophyllin-B, jacareubin, 6-desoxy jacareubin, mesuaxanthone-A, mesuaxanthone-B and euxanthone were found in *M. ferrea* (Gopalakrishnan et al. 1980). A new xanthone, ferrxanthone, was isolated from the heartwood of *Mesua ferrea* and its structure determined as 1,3-dimethoxy-5,6-dihydroxyxanthone (Walia and Mukerjee 1984). The root bark extracts of *Mesua ferrea* afforded two new pyranoxanthones, mesuaferrin A (1) and mesuaferrin B (2), and five other compounds—caloxanthone C (3), 1,8-dihydro-3-methoxy-6-methylanthraquinone (4), β-sitosterol (5), friedelin (6) and betulinic acid (7) (Teh et al. 2011).

Some of the pharmacological proprieties of the various plant parts are elaborated below.

Antioxidant Activity

Four edible flower extracts including *M. ferrea* elicited antioxidant activity in ABTS assay with the Trolox equivalent antioxidant capacity (TEAC) of 0.15–0.70 (Wessapan et al. 2007). Antioxidant activity in the flower extract was low, TEAC value = 0.15, IC_{50} = 61 μg/50μl (Wetwitayaklung et al. 2008). Total polyphenol yield was 33.78 %, and total polyphenol content in the dried flowers was 1.94 g/100 g and in the crude methanol flower extract was 5.74 g/g.

The water and hot water extracts of *M. ferrea* flowers exhibited strong DPPH radical scavenging activity with EC_{50} = 7.49, 6.95 μg/ml, respectively, which were stronger than BHT (Makchuchit et al. 2010). The ethanol flower extract exhibited potent inhibitory activity on LPS-induced NO production in RAW 264.7 cells with IC_{50} value 26.32 μg/ml.

The extracts of *M. ferrea* leaves showed good antioxidant activity with the ethanol (70 %) extract showing better activity than other extracts (methanol, ethyl acetate and hexane) in DPPH, superoxide and hydroxyl radical scavenging activities (Prasad et al. 2012). However, the antioxidant activities were lower than ascorbic acid. The leaf essential oil showed antioxidant in the DPPH assay with IC_{50} of 31.67 mg/ml (Keawsaard and Kongtaweelert 2012).

Analgesic Activity

The *n*-hexane extract of *M. ferrea* leaves administered orally to mice produced significant antinociceptive action against acetic acid-induced visceral pain models of nociception in mice (Hassan et al. 2006). In acetic acid-induced writhing model, the *n*-hexane, methanol and ethyl acetate partition fractions at a dose of 125 mg/kg body weight produced 36.08, 16.33 and 10.21 % reduction of writhing response. The extracts also produced 42.21, 19.63 and 17.06 % reduction of writhing response at a dose of 250 mg/kg body weight, respectively.

Immunomodulatory Activity

Mesuol isolated from *M. ferrea* seed oil exhibited immunomodulatory activity in experimental animals (Chahar et al. 2012). In humoral immune response model, mesuol evoked a significant dose-dependent increase in antibody titre values in cyclophosphamide-induced immunosuppression which was sensitized with sheep red blood cells (SRBC). In cellular immune response model, an increase in paw volume was recorded on the 23rd day in cyclophosphamide-induced immunosuppressed rats treated with SRBC on the 21st day. Mesuol restored the haematological profile in cyclophosphamide-induced myelosuppression model. Mesuol potentiated percentage neutrophil adhesion in neutrophil adhesion test in rats and phagocytosis in carbon clearance assay.

Anticancer Activity

The crude methanol flower extract exhibited a strong cytotoxic activity (i.e. IC_{50} of 12.5 μg/ml) towards T-lymphocyte leukaemia cell (Nordin et al. 2004). *M. ferrea* extract inhibited the growth of Ehrlich ascites carcinoma cells in Swiss albino mice (Masud Rana et al. 2004). The ethanol plant extract of *Mesua ferrea* exhibited promising in-vitro activity against human cholangiocarcinoma CL-6 cell line with survival of less than 50 % at the concentration of 50 μg/ml and an IC_{50} value of 48.23 μg/ml, for cytotoxicity activity (Mahavorasirikul et al. 2010). The extract also showed activity against human laryngeal (Hep-2) and human hepatocarcinoma (HepG2) cell lines. The leaf essential oil also exhibited anticancer activities against KB human oral carcinoma, MCF-7 breast cancer and small cell lung cancer NCI-H 187 cell lines with IC_{50} values of 24.02, 16.19 and 20.32 μg/ml, respectively, but was not toxic to primate Vero cell line (Keawsaard and Kongtaweelert 2012).

