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Review Article

A Review of the Botanical, Conventional Applications, Phytochemical Constituents, and Pharmacology of *Madhuca longifolia* (Koenig) J.F. Macb

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ABSTRACT

In underdeveloped countries, between 75 and 80 percent of the world's population still significantly relies on herbal medicine for primary treatment. *Madhuca longifolia* (Mahua), commonly referred to as butternut tree, is a species of tree significant to the daily life of tribal people. It belongs to the Sapotaceae family, a significant economic tree that is spread over the sub-tropical Indo-Pak peninsula. A large to medium-sized deciduous tree with a short bole and a broad, rounded crown, the mahua tree typically possesses these characteristics. A phytochemical analysis of the plant *M. longifolia* revealed the presence of several secondary metabolites, including sapogenins, triterpenoids, saponins, flavonoids, and glycosides. These substances exhibit notable antidiabetic, antiulcer, antioxidant, antipyretic, hepatoprotective, anti-inflammatory, analgesic, anti-tumor, anti-progestational, anti-estrogenic, wound healing activity, rheumatism, ulcers, bleedings, tonsillitis, swelling, inflammation, piles, emetic, dermatological, laxative, tonic, anti-burn, anti-earthworm, headache and many more problems. In this review, we explore the many traditional and an ethnomedical use of the bark, fruit, flower, and leaves of *M. longifolia*. These studies' findings have emphasised Mahua's present pharmacological profile and effectively demonstrated its potential for therapeutic use in modern medicine.

Keywords: *Madhuca longifolia*, Phytoconstituents, Pharmacological activity, Traditional medicines, Herbs.

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INTRODUCTION

The abundance of diverse plants utilised for ornamentation, flowering, fruiting, and medicinal purposes is a great gift from nature. Many plants have medical applications that are now being adopted and used commercially. As a result, underutilized plants that have been used traditionally have attracted prospective attention from researchers and industry professionals. *Mahua, rhododendron, kachnar, moringa, gulmohar, palash*, and other such plants that are widely used traditionally and have the potential to be commercialised can be found in India. India is regarded as a treasure trove of different plant species that have been used for medicinal and aromatic purposes since ancient times. Traditional medicine is widely used for treatment of a variety of diseases in several countries due to its safe, cost-efficient and effective character.[1,2]

Since the beginning of human civilization, plants have been used as both traditional and pharmacopoeial treatments. In order to treat a wide range of ills and diseases, a staggering 80% of the world's population only uses plant extract and its by products. In India, some 2000 medications manufactured from plants are used, and ongoing research is being done to identify safe and affordable phytomedicines.[1]

One of the naturally occurring plants with many health advantages is mahua. As seed oils and fats are used more frequently for biofuels, their price may rise and their availability as a supply for food needs may decrease. The market for oils and fats is interested in solutions that can either address these problems with the agriculture supply chain. There aren't many plants that can generate enough oil and fat for commerce. About 85% of the

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visible oil or fat that is available for eating comes from vegetable oils.[3,4]

Numerous plants are grown for a wide range of innovative industrial goods in addition to food and fodder. Finding new oil plant sources that offer high oil or fat recovery for dietary, medicinal, and other uses is important. The Sapotaceae family's *Madhuca* genus includes a number of useful tree species, the three most common of which are *Madhuca longifolia, Madhuca latifolia*, and *Madhuca butyracea*. The buttercup or mahua, *M. longifolia* (Koenig) (also known as *M. indica* Gmelin; Family: Sapotaceae), is a sizable, shaded, deciduous tree that can be found growing both wild and in cultivation throughout most of central India. The tree's blooms, fruits, seeds, and lumber are used in a variety of products, making it economically significant.[5,6]

The flower-derived alcohol that is used to produce vinegar gives the tree its notoriety. The expectorant flowers are used to treat bronchitis and other chest conditions. They are also used to boost breast milk production. The distilled floral juice is regarded as a tonic that is both nourishing and cooling. To treat eczema, the leaves are used as a poultice. The leaf ash is combined with ghee in Indian traditional medicine to create a treatment for cuts and burns. Mahua formulations are used to treat debility and emaciation, respiratory illnesses, and intestinal worm infestations. Diabetes, rheumatism, and dental issues are treated with the astringent bark extract.[4] This plant has not been extensively studied by researchers or food processors, with the exception of a few for its value addition, due to its instant availability in certain locations. Therefore, the focus of this review is on current developments in the use of mahua as food and medicine, as well as its potential for future value addition.

PLANT PROFILE

Vernacular/Common name

The mahua tree is known by several common names in local languages. It is a large evergreen tree distributed in India, Sri Lanka and Nepal.[5] Vernacular names of *M. longifolia* in different languages are reported in Table 1.

Distribution and Habitat

Madhuca, also known as mahua or butternut tree, is a 17-meter tall tree with a broad crown.[4]

The damp forests on the west coast of India, from Konkan south to Travancore, Deccan, and common in Ceylon, are the natural habitat of *M. longifolia*. It is also grown in cultivation in the Carnatic region and upper Burma. Mahua trees are distributed from India to other Asian countries like The Philippines, Pakistan, Nepal, Burma, Sri Lanka to Australia.[5,7] Distribution of mahua tree in the world is depicted in Figure 1.

The species is dispersed in northern, central and southern part of peninsular India. It is common in dry mixed deciduous forests in India in the states of Odisha, Chhatisgarh, Jharhand, Uttar Pradesh, Bihar, Maharashtra, Telangana, Andhra Pradesh, Madhya Pradesh, Kerala, Karnataka, Tamil Nadu, Gujarat, Rajasthan and West Bengal.[8,9] Figure 2 represents distribution of mahua tree in India.

Cultivation

It is grown for its oleaginous seeds (one tree can produce between 20 and 200 kg of seeds annually, depending on maturity), flowers, and wood in hot, humid climates. A plant that can be found up to 1,200 metres above sea level and it grows from the subtropics to the tropics. It can endure mild cold and flourishes in areas with yearly daily temperatures between 2°C and 46°C. It thrives in areas with an annual precipitation range of 550 to 1,500 millimetres. It prefers a sunny atmosphere for growth. Although mahua loves well-drained loamy or sandy-loam soils where it may develop to its full capacity, it is incredibly hardy and can be found in shallow stony, clayey, and calcareous soils as well. Its development can be supported by even little pockets of soil between arid rock fractures. Plants that have grown up can tolerate drought. It has a long lifespan and starts to bear when the tree is about 10 years old. A fully developed tree can yield up to 90 kg of blossoms each year. Trees coppice well if they are felled during the warmer season when they are dormant. They can be worked on a 25-30 year coppice cycle to provide a mean annual increment of 3-5 cubic meters/ha. Every year, this medium-sized tree blooms during the months of March and April.[10-12]

Botanical Description and Identification Features

Mahua is an evergreen, medium-sized deciduous tree that can reach heights of 16 to 20 metres. It has a spreading, dense, round, and shaded canopy. The tree grows and starts bearing fruit between the ages of 8 and 15; it can continue to bear fruit for up to 60 years. It has a short, sturdy trunk with an 80 cm diameter. The crown is elongated and has many branches. The leaves are elliptic, lanceolate, 15-25 cm long and 8-15 cm wide, smaller at both ends with pointed tips, thick, hairy underside at the base, and have approximately 12 pairs of noticeable, strong, glabrous nerves; the edge is entire but may be wavy. 2-4 cm long, reddish stem (Figure 3).[13]

Seasonal *M. longifolia* blooms are small, fleshy, pale white in colour, 2 cm long, pointed, sweat-scented, meaty, and produce ovoid, fleshy fruits that are green in colour while immature and turn greenish yellow when ripe. Each fruit contains three to four seeds. Buttercup fruit-seeds ranged in size from 2.0 cm to 6.0 cm and from 1.3 to 1.6 cm across the length and breadth, respectively. They were typically ellipsoidal in shape. The 2 cm long, brown, shiny, elongated seeds have a shiny appearance.[14] Mahua Fresh and dried Fruits are shown in Figure 4(a) and Figure 4(b) respectively.

Table 1: Vernacular names of *M. longifolia* in different languages.

Language	Vernacular Names of *M. longifolia*
English	Honey tree, butter tree
India	Mahua
Sri Lanka	Mi, Illuppai
Sanskrit	Madhukah
Bengali	Mohua
Oriya	Mahula
Kannada	Errape
Telugu	Ippi
Tamil	Illuppai
Malayalam	Irippa
Gujarat	Mahuda
Marathi	Mahu and muvda
Marwari	Dolma

Synonym(s): Madhuca latifolia Macb., Bassia latifolia Roxb., *Mahua indica* J.F. Gmel.Varieties: *Madhuca longifolia* (Koenig) J.F. Macb. var. longifolia, and *Madhuca longifolia* (Koenig) J.F. Macb. var. latifolia (Roxb.) Cheval.

Taxonomic arrangement of *M. longifolia*

Taxonomy	*Madhuca longifolia*
Kingdom	Planta, Vegetal, Plants
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Division	Tracheophyta
Subdivision	Spermatophytes
Class	Equisetopsida C. Agardh
Order	Ericaleae
Family	Sapotaceae
Subfamily	Caesalpiniodeae
Tribe	Caesalpinieae
Genus	*Madhuca*
Species	*longifolia*

The inner bark is red and emits a white, milky sap when cut. The outside bark is tough, brown in color, somewhat cracked, and fissured. Tannins make around 17% of bark.[15] Bark is used for rheumatism, ulcers, itches, bleeding and spongy gums. The bark is a successful treatment for pruritus, sprains, and inflammation. Mahua seeds are of economic importance as they are good source of edible fats.[6]

Active phytochemicals constituents

The active ingredients found in various plant parts, which may be present in tiny or great quantities, determine the plant's medicinal efficacy.[16] The primary component responsible for the primary therapeutic effects of crude medicines is the secondary metabolites.[17]

Mahua tree leaves contain glucoside, an alkaloid, and saponin. The seeds contain sapogenin and other basic acids. Characterization of sapogenin, triterpenoids, steroids, saponin, flavonoids, and glycosides are among the results of many photochemical research on Mahua. Four novel oleanane type triterpene glycosides, madhushazone, madhucosides A and B, madhucic acid (penta cyclic triterpenoids), and madhushazone are new substances with associated therapeutic characteristics.[18] The fragrance compound 2 acetyl 1 pyrroline is present in the fresh Mahua flower. Additionally, they contain polysacheride, which when hydrolyzed, yields D-galactose, D-glucose, L-araninose, L-rhamose, D-xylose, and D-glucuronic acid.[19] Pharmacological screening is the process of determining the pharmacological activity of a certain crude medication and is crucial for activity prediction.[20] Phytochemical analysis of Mahua plant confirms the presence of various phytochemicals like phenols, flavonoids like quercetin in different extracts Table 2.[21]

Leaves are composed of quercetin (1), β-carotene (2), erthrodiol (3), palmitic acid (4), myricetin (5), xanthophylls (6), oleanolic acid (7), β-sitosterol (8), stigmasterol (9), n-octacosanol (10).[26-32]

Bark is composed of ethylcinnamate (12), sesquiterpene alcohol (13), α-amyrin acetates (14) and β-amyrin acetates (15), α-tocopherol (16).[33-37]

Sugars, Vitamin A, ascorbic acid, thiamine, riboflavin, calcium, phosphorus, iron, magnesium, copper, anthocyanins, beta-carotene, and salts of malic and succinic acids are all abundant in flowers.[38] Table 3 depicted the Nutritional Properties of Mahua flower.

Eswaraiah CM *et al.* reported five compounds ie β-amyrin acetate, 21-Hydroxy-3-oleanyl myricitate (17), Ursolic Acid (18), n-hexyl-3-acetyl betulinate (19) and 3-(27-Carboxy oleanyl)-Octanate(20) isolated from the ethyl acetate extract of stem bark.[22]

Seeds are composed of quercetin, oleic, linoleic, arachidic (21), stearic (22) and palmitic acids, aspartic acid (23), isoleucine (24), leucine (25), cysteine (26), α-alanine (27), proline (28), threonine (29).[40-44] Physiochemical and Nutritional Properties of Mahua Seed oil are reported in Table 4.

Fruits are composed of quercetin, α and β-amyrin acetates, β-sitosterol and its 3β-D-glucoside (30), n-hexacosanol (31).[45-47]

Triveni SI *et al.* isolated the compound was identified as 10-(Carboxyoxy) 1,2,2,6a,9,9-hexamethyl docosahydropicene-4a-Carboxylic acid (11) from Petroleum ether extract of leaves.[48] Table 5 lists the phytoconstituents found in the various parts of *M. longifolia*. Different phytoconstituents reported from the different parts of mahua plant is depicted in Table 5.

Figure 5 shows the structures of various isolated compounds from the various sections of *M. longifolia*.

Figure 1: Distribution of *mahua* tree in world.

Figure 2: Distribution of mahua tree in India.

Bioactivity and Pharmacological Properties

Tribal and Traditional use

Different parts of the tree, including whole young plants, leaves, stems, barks, roots, fruits, flowers, and seeds, are utilised in the folk medicine of Bangladesh and India. Along with being used as a blood purifier and an antidote to poison, these parts are used to treat a variety of illnesses, including tuberculosis, rheumatoid arthritis, cholera, paralysis, snake-bite, debility, tonsillitis, influenza, piles, arthritic pain, helminthiasis, low semen count, headache, flatulence, and infections.[53]

Hydrocele is a skin condition that is treated with a stem bark decoction. Stem bark is used in tonsillitis, leprosy, fever, itching, swelling, fractures, snake-bite poisoning, scabies bleeding gums. Infusion of bark given orally to treat diarrhoea.[54-56]

The flowers are used for impotence, inflammation, eczema, tonsillitis, aphrodisiac, astringent, demulcent, pharyngitis, and bronchitis. Flowers used to treat eye conditions. Skin conditions can be treated with flower juice.[57]

Figure 3: Mahua plant leaves.

M. longifolia leaves have expectorant properties and are also used to treat Cushing's disease and chronic bronchitis.[58] Fruits are astringent and are used to treat pharyngitis and chronic tonsillitis.[59] Seeds are used as a galactogogue, laxative, and as a treatment for piles, rheumatism, and skin conditions. Roots are used to treat diarrhoea, chronic fluxes, scrofula, phthisis, and antipyretic, anti-inflammatory, and antioxidant conditions.[60] For a summary of the ethnomedicinal uses reported for *M. longifolia* (Table 6), whereas parts wise use and Ethnomedical uses of *M. longifoliais* depicted in Tables 7 and 8 respectively.

According to a survey of the literature, *M. Longifolia* extracts and isolated molecules have effects on Cushing's illness, chronic fluxes, wound healing, cephalgia, hepatoprotection, antimicrobial resistance, astringency, dermatopathy, scrofula, aphrodisiacs, and stimulants, emollient, helminth, phthisis, demulcent, nutritive, verminosis, gastropathy, dipsia, bronchitis, haemorrhoids, analgesic, antiinflammatory, swelling, rheumatism, diarrhoea, tonic, diuretic, cooling agent, pharyngitis, bronchitis, astringent, lotion for a chronic ulcer, emulsifier, demulcent, skin condition, itch, rheumatism, headache, piles galactogogue, laxative, fractures, bleeding spongy gums, skin conditions, epilepsy, pneumonia, and piles.[24,58,60,69,88]

Analgesic Activity

Aqueous and alcoholic extracts of *M. longifolia* flowers were reported to have analgesic effects, and graded doses of both extracts (4.0 to 64.0 mg/kg, i.m. X 3 days) had dose-dependent analgesic effects when tested on rats or mice using the tail flick, hot plate, and chemical writhing procedures.[69]

Anticancer Activity

Acetone and ethanol extracts of *M. Longifolia* leaves were utilised in comparison to the usual medication 5-Flurouracil to conduct a trial against Ehrlich Ascites Carcinoma in mice. Haematological tests, *in-vitro* cytotoxicity, body weight, tumour volume, weight, and cell count were among the criteria evaluated. The findings

Figure 4: Mahua Fresh Fruits.