Antimicrobial Activity

Mesuol and mesuone from the seed oil were found to have antibacterial activity against *Staphylococcus aureus* (Chakraborty et al. 1959). Mesuol was more active than mesuone against *Mycobacterium phlei*. Both were inactive against fungi tested. The crude methanol flower extract exhibited weak antimicrobial activities against bacteria, namely, *Staphylococcus aureus, Bacillus subtilis* and *Pseudomonas aeruginosa* (Nordin et al. 2004).

A series of 4-alkyl and 4-phenyl 5,7-dihydroxycoumarins (9 compounds) extracted from *Mesua ferrea* blossoms were found to be potent antibacterials on resistant Gram-positive bacterial strains but were weak antiprotozoal agents against *Plasmodium falciparum* (Verotta et al. 2004).

Methanol flower extracts of five edible flowers including *M. ferrea* exhibited antibacterial effect against *Staphylococcus aureus* with MIC at 50–800 μg/ml (Wessapan et al. 2007). The methanol leaf extract of *Mesua ferrea* exhibited significant antibacterial effects in vitro against *Staphylococcus aureus, Bacillus* spp., *Escherichia coli*, *Lactobacillus arabinosus*, *Shigella* and *Salmonella* bacteria (Mazumder et al. 2003). In in-vivo tests, methanol flower extract of *Mesua ferrea* at concentrations of 100 and 200 μg/g of body weight significantly protected Swiss strain of albino mice against a virulent strain *Salmonella typhimurium* (Mazumder et al. 2004). The extract at 200 μg/g dosage significantly reduced the viable count of the *Salmonella* strain in the liver, spleen and heart blood of the extract-treated challenged mice. The flower extract exhibited in vitro antimicrobial efficacy against five different strains of *Salmonella* spp. with MICs of 50 μg/ml (Mazumder et al. 2005). The extract at 2 and 4 mg/mouse significantly protected Swiss albino mice against *S. typhimurium*. The ethanol/methanol seed extract was more active in-vitro against *Proteus mirabilis* and *Klebsiella pneumoniae* than the aqueous extract (Parekh and Chanda 2007). The methanol seed extract was effective in vitro against *Candida albicans* and *Trichosporon beigelii* at 125 μg/disc (Parekh and Chanda 2008). The extract was also effective against *Aspergillus candidus* (500 μg/disc), *Aspergillus flavus* (125 and 250 μg/disc), *Aspergillus niger* (125 and 250 μg/disc) and *Mucor hiemalis* (250 and 500 μg/disc).

The chloroform bark extract exhibited strong activity against Gram-positive *Streptococcus aureus* and Gram-negative *Escherichia coli*, but the leaf extracts exhibited mild to moderate activity against the tested bacteria (Ali et al. 2004). Nahar seed kernel oil emulsion demonstrated appreciable bacterial disinfestations at high concentration using the pour plate method (Adewale et al. 2011). At concentrations of 2 mg/ml or higher, total disinfestations were obtained with little or no bacterial colonies seen after incubation. The ethanol leaf extract exhibited marked antibacterial property against selected microbes (*Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis* and *Staphylococcus aureus*) with the inhibition zones ranging from 16.0 to 18.05 mm for all the tested bacteria (Adewale et al. 2012). The MIC range of 2.5–0.625 mg/ml with MBC value of 5 mg/ml was obtained for the Gram-negative bacteria, while MIC range of 1.3–0.313 mg/ml with MBC value of 2.5 mg/ml was obtained for the Gram-positive bacteria. The leaves extract was found to be toxic to the Brine shrimps with LC_{50} of 500 ppm (μg/ml), suggesting that the extracts may contain bioactive compounds of potential therapeutic and prophylactic significance.

The leaf essential oil exhibited antibacterial activity against *Escherichia coli* and *Staphylococcus aureus* with MIC values of 250 and 125 mg/ml, respectively (Keawsaard and Kongtaweelert 2012). Both leaf and fruit extracts of *M. ferrea* displayed good antibacterial activity against *Staphylococcus aureus* with a minimum inhibition concentration of 0.048 mg/ml (Aruldass et al. 2013). Both extracts are bacteriostatic at a minimum bacteriostatic concentration of 0.39 mg/ml. The treatment with the extracts caused extensive lysis of the cells, leakage of intracellular constituents and aggregation of cytoplasmic contents forming an open meshwork of the matrix.

Antiarthritic Activity

Studies demonstrated that *Mesua ferrea* seed extract protected rats against formaldehyde and complete Freund's adjuvant (CFA)-induced arthritis (Jalalpure et al. 2011). The body weight changes and haematological perturbations induced by CFA were maintained.