Figure 4a: Mahua Dried Fruits.

indicate that oral administration of extracts increases survival duration, tumour weight, body weight, and tumour volume, and dramatically lowers tumour cell count.[5]

Fruit seeds from *M. longifolia* are divided into four separate fractions, including Methanol, Ethanol, Acetone, and Chloroform. MTT assay was used to examine the cell growth suppression in *in vitro* anticancer research using the human cancer cell line (HeLa). The findings indicate that different fruit-seed extracts of Mahua. Very good to moderate anti-cancer activity is exhibited by *M. longifolia*.[57] In a study using the acetone and ethanol extracts of *M. longifolia* leaves, the activity of the extract was compared with that of the standard drug 5-Flurouracil against Ehrlich Ascites Carcinoma in mice. Mean survival time, tumour volume, weight, and cell count were among the metrics utilised for evaluation, along with body weight, haematological tests, and *in vitro* cytotoxicity. Based on the data, it can be concluded that oral administration of extracts increases survival time and significantly reduces tumour volume, weight, and body weight.[5,71]

Cytotoxic Activity

Vincristine sulphate was used as the reference standard, and its LC_{50} value of 8.84 g/mL was used to determine the cytotoxic effects of crude extracts of *M. longifolia*. The crude extracts of the leaves and bark demonstrated notable cytotoxicity with LC_{50} values of 17.09 g/mL and 45.96 g/mL, respectively.[61]

Antioxidant Activity

It is well known that oxidative stress contributes significantly to the pathophysiology and development of a number of diseases. Plants can be an excellent source of antioxidants since they create a lot of them, making them a source of novel compounds with potential antioxidant activity to suppress free radicals during metabolic processes. Using the DPPH free radical scavenging method, the antioxidant activity of the crude extracts was evaluated. Ascorbic acid was employed as the reference, and its IC_{50} value was 45.738 g/mL. bark and leaves of *M. longifolia* with IC_{50} values of 61.832 g/mL and 66.342 g/mL, respectively, demonstrated significant antioxidant activity. The amount of phenolics was found to be 62.43 mg, while the amount of phenolic content for the bark was 61.08 mg, both of which were linked to good antioxidant potentiality.[61] Through the use of *in vitro* scavenging models and measurements of GSH and lipid peroxidation levels, the antioxidant properties of a 70% ethanolic extract of *M. longifolia* (koenig) bark were investigated. All of the animal models that the test extract was used on demonstrated dose-dependent antioxidant activity.[62] The antioxidant property of these plants may be because of the phenolic content as *M. longifolia* shown increased activity in cases of DPPH, ABTS, and hydrogen peroxide radical scavenging.[63] The antioxidant activity of the ethanolic bark extract of *M. longifolia* was measured using the DPPH free radical scavenging assay, the reducing power assay, and the superoxide scavenging activity. The test's results were contrasted with those of an ascorbic acid, a naturally occurring antioxidant (Vitamin C).[64] The methanolic extract of *M. longifolia* was tested *in vitro* for its capacity to act as an antioxidant and free radical scavenger. The ABTS (2,2'-azino-bis(3-et hylbenzothiazoline-6-sulphonic acid), DPPH (2,2-diphenyl-1-p icrylhydrazyl), Nitric oxide, hydroxyl radical and hydrogen peroxide scavenging, and butylated hydroxyanisole, butylated hydroxytoluene, and ascorbic acid were used as the standard antioxidants were the models used for antioxidant studies.

The antioxidant capacity of derivatives of madhucic acid and the methanolic extract of *M. longifolia* (L) leaves was examined using the hydroxyl radical scavenging activity, reducing power assay,

and super oxide radical scavenging activity assays. The results showed that *M. longifolia* leaves can serve as powerful natural radical scavengers when compared to the benchmark antioxidant butylated hydroxyl anisole.[48] Two naturally occurring antioxidants, ascorbic acid and gallic acid, were used to test the antioxidant capacity of the methanolic extract of the bark of *M. longifolia* using the DPPH, reducing power assay, and superoxide scavenging activity. The results showed that Madhuca engages in significant scavenging activities.[65] In order to evaluate the antioxidant capability of *M. longifolia* seed, hydrogen peroxide scavenging activity and reducing power assays were utilised. Comparatively speaking, the methanol extract has greater antioxidant activity than the water extract. These findings show that the seeds of *Madhuca longifolia* have potent antioxidant qualities.[66] The antioxidant activity of a 70% ethanolic extract of *M. longifolia* (Koenig) was tested by screening GSH estimation and lipid peroxidation, and it is evident from the results that the plant has stronger antioxidant capability.[67] At two dose levels of 500 mg/kg and 750 mg/kg body weight, the ethanolic leaf extract from *M. longifolia* possesses antioxidant activity against acetaminophen-induced toxicity in rats.[68]

Anticonvulsant Activity

The fruit-seed extracts of *M. longifolia* were used to perform anticonvulsant activity, and the results indicate that the extracts protect animals from seizures and significantly shorten the duration of tonic hind leg extension when compared to the standard drug phenytoin, which completely abolishes tonic hind leg extension. The different phenytoin-treated animals that have 100% protection against seizures are protected against them by 95.85% by the fruits and seeds of *M. longifolia*.[72]

Anthelminthic Activity

Antihelminthic medications are used to eliminate helminthic parasites from the tissues or digestive tract of people and other animals. The antihelminthic properties of several *M. longifolia* leaf extracts were assessed separately for Adult Indian earthworms (*Pheritima posthuma*). At a concentration of 60 mg/mL of each, it was discovered that *M. longifolia*'s methanolic extract and aqueous extract both exhibited anthelminthic activity. Albendazole (60 mg/mL) used as the reference standard. The methanolic extract of *M. longifolia* performed better than the aqueous extract.[73]

Immunomodulatory Activity

M. longifolia bark methanolic extract (MLL) was administered orally to healthy mice at doses of 50, 100, and 150 mg/kg/day, and the immunological responses to the antigenic challenge by sheep RBCs were examined to determine the immunomodulatory activity. As a result, mice exposed to MLL showed a significantly lower response to sheep RBCs in terms of footpad thickness. At dosages of 100 and 150 mg/kg/day, the DTH response was 7.66, 2.75 and 6.41, 1.21, respectively, compared to a value of 14.50 2.38 for the untreated control group. According to the study, there were statistically significant changes in the DTH response (P 0.05), and MLL preferentially lowers aspects of cell-mediated immunity while having no effect on humoral immunity.[76] At doses of 100 and 200 mg/kg body weight, the ethanolic extract of *M. longifolia* was studied for its immunological modulatory effect on albino mice. Comparing the control and the common inducer, cyclophosphomide, on the value of the antibody titre, the DTH reaction, and the effect on myelosuppression. The significant ($p<0.01$) increases in antibody titre value and DTH reaction, respectively, suggest that it has a stimulatory effect on humoral and cell-mediated immunity. Due to *M. longifolia*'s potent immune-stimulatory impact on both particular and non-specific immunological pathways, its application as an immune-modulating medication has a lot of promise.[77]

Anti-microbial Activity

M. longifolia was tested *in vitro* for antibacterial activity using the disc diffusion method using Kanamycin as the reference antibiotic. Four gram-positive pathogenic bacteria and eight gram-negative pathogenic microorganisms both displayed zones of inhibition during disc diffusion. The leaf and bark extracts showed an average zone of inhibition between 7 and 10 mm. Maximum zones of inhibition were seen at 10 mm for *Bacillus*

Table 2: Phytoconstituents of *M. longifolia*.

Plant Part	Extracts	Type of phytochemical reported	References
Stem Bark	Ethyl acetate extract	Phytosterols, Triterpenes.	[23]
	Methanolic extract	Tannins, saponins, carbohydrates, Glycosides.	[23]
Flowers	Ethanolic extract	Alkaloids, tannins, proteins, carbohydrates, saponins.	[6,24]
	Methanolic extract	Alkaloids, tannins, carbohydrates.	[6]
	Aqueous, ether, acetone extract	Carbohydrates, proteins, flavonoids and tannins.	[25]
Leaves	Methanolic extract	Alkaloids, carbohydrates, Phytosterols, Triterpenes, proteins, flavonoids and tannins.	[26]
Seeds	ethanol extract and saponin mixture	Saponins, flavonoids, tannins, phenols, glycosides and alkaloids.	[27]

Table 3: Nutritional Properties of Mahua flower.[39]

Constituents name	Constituents in Quantity (%)
Moisture	19.8
Protein	6.37
Fat	0.50
Total Sugar	54.06
Calcium	8.00
Phosphorus	2.00
Ash	4.36

Table 4: Physio-chemical and Nutritional Properties of Mahua Seed oil.[39]

Properties	Oil Percent (%)
Refractive index	1.452-1.462
Saponification value	187-197
Iodine value	55-70
Unsaponponifiable matter (%)	1-3
Palmitic C 16:0 (%)	24.5
Stearic acid C 18:0 (%)	22.7
Oleic acid C 18:0 (%)	37.0
Linolic acid C 18:2 (%)	14.3

megaterium, Salmonella paratyphi, Vibrio parahemolyticus for barks, and *Vibrio mimicus* for leaves.[61] According to studies, *Madhuca longifolia* extracts significantly reduce the growth of test microorganisms such *Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Aspergillus oryzae*, and *Aspergillus niger*.[78] The antibacterial activity of extracts from *Madhuca longifolia* bark in petroleum ether, chloroform, ethyl-acetate, and methanol was assessed using agar well diffusion and micro dilution assays against *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Bacillus subtilis*. Out of the 64 extracts tested in the well diffusion experiment, 27 had good efficacy. The micro dilution experiment revealed considerable action in all extracts, demonstrating that Madhuca has a high antibacterial potential.[79]

Anti-pyrexia Activity

Research demonstrated that *M. longifolia*'s methanolic extract mimicked possible antipyretic action in both normal and yeast-induced rats, demonstrating the scientific underpinnings of the plant's use in traditional medicine.[85]

Wound Healing Activity

When compared to the usual medication betadine and the control therapy, ethanolic extracts of the leaves and bark of *M. longifolia* significantly reduced the wound area and length of epithelization in mice when used in an excision wound model.[86]

Anxiolytic Activity

The closed field test that was utilised to assess the anxiolytic action of *M. longifolia* leaves revealed that following administration of the hydro-alcoholic extract of *M. longifolia* leaves (100 mg/kg) or diazepam (1 mg/kg) standard, the number of rearing, aided rearing, and squares travelled significantly decreased as compared to the control group.[81]

Neuropharmcological Activity

Study shows an increment in sleeping time and reduction in motor activity when treated with the methanolic extract and a triterpene, compound isolated from the leaves of *M. longifolia* using phenobarbitone as a standard which confirm its sedative nature.[87]

Hepatoprotective activity

Animals with hepatotoxicity brought on by paracetamol (2 g/kg) received two doses of *M. longifolia* methanolic extract orally (100 and 200 mg/kg) and shows a significant protective effect in the chosen model by increasing serum levels of total protein and albumin and decreasing serum levels of several biochemical parameters, including Serum Glutamic Oxaloacetic Transaminase (SGOT), Serum Glutamic Pyruvic Transaminase (SGPT), serum Alkaline Phosphatase (ALP), and serum total bilirubin.[89]

Anti-hyperglycemic Activity

A dose-dependent hypoglycemic effect was produced by the ethanolic extract of *M. longifolia* seeds, which decreased the plasma glucose level in healthy albino rats. This action was caused by either stimulating the release of insulin from cells or boosting the absorption of glucose from the plasma.[23]

The three animal groups-control, glucose-loaded, and streptozotocin-induced diabetic rats were given the ethanolic extract of *M. longifolia* at doses of 100 and 200 mg/kg body weight (p.o.) along with the standard drug, glibenclamide, at a dose of 500 g/kg in order to study the extract's antihyperglycemic effect. The ethanolic extract of *M. longifolia* showed a dose-dependent hypoglycemic action, and the study's overall conclusion is that it has a lot of potential as an anti-diabetic medicine.[64]

Using a methanolic extract of the bark, the antihyperglycemic effect was examined in normal, glucose-loaded, and streptozotocin-induced diabetic rats. The methanolic extract of *M. longifolia* demonstrated a dose-dependent hypoglycemic activity in comparison to the common anti-diabetic drug glibenclamide in all three animal models when administered at doses of 100 and 200 mg/kg body weight (p.o.) and 100 and 200 g/kg, respectively. The study's findings support the use of *M. longifolia* in traditional medicine by showing that its methanolic extract has potential as an anti-diabetic medication.[65]

Table 5: Compounds of *Madhuca longifolia*.

Plant Part	Compound Name	References
Leaves	Quercetin (1), β-Carotene (2), Erthrodiol(3), Palmitic acid (4), Myricetin (5),Xanthophylls (6), Oleanolic acid (7), β-Sitosterol (8), Stigmasterol (9), n-octacosanol (10), 10-(Carboxyoxy) 1,2,2,6a,9,9,he xamethyldocosahydropicene-4a-Carboxylic acid(15).	[31,48]
	B-carotene, xanthophylls, erthrodiol, palmitic acid, myricetin and its 3-O-arabionoside and 3-O-L-rhamnoside, quercetin, 3-galactoside, 3β-palmitoxy-olean-12-en-28-ol, oleanolic acid, β-sitosterol and its 3-O-β-D-glucoside, stigmasterol, β-sitosterol-β-D-glucoside, n-hecacosanol, 3-β-caproxyolcan-12-en-28-ol, n-octacosanol, sitosterol.	[27-32,49]
Bark	Ethylcinnamate (12), Sesquiterpene alcohol(13), α-Amyrin acetates(14), β-Amyrin acetates(15), α-Tocopherol (16).	[36]
	21-Hydroxy-3-oleanyl myricitate (17), Ursolic Acid (18), n-Hexyl-3-acetyl betulinate (19), 3-(27-Carboxy oleanyl)-Octanate (20).	[22]
	Ethylcinnamate, sesquiterene alcohol, α-tocopherol, 3β-monocaprylic ester of eythrodiol and 3β-capryloxy oleanolic acid, α and β-amyrin acetates.	[27,30, 33-37,40]
Seeds	Arachidic acid (21), Stearic acid (22), Aspartic acid (23), Isoleucine (24), leucine(25), Cysteine (26), α-Alanine (27), Proline (28), Threonine (29).	[42]
	Arachidic, linoleic, oleic, myristic, palmitic and stearic acids, α-alanine, aspartic acid, cystine, glycine, isoleucine and leucine, lysine, methionine, proline, serine, threonine, myricetin, quercetin, Mi-saponin A and B.	[41,42,50,51]
Fruits	3β-D-glucoside (30), n-Hexacosanol (31).	[47]
	n-hexacosanol, quercetin and dihydroquercetin, β-sitosterol and its 3β-D-glucoside, α and β-amyrin acetates.	[44-46]
Flower	Vitamin A, Vitamin C.	[52]

The ethanolic extract of *M. indica* seeds had a hypoglycemic effect, lowering the plasma glucose level in healthy albino rats in a dose-dependent manner. Either boosting the release of insulin from cells or enhancing the absorption of glucose from the plasma was responsible for this effect.[23] To assess the hypoglycemic efficacy of the hydro-ethanolic extract of *M. longifolia* leaves, diabetic rats induced with alloxan were employed. According to the study, the hydro-ethanolic extract substantially decreased blood glucose levels.[87]

Anti-ulcer activity

The study demonstrates that ethanolic extract was nearly as efficient as lansoprazole at guarding against pylorus ligation-induced stomach ulcers at a dose level of 10 mg/kg.[23]

Anti-inflammatory activity

At dose levels of 10 and 15 mg/kg and 1.5 and 3 mg/kg, respectively, the ethanol extract and saponin mixture effectively decreased the edoema caused by carrageenan in an acute model of inflammation, suppressing both phases of inflammation. In the sub-acute inflammation model, both extracts performed better than the reference medication diclofenac sodium. Results showed that *Madhuca longifolia* saponins significantly reduced inflammation in cotton pellet granuloma.[26]

Use of Mahua as a Food

Raw consumption of Mahua

Although these blossoms are a great source of nourishment and are readily available in rural regions, they are not especially well-liked as foods. Only a little amount of flowers are consumed fresh, boiled, or fried in some parts of India.[90]

Utilization of mahua for processing of different food products Sugar syrup

Abhyankar and Narayana claim that a range of food products can be sweetened with sugar syrup prepared from dried mahua flowers.[91]

Jam, Jelly, Marmalade, Pickle

Citric acid is added to fully grown but unripe fruits to create jam, according to Reuther *et al.* 1967 report.[92] The pulp is also

transformed into syrup or marmalade, both of which are used as food ingredients. The pulp can also be used by itself or in a jelly to soften the astringent flavour. Additionally pickled, the pulp. A significant amount of flowers are utilised in the production of distilled spirits.[90]

Patel, 2008 prepared the mahua jam and jelly by using fresh flowers. The developed products were tested for their colour, flavor, taste, texture and overall acceptability, using hedonic test. According to the findings of hedonic test all the developed Mahua products were found to be highly acceptable.[93]

Bakery and confectionary

As a liquid sweetener, candy, biscuits, and cake were made using mahua concentrate.