Antiinflammatory Activity

The xanthones of *Calophyllum inophyllum* and *Mesua Ferrea*, namely, mesuaxanthone-A and mesuaxanthone-B, exerted 37 and 49 % reduction in carrageenan-induced hind paw oedema upon oral administration in normal and adrenalectomized rats (Gopalakrishnan et al. 1980). In the granuloma pouch test, mesuaxanthone-A and mesuaxanthone-B elicited 46 and 49 % reduction in inflammation, respectively, and 47 % reduction was observed in the cotton pellet granuloma test.

Antivenom Activity

M. ferrea extract was one of several plant species that was found to have antidote activity against *Heterometrus laoticus* scorpion venom activity on fibroblast cell lysis (Uawonggul et al. 2006).

Antiulcerogenic Activity

The xanthones of *Calophyllum inophyllum* and *Mesua Ferrea,* namely, jacareubin and -desoxy jacareubin exhibited antiulcer activity in rats (Gopalakrishnan et al. 1980). The untreated control animals had extensive ulceration, haemorrhage and perforation; in contrast, the xanthone-pretreated animals exhibited only scattered areas of hyperaemia and occasional haemorrhagic spots.

Anticonvulsant Activity

The ethanol extract of *Mesua ferrea* inhibited maximum electroshock seizure (MES)-induced convulsions in albino mice (Tiwari et al. 2012). The extract also reduced the duration of hind limb tonic extension in a dose-dependent manner against MES model.

Wound Healing Activity

The ethanol extract of *Mesua ferrea* aerial parts in the form of ointment (5 and 10 % w/w) exhibited wound healing activity in both excision and incision models in albino rats (Choudhary 2012). The results suggested that the wound healing activity of *Mesua ferrea* was due to its tannin content, which appeared to be responsible for wound contraction and increased rate of epithelialization.

CNS (Central Nervous System) Depressant Activity

The xanthones of *Calophyllum inophyllum* and *Mesua Ferrea,* namely, jacareubin (JR), dehydrocycloguanandin, calophyllin-B, 6-desoxy jacareubin, mesuaxanthone-A, mesuaxanthone-B and euxanthone, produced varying degrees of CNS depression characterized 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.

Antispasmodic Activity

The crude *M. ferrea* seed oil showed significant antispasmodic activity in the isolated rat ileum, but the purified oil was devoid of antispasmodic activity (Prasad et al. 1999).

Antihaemorrhoidal Activity

Paranjp et al. (2000) conducted a 4-week clinical assessment of a multiherbal indigenous formulation administered orally as capsule to 22 patients with bleeding piles. The Ayurvedic formulation was composed of *Berberis aristata, Holarrhena antidysenterica, Picrorhiza kurroa, Mesua ferrea, Terminalia chebula, T. belerica* and *Emblica officinalis.* After 4 weeks, only 6 out of 22 patients still complained of bleeding. The formulation was well accepted and no adverse effects were reported.

Estrogenic/Progestational Activities

M. ferrea flower extract was found to have compounds which exhibited estrogenic and progestational activity in humans and mice (Meherji et al. 1978). The results suggested that these compounds in *M. ferrea* may help to correct hormonal imbalance in menstrual disorders.

Traditional Medicinal Uses

The root, leaves, flowers and seeds are used in traditional medicine (CSIR 1962; Burkill 1966; Chopra et al. 1986; Khare 2004). *M. ferrea* traditionally is being used for its antiseptic, antiinflammatory, blood purifier, anthelmintic, cardiotonic, diuretic, expectorant, antipyretic, purgative, antiasthmatic, antiallergic and several other effects (Chahar et al. 2013). It is an ingredient of Ayurvedic formulations like Brahma Rasayana and Chyawanprash which are being used to improve immunity. Nagakeshara (*M. ferrea*) is a hot, dry digestive and good for fever, foul breath, sweats, scabies, skin eruptions, itching, small tumours, headache, blood and heart problems, sore throat, cough, hiccough, vomiting, excessive thirst, dysentery and bleeding piles (Joseph et al. 2010). The dried flower bud is antidysenteric and used for dysentery with mucus; the dried flowers are astringent, haemostatic, antiinflammatory and stomachic and used in cough, bleeding haemorrhoids and metrorrhagia (CSIR 1962; Chopra et al. 1986; Khare 2004). Fresh flowers are prescribed for excessive thirst, excessive perspiration, cough and indigestion. The leaves are applied to the head in the form of a poultice for severe colds. Oil from the seeds is used for sores, scabies, wounds and rheumatism. The root of this herb is often used as an antidote for snake poison.