Puree and sauce

After physically removing the stamens, Patel, 2011, used fresh flowers and processed them into puree and sauce.[94]

Sugar syrup

There are numerous accounts on making sugar syrup from dried Mahua flowers since the fermentation process makes use of the blossoms' sweetness.[28,95,96]

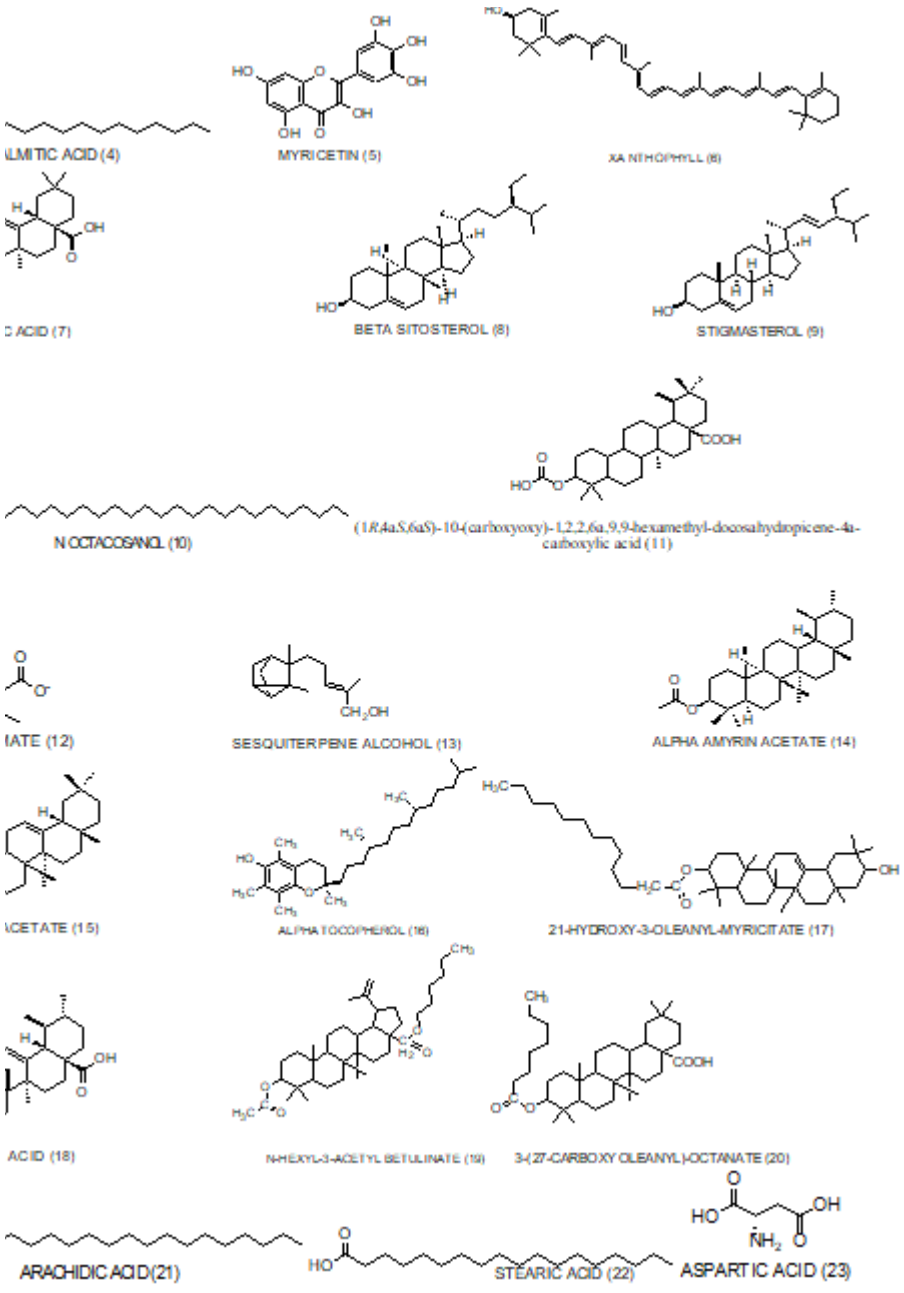

Figure 5: Structure of isolated compound of *Madhuca longifolia.*

Table 6: Traditional Uses of *Madhuca longifolia*.

Ethnomedical uses	Place, Country	Part (s) used	Preparation (s)	Reference
Antioxidant activity	India	Leaves/Bark	Crude extract	[61]
	India	Bark	Ethanol	[62]
	India	Leaves	Methanol	[63]
	India	Bark	Ethanol	[64]
	India	Leaves	Methanol	[48]
	India	Bark	Methanol	[65]
	India	Seed	Methanol	[66]
	India	Leaves	Ethanol	[67]
	India	Leaves	Ethanol	[68]
Analgesic	India	Flowers	Aqueous/Alcoholic	[69]
	India	Aerial part Crude	methanol	[70]
Anti-cancer activity	India	Fruit/Seeds	Methanol/Ethanol/Acetate/ Chloroform	[57]
	India	Leaves	Acetone	[71]
	India	Leaves	Acetone/Ethanol	[5]
Anti-convulsant activity	India	Fruit/Seeds	Methanol/Ethanol/Alcohol/ Chloroform	[72]
Anthelminthic activity	India	Leaves	Methanol/Aqueous	[73]
Hepatoprotective activity	India	Bark	Ethanol	[67]
	India	Leaves	Ethanol	[68]
	India	Leaves	Ethanol	[74]
	India	Bark	Ethanol	[75]
Immunomodulatory activity	India	Bark	Methanol	[76]
	India	Leaves	Ethanol	[77]
Anti-microbial activity	India	Leaf/Bark	Crude extract	[66]
	India	Leaves/Flowers	Alcohol	[78]
	India	Bark	Petroleum ether/Chloroform/ Ethylacetate/Methanol	[79]
Anti-ulcer Activity	India	Leaves	Methanol	[80]
	India	Flowers	Ethanol	[78]
Anxiolytic activity	India	Leaves	Hydro-alcoholic	[81]
Cytotoxic activity	India	Leaf/Bark	Crude extract	[66]
Anti-hyperglycemic activity	India	Bark	Ethanol	[61]
	India	Bark	Methanol	[82]
	India	Seed	Ethanol/Crude alkaloid	[23]
	India	Seed	Hydro Ethanolic	[87]
Anti-inflammatory activity	India	Bark	Methanol	[70]
	India	Leaves	Methanol	[79]
	India	Leaves	Petroleum ether/Ethylacetate/Methanol	[83]
	India	Leaves	Acetone	[84]
	India	Seed	Ethanol/Crude alkaloid	[23]
	India	Leaves	Ethanol	[26]

Ethnomedical uses	Place, Country	Part (s) used	Preparation (s)	Reference
Anti-pyretic activity	India	Leaves	Methanol	[85]
Wound healing activity	India	Leaves/Bark	Ethanol	[86]
Neuropharmcological activity	India	Leaves	Methanol / compound triterpene	[87]

Table 7: Parts wise use of ***Madhuca longifolia*.**

Part of Plant	Medicinal Properties	References
Leaves	Wound healing, hepatoprotective, antioxidant, antimicrobial, astringent, stimulant, emollient, demulcent, rheumatism, piles, nutritive, verminosis, gastropathy, dipsia, bronchitis, dermatopathy, cephalgia, hemorrhoids and Cushing's disease.	[24]
Root	Anti-pyretic, anti-inflammatory, antioxidant, phthisis and scrofula, diarrhea and chronic fluxes.	[60]
Flower	Tonic, analgesic, diuretic, cooling agent, aphrodisiac, astringent, demulcent, helminthes, acute and chronic tonsillitis, pharyngitis as well as bronchitis.	[69]
Fruits	Astringent, lotion in chronic ulcer, acute and chronic tonsillitis and pharyngitis.	[88]
Seeds	Emuluscent, skin disease, rheumatism, head ache, laxative, piles and galactogogue.	[60]
Bark	Itch, swelling, fractures, rheumatism, bleeding spongy gums, ulcer and tonsillitis, skin diseases, epilepsy, pneumonia and piles.	[58]

Table 8: Ethnomedical uses of ***M. longifolia*.**

Plant part	Method of preparation	Uses	References
Stem Bark	Decoction	Skin disease, hydrocele	[54]
	Infusion	Diarrhoea	[56]
	Unspecified	Tonsillitis, leprocy, fever, itching, swelling, fractures, snake-bite poisoning, scabies bleeding gums.	[54-56]
Flowers	Juice	Skin disease	[57]
	Unspecified	Cooling agent, aphrodisiac, astringent, demulcent, tonsillitis, helminthes, pharyngitis, bronchitis, impotency, inflammation, eczema.	[57]
Leaves	Unspecified	Expectorant, chronic bronchitis and cushing's disease	[58]
Fruits	Unspecified	Astringent, chronic tonsillitis and pharyngitis.	[59]
Seeds	Unspecified	Emuluscent, skin disease, rheumatism, head ache, laxative, piles and galactogogue.	[60]
Root	Unspecified	Antipyretic, anti-inflammatory, antioxidant, phthisis and scrofula, diarrhea and chronic fluxes.	[60]