Nagakesara in Indian system of medicine is used as deodorant, diaphoretic and stimulant (Anandakumar et al. 1986). It is a brain tonic appetizer, antiemetic, anthelmintic, aphrodisiac, diuretic and antidote. Nagakesara is mostly attributed to the stamens or the flowers of *Mesua ferrea*. Dried fruits of *Dillenia pentagyna* and dried fruiting inflorescence of *Cinnamomum wightii* are also used as Nagakesara in different regions of India.

In Peninsular Malaysia, the pounded kernels or seed oil have been used for poulticing wounds; flowers were used in a draught taken after childbirth and so is a root decoction (Burkill 1966). In Singapore, ashes of leaves were used as a lotion for sore eyes.

In Thailand, the seed is used as a cardiotonic and expectorant, for wounds and for its aroma (Wetwitayaklung et al. 2008).

Other Uses

Mesua ferrea is an important forest tree for timber production. The deep dark red wood is hard, heavy and suitably strong for all forms of heavy construction, railway sleepers, transmission posts, heavy-duty furniture, parquet flooring, posts and tool handles. The tree is also popularly planted as landscape, avenue trees or hedgerows. The incense sticks made from the flowers of this plant are popular worldwide for their intense fragrance. Fragrant stamens are used for stuffing pillows and cushions in the bridal beds.

The fraction of *M. ferrua* seed oil distilling between 200 and 300 °C may be used as fuel for diesel engines (Konwer et al. 1989). Studies showed that blending of *M. ferrea* seed oil with diesel up to 15 % (by volume) can be used in a compression–ignition (CI) engine without any major engine modification (Kushwah et al. 2008). Due to higher viscosity and density and low volatility of straight *M. ferrea* oil, it was found suitable for direct use in Cl engine.

M. ferrea seed oil can be used in the manufacture of polyurethane paints, epoxy resins and nanocomposites. Three different polyester resins were synthesized from a purified seed oil (Dutta et al. 2004; Mahapatra and Karak 2004). The resins were formed by the reaction of monoglyceride obtained from the oil with phthalic and/or maleic anhydride and adipic acid separately. Poly(urethane amide) resins with varying ratio of NCO/OH (0.8:1–2:1) were synthesized from purified Nahar oil (*Mesua ferrea*) with toluene diisocyanate in the presence of dibutyl tin dilaurate as the catalyst (Dutta and Karak 2005). The results show better performance of the poly(urethane amide) resins exhibited better performance compared to polyester or polyesteramide resins of the same oil. The study showed that these resins may hold promise for use as effective surface-coating materials. Thermogravimetric analysis demonstrated that the thermal stabilities of the cured resins prepared from *M. ferrea* seed oil increased with an increase in the NCO/OH ratios (Dutta and Karak 2006). The amounts of char residues at 550 °C were also found to be greater for higher NCO/OH ratios of the Nahar oil-modified polyurethane resins. A hyperbranched polyamine was utilized as an effective curing agent for a *Mesua ferrea* seed oil-based poly(ester-amide) resin (Mahapatra and Karak 2007). The hyperbranched polyamine not only enhance the rate of cross-linking reaction, but it also improved many desirable performance characteristics especially the thermostability, flame retardancy, hardness, impact strength, chemical resistance, etc. of the cured resin.

Two types of stoving paints had been prepared from *Mesua ferrea* seed oil-modified polyurethane ester (PUE) binder systems (Dutta et al. 2009a). Of the two test paints, the epoxy-modified PUE-based stoving paint was preferred. An epoxidized vegetable oil of *Mesua ferrea* seed was prepared and used as a reactive diluent for commercial BPA (bisphenol A)-based epoxy resin at different compositions and green nanocomposites (Das and Karak 2009). Epoxy-modified *Mesua ferrea* seed oil-based polyurethane nanocomposites also have the potential to be applicable as biomaterials (Dutta et al. 2009b). A bio-based sulphone epoxy resin (BPSE) was synthesized from the monoglyceride of *Mesua ferrea* seed oil, bis(4-hydroxyphenyl) sulphone, bisphenol A and epichlorohydrin (Das and Karak 2010). These bio-based epoxy/clay nanocomposites had improved flame retardancy and exhibited potential for multifaceted advanced applications. *Mesua ferrea* seed oil-based polyester was modified by methyl methacrylates to form a modified polyester for use as matrix for polyester resin/clay nanocomposite preparations with improved mechanical and thermal properties (Konwar et al. 2011).

Comments

The tree is sacred in India and is the national tree of Sri Lanka. The plant is propagated from seeds or cuttings.

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