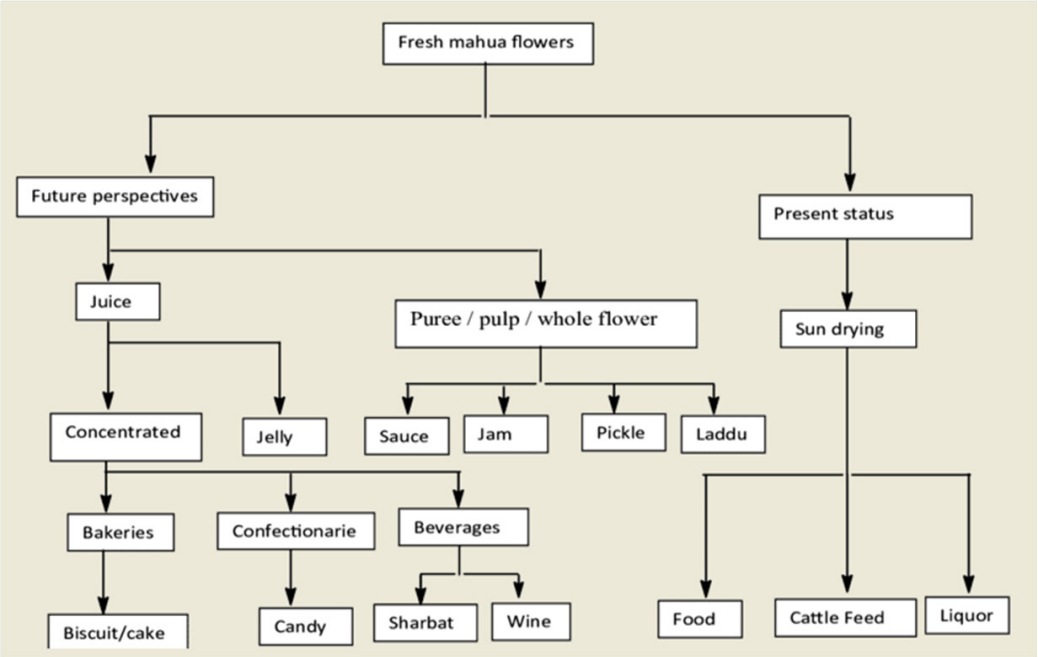

Figure 6: Utilization of *mahua* flowers.

Before being concentrated to the required concentration, the water extract of dried flowers is decolored with various colourizing agents such as slacked lime and activated charcoal. The optimal agent for making Mahua sugar syrup was discovered to be activated charcoal at a concentration of 3.5–10.0% Madhumita and Naik, 2010.[96]

The syrup made in this way from the Mahua flower is used for a variety of purposes, including the production of chocolate and as a sweetener (CSIR, 2006).[49] Utilization of mahua flower is outlined in Figure 6.

Fermented products

Mahua flowers that have been dried are a desirable source of fermented goods because of their high sugar content. Mahua wine preparation using fresh flowers.[97]

The dry mahua has been used to make a variety of products, including alcohol, brandy, acetone, ethanol, lactic acid, and other fermented goods.[98]

CONCLUSION

Since the past few decades, the plant *M. longifolia* has been employed in traditional medicine since it is widely popular and has spread like wildfire throughout many regions of the world. Because the isolated chemicals from the extracts of the various portions of *M. longifolia* have encouraging biological properties, there is need for more investigation. This has made natural product-based drug research interesting bio resource. Despite the plant's high traditional value and several biological functions, a thorough phytochemical investigation has not yet been adequately investigated. Consequently, a phytochemical examination of the *M. longifolia* plant is required.

Mahua trees yield a significant amount of oil. The oil is appropriate for use as a substitute for cocoa in confectionery products, margarine production, cosmetics, and the pharmaceutical industries since it is high in Polyunsaturated Fatty Acids (PUFA) and has an optimal level of oleic and stearic acid. Mahua oil has the potential to replace diesel in several applications. The blossoms are used as a vegetable to produce cake, liquor, and other things. Among the many illnesses and ailments that are treated with mahua are bronchitis, rheumatism, diabetes, piles, eczema, gum disease, and burns. The seeds are valuable because they can be used for industrial purposes, functional, health-promoting food and supplements, and for industrial purposes. High-grade mahua trees should be propagated via plant tissue culture and micro-propagation to the fullest extent possible. Traveling alongside the tribal community members is necessary for the researchers to gather ever-more-valuable information. Plants and mahua trees will be more significant in the approaching generation because to its effectiveness, simplicity of availability, low cost, and comparatively absence of dangerous effects. It makes sense to grow *Madhuca indica* on a large scale, especially on wastelands and arid areas because of its potential for a wide range of purposes. Many well-known medications derive a sizable portion of their revenue from plants. This will contribute to giving low-income, landless families complete financial support. *Madhuca indica* is typically only used to manufacture alcohol, but someone needs to speak up to change the misinformed public's perception. The Mahua tree is concealed due of its possible therapeutic benefits. High-grade mahua trees should be

propagated via plant tissue culture and micro-propagation to the fullest extent possible. The researchers must go with the people who live in the rulers' domain in order to learn more and more useful information. Plants and mahua trees will be more significant in the approaching generation because to its effectiveness, simplicity of availability, low cost, and comparatively absence of dangerous effects. Although a few of the pharmacological effects of *Madhuca indica* have been established, many more remain to be explored.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1. The WHO traditional medicine strategy. Geneva: WHO; 2014-23.
2. Boyce PC. A review of *Pothos* L. (Araceae: Pothoideae: Pothoeae) for Thailand. Thai Forest Bull. 2009;37:15-26.
3. Lawson H. Sources of oils and fats. In: Lawson H, editor. Food oils and fats, technology, utilization and nutrition. Chapman and Hall. 1995:39-48.
4. Yadav S, Suneja P, Hussain Z, Abraham Z, Mishra SK. Genetic variability and divergence studies in seed and oil parameters of mahua (*Madhuca longifolia* Koenig) J.F. Macribide accessions. Biomass Bioenergy. 2011;35(5):1773-78. doi: 10.1016/j.biombioe.2011.01.010.
5. Saluja MS, Sangameserwaran B, Hura IS, Sharma A, Gupta SK, Chaturvedi M. *In vitro* cytotoxic activity of *Madhuca longifolia* against Ehrlich ascites carcinoma cell lines (EAC). Int J Drug Discov Herb Res. 2012;1:55-7.
6. Ramadan MF, Sharanabasappa G, Parmjyothi S, Seshagiri M, Moersel JT. Profile and levels of fatty acids and bioactive constituents in mahua butter from fruit-seeds of buttercup tree [*Madhuca longifolia* (Koenig)]. Eur Food Res Technol. 2006;222(5-6):710-8. doi: 10.1007/s00217-005-0155-2.
7. Behera S, Ray RC, Swain MR, Mohanty RC, Biswal AK. Traditional and current knowledge on the utilization of *Mahua* (L.) flowers *Madhuca latifolia* by the Santhal Tribe in Similipal biosphere reserve, Odisha, India. Ann Trop Res. 2016;38:94-104.
8. Product profile, Mahuwa, trifed, Ministry of Tribal Affairs, Government of India.
9. Ekka A, Ekka NS. *Madhuca longifolia* var. latifolia: An important medicinal plant used by tribes of north–east part of Chhattisgarh. Online Int Interdisc Res J. 2014;4:227-31.
10. Sinha J, Singh V, Singh J, Ak R. Phytochemistry, Ethnomedical uses and Future Prospects of Mahua (*Madhuca longifolia*) as a Food: A Review. J Nutr Food Sci. 2017;07(1):1-7. doi: 10.4172/2155-9600.1000573.
11. Devi LE, Laishram V, Dhamaraja MU, Jamoh A. Effect of taurine on renal pathophysiology in Experimental animals. Int J Pharm Bio Sci. 2016;7(4):106-14. doi: 10.22376/ijpbs.2016.7.4.p179-183.
12. Jaydeep PD, Kumar V, Kumar A, Gat Y, Suri S, Sharma K. Mahua: A boon for Pharmacy and Food Industry. Curr Res Nutr Food Sci. 2018;6(2):371-81. doi: 10.12944/CRNFSJ.6.2.12.
13. Awasthi YC, Bhatnagar SC, Mitra CR. Chemurgy of sapotaceous plants: *Madhuca* species of India. Econ Bot. 1975;29(4):380-9. doi: 10.1007/BF02862185.
14. Variers PS, Vaidyarathanam. Indian medicinal plants. New Delhi: Orient Longman Publication.1995;1(3):362-6.
15. Bhatnagar SC, Awasthi YC, Mitra CR. Constituents of *Madhuca longifolia* leaves. Phytochemistry. 1972;11(1):465-7. doi: 10.1016/S0031-9422(00)90058-X.
16. Sardana S, Sharma OP. Fundamentals of pharmacognosy. 1st ed. New Delhi: Birla Publication. 2009-10:40-2.
17. Sengar NPS, Agarwal RS. A text book of pharmacognosy. 1st ed. Hyderabad: Pharmamed press. 2009:44-5.
18. Siddiqui BS, Khan S, Nadeem KM. A new isoflavone from the fruits of *Madhuca latifolia*. Nat Prod Res. 2010;24(1):76-80. doi: 10.1080/14786410902830100. PMID 20013476.
19. Miller LG. Herbal medicinal. A Clinicians guide. New Delhi, Viva book private limited. 1st ed. 2005:2-3.
20. Ansari SH. Essential of pharmacognosy. 2nd ed. New Delhi: Birla Publication. 2007-08:575-76.
21. Krishnaveni M, Amsavalli L, Chandrasekar R, Madhaiyan P, Durairaj S. Antioxidant activity of plants at Govt. College of Engineering campus, Salem, Tamil Nadu, India. Int J Pharm Sci Rev Res. 2013;21(1):160-3.
22. Chinna EM, Elumalai A, Habibur R. Isolation of phytochemical constituents from stem barks of *Madhuca longifolia*. Int Res J Pharm App Sci. 2011;1(1):43-60.
23. Seshagiri M, Gaikwad RD, Paramjyothi S, Jyothi KS, Ramchandra S. Anti-inflammatory, anti-ulcer and hypoglycaemic activities of ethanolic and crude alkaloid extracts of *Madhuca indica* (Koenig) Gmelin seed cake. Orient Pharm Exp Med. 2007;7(2):141-9. doi: 10.3742/OPEM.2007.7.2.141.
24. Verma N, Jha KK, Kumar U, Kanad D, Singh K. Biological properties photochemistry and traditional uses of mahua (*Madhuca longifolia*): A review. Int J Adv Res Innov. 2014;2:630-8.
25. Annalakshmi R, Uma R, Chandran GS, Sahayam CS, Charles A. Evaluation of physico-chemical constants and phytochemical analysis of *Madhuca longifolia*. Int J Nat Res. 2012;1(3):64-6.
26. Gaikwad RD, Ahmed ML, Khalid MS, Swamy PJ. Anti-inflammatory activity of *Madhuca longifolia* seed saponin mixture. Pharm Biol. 2009;47(7):592-7. doi: 10.1080/13880200902902513.
27. Benerji DSN, Rajini K, Rao SB. Studies on physico-chemical and nutritional parameter for the production of ethanol from mahua flower using *Saccharomyces cerevisiae*-3090 through submerged fermentation. J Microbiol Biochem Tech. 2010;2:46-50.
28. Shriwastaea RK, Sawarkar SK, Bhutey PG. Decolourization and deodorizations studies on mahua extract. Res Edu-Res India. 1970;15:114-7.
29. Shashikant VG, Raheman H. Biodiseal production from Mahua oil having High free fatty acid. Biomass Bioenergy.1970. 2008;28:601-5.
30. Puhan S, Vedaraman N, Ram BVB, Sankarnarayanan G, Jeychandran K. Mahua oil (*Madhuca indica* seed oil) methyl ester as biodiesel-preparation and emission characterstics. Biomass and Bioenergy. 2005;28(1):87-93. doi: 10.1016/j.biombioe.2004.06.002.
31. Chakma CS. Pharmacological screening of isolated compound from seeds *Madhuca longifolia* gives significant analgesic effect. Int Res J Pharm. 2011;2:43-5.
32. Khare CP. Rational western therapy, ayurvedic and other traditional usage. Encyclopedia of Indian medicinal plant. Botany. Springer. 2000;292.
33. Rajagopal PL, Dhilna KK, Kumar SPN, John J. Herbs in inflammation-a review. Int J Ayurvedic Herbal Med. 2013;3(4):1289-307.
34. Alexander J, Atli G, Bentord D. Saponin in the *Madhuca longifolia* as undesirable substance in animal feed. European Food Safety Authority. 2009;979:1-36.
35. Liang YZ, Xie P, Chan K. Quality control of herbal medicines. J Chromatogr. 2004;812(1-2):53-70. doi: 10.1016/S1570-0232(04)00676-2.
36. Yadav P, Singh D, Mallik A, Nayak S. *Madhuca longifolia* (Sapotaceae): A review of its traditional uses, phytochemistry and pharmacology. Int J Biol Med Res. 2012;3(7):291-305.
37. Akshatha KN, Murthy SM, Lakshmidevi N. Ethnomedical uses of *Madhuca longifolia*-A review. Int J Life Sci Pharm Res. 2013;3(1):44-53.
38. Yoshikawa K, Tanaka M, Arihara S, Pal BC, Roy SK, Matsumura E, *et al*. New oleanene triterpenoid saponins from *Madhuca longifolia*. J Nat Prod. 2000;63(12):1679-81. doi: 10.1021/np000351r, PMID 11141115.
39. Kureel RS, Kishor R, Dutt D, Mahua AP. A potential tree born oil seed. National oil seed and development board. Gurgaon: Ministry of Agriculture Govt. of India. 2009:1-27.
40. Shirode D, Patel T, Roy SP, Setty RS, Rajendra SV. Anti-inflammatory activity of 70% ethanolic extract of *Albizzia lebbeck* leaves and *Madhuca longifolia* bark. Int J Pharm Biol Sci. 2008;2(3):127-30.
41. Ramadan MF, Mohdaly AAA, Assiri AMA, Tadros M, Niemeyer B. Functional characteristics, nutritional value and industrial applications of *Madhuca longifolia* seeds: An overview. J Food Sci Technol. 2016;53(5):2149-57. doi: 10.1007/s13197-015-2095-6, PMID 27407181.
42. Sengupta A, Choudhury RSK. Triglyceride composition of *Madhuca butyraceae* seed fat. J Am Oil Chem Soc. 1978;55(8):621-4. doi: 10.1007/BF02678959.
43. Jayasree B, Harishankar N, Rukmini C. Chemical composition and biological evaluation of mahua flowers. J Oil Technol Assoc. 1998;30:170-72.
44. Saikia B. Ethnomedicinal plants from Gohpur of Sonitpur District, Assam. Indian J Trad Knowl. 2006;5(4):529-30.
45. Panghal M, Arya V, Yadav S, Kumar S, Yadav JP. Indigenous knowledge of medicinal plants used by Saperas community of Khetawas, Jhajjar District, Haryana, India. J Ethnobiol Ethnomed. 2010;6(4):4. doi: 10.1186/1746-4269-6-4, PMID 20109179.
46. Dubey NK, Kumar R, Tripathi P. Global promotion of herbal medicine: India's opportunity. Curr Sci. 2004;86(1):37-41.
47. Vohra A, Kaur H. Chemical investigation of medicinal plant *Ajuga bracteosa*. J Nat Prod Plants Resour. 2011;1(1):37-45.
48. Triveni SI, Paramjyoti LS. Evaluation of *in vitro* antioxidant activity of a triterepne isolated from *Madhuca longifolia* leaves. Int J Pharm Pharm Sci. 2013;5(4):389-91.
49. The useful Plants of India, 1986. New Delhi, publication and information directorate, CSIR.
50. Agarwal SS, Paridhavi M. Herbal drug technology. Hyderabad: University Press (India) Pvt. Ltd; 2000:1-8.
51. Mishra S, Padhan S. *Madhuca longifolia* (Sapotaceae): A review of its traditional use and Nutritional properties. Int J Humanit Soc Sci Inven. 2013;2(5):30-6.
52. Hoffman FA, Leaders FE. Botanical (herbal) medicine in heath care. Regul Perspect Pharm New. 1996;1:23-5.

53. Khan S, Zahan D. Anti-hyperglycemic activity studies with methanol extract of *Madhuca indica* J.F. Gmel. leaves and *Paederia foetida* L. stem in mice. Adv Nat Appl Sci. 2011;5:122-6.
54. Ayyanar M, Ignacimuthu S. Traditional knowledge of Kani tribals in Kouthalai of Tirunelveli hills, Tamil Nadu, India. J Ethnopharmacol. 2005;102(2):246-55. doi: 10.1016/j.jep.2005.06.020, PMID 16054791.
55. Thas JJ. Siddha medicine–background and principles and the application for skin diseases. Clin Dermatol. 2008;26(1):62-78. doi: 10.1016/j.clindermatol.2007.11.010. PMID 18280906.
56. Kirtikar KR, Basu BD. Indian medicinal plants. Orient Enterpr. 2001;7:2058-61.
57. Bhaumik A, Kumar MU, Khan KA, Srinivas CH. The bioactive compounds obtained from the fruit-seeds of *Madhuca longifolia* (L.) act as potential anticancer agents. Scholars J Appl Med Sci. 2014;2(4A):1235-8.
58. Prajapati V, Tripathi AK, Khanuja SPS, Kumar S. Anti-insect screening of medicinal plants from Kukrail Forest, Lucknow, India. Pharm Biol. 2003;41(3):166-70. doi: 10.1076/phbi.41.3.166.15092.
59. Bisht V, Neeraj SVK, Dalal N. Mahua an important Indian species: A review. J Pharmacogn Phytochem. 2018;7(2):3414-8.
60. Chatterjee A, Pakrashi SC. The treatise on Indian. Med Plants. 2000;4:56-8.
61. Israt JB, Yesmin B. Antibacterial, cytotoxic and antioxidant activities of *Madhuca indica*. Sci Res J. 2014:15-20.
62. Roy SP, Shirode D, Patel T, Shastry CS, Gheewala N, Sonara G, *et al*. Antioxidant and hepatoprotective activity of *Madhuca longifolia* (Koenig) bark against CCl4-induced hepatic injury in rats: *In vitro* and *in vivo* studies. Res J Pharm Biol Chem Sci. 2010;1(1):1-10.
63. Agrawal S, Kulkarni GT, Sharma VN. A comparative study on the antioxidant activity of methanolic extracts of *Terminalia paniculata* and *Madhuca longifolia*. Free Radic Antioxid. 2011;1(4):62-8. doi: 10.5530/ax.2011.4.10.
64. Srirangam P, Annampelli AK, Burra M, Yennamaneni PK. Antihyperglycemic and antioxidant activity of ethanolic extract of *Madhuca longifolia* Bark. Int J Pharm Sci Rev Res. 2010;5(3):89-94.
65. Dahake AP, Chakma C, Joshi D, Chakma R, Tripathi A. Antioxidant activity of methanolic extract of *Madhuca longifolia* bark. J Pharm Res. 2010;3(8):1709-11.
66. Umadevi U, Kamalam M. Screening of an indigenous medicinal plant *Madhuca longifolia* for its antioxidant and antimicrobial properties. IJPSR. 2015;6(1):273-6.
67. Kumar A, Biswas K, Ramachandra Setty S. Evaluation of the antioxidant and hepatoprotective activity of *Madhuca longifolia* (*Koenig*) leaves. Indian J Res Pharm Biotechnol. 2013;1(2):191-6.
68. Palani S, Raja S, Karthi S, Archana S, Sendhil KB. *In vivo* analysis of nephro and hepato protective effects and antioxidant activity of *Madhuca longifolia* against acetaminophen induced toxicity and oxidative stress. J Pharm Res. 2010;3(1):9-16.
69. Chandra D. Analgesic effect of aqueous and alcoholic extracts of *Madhuca longifolia* (Koeing). Indian J Pharmacol. 2001;33:108-11.
70. Shekhawat N, Vijayvergi R. Investigation of anti-inflammatory, analgesic and antipyretic properties of *Madhuca indica* GMEL. Int J Mol Med Adv Sci. 2010;6(2):26-30. doi: 10.3923/ijmmas.2010.26.30.
71. Sangameswaran B, Saluja MS, Sharma A, Manocha N. Antitumor effect of acetone extract of *Madhuca longifolia* against Ehrlich Ascites Carcinoma (EAC) in mice. Phytopharmacol. 2012;3(1):130-6.
72. Boddupally M, Bhaumik A, Chaitanya RGV, Das P, Das S. The biomolecules present in the fruit-seeds of *Madhuca longifolia* (L.) act as potential anticonvulsant agents against MES-induced rats. Int J Cur Pharm Res. 2015;1(7):96-8.
73. Akhil M, Sarma DSK, Poornachandra Rao GVN, Jyothi CH. VS, Rajesh Kumar D, Ram Sarath Kumar. Evaluation of anthelminthic activity of leaves of *Madhuca longifolia*. Int J Pharmacol Toxicol. 2014;4(2):99-104.
74. Roy SP, Gupta R, Kannadasan T. Hepatoprotective activity of ethanolic extract of *Madhuca longifolia* leaves on D-galactosamine induced liver damage in rats. J Chem Pharm Sci. 2012;5:205-9.
75. Roy SP, Kannadas T, Gupta AR. Screening of hepatoprotective activity of *Madhuca longifolia* bark on D-Galactosamine induced hepatotoxicity in rats. Biomed Res. 2015;26(2):365-9.
76. VC, Ganesh D, Shrinivas S. Study of the immunosuppressive activity of methanolic extract of *Madhuca longifolia* (Koenig). Orient Pharm Exp Med. 2010;10(3):150-4. doi: 10.3742/OPEM.2010.10.3.150.
77. Shrivastava M, Dhingra N, Dwivedi LK. Immunomodulatory activity of ethanolic extract of *Madhuca longifolia* in mice. Int J Pharm Technol. 2014;5(4):6094-103.
78. Kalaivani M, Jegadeesan M. Antimicrobial activity of alcoholic extract of leaves and flowers of *Madhuca longifolia*. Int J Sci Res Publ.2013;3(5):1-3.
79. Agrawal S, Kulkarni GT, Sharma VN. Antimicrobial and anti-inflammatory activities of bark of four plant species from Indian origin. Webmed Cent Pharm Sci. 2012;3(10):2-14.
80. Mohod SM, Bodhankar SL. Evaluation of antiulcer activity of methanolic extract of leaves of *Madhuca indica*. Pharmacol Online. 2011;3:203-13.
81. Singh H, Mani M. Evaluation of anxiolytic activity of hydro-alcoholic extract of *Madhuca longifolia* leaves. J Nat. Prod Plant Resour. 2014;4(1):19-22.
82. Dahake AP, Chakma CS, Chakma RC, Bagherwal P. Antihyperglycemic activity of methanolic extract of *Madhuca longifolia* bark. Diabetol Croat. 2010:39-1.
83. Kanakam V, Kalakota C. Anti-inflammatory and analgesic activities on leaves methanolic extract of *Madhuca indica* Linn. IJPCBS. 2014;4(2):268-71.
84. Chakma CS, Chakma RC, Ghosh TK. Anti-inflammatory activity of the fruit-seeds of *Madhuca longifolia* (Koenig) in Wistar albino rats. Research to Prevent Blindness. 2011;1(1):56-9.
85. Jana GK, Gupta A, Soni D, Debnath S, Panda S. Evaluation of pharmacological potentials of methanolic leaf extract of *Madhuca longifolia* (Sapoteacae) against pyrexia. J Pharm Res. 2011;4(4):1298-9.
86. Sharma S, Sharma MC, Kohli DV. Wound healing activity and formulation of ether-benzene-95% ethanol extract of herbal drug *Madhuca longifolia* leaves in albino rats. J Optoelectron Biomed Mater. 2010;19(1):13-5.
87. Inganakal TS, Ahmed ML, Swamy P. Neuropharmcological potential of methanolic extract and a triterpene isolated from *Madhuca longifolia* L leaves in mice. Indian J Exp Biol. 2012;50(12):862-6. PMID 23986969.
88. Patel S, Patel S, Patel V. Investigation into the Mechanism of Action of *Madhuca longifolia* for its Anti-epileptic Activity. Phcog Commn. 2011;1(2):18-22. doi: 10.5530/pc.2011.2.4.
89. Umadevi M, Maheswari C, Jothi C, Paleti SK, Reddy YS. Hepatoprotective activity of flowers of *Madhuca longifolia* (Koen.) Macbr. against paracetamol induced. Res J Pharm Technol. 2011;4:259-62.
90. Anonymous. Wealth of India. A dictionary of Indian raw materials and industrial products-raw materials publications and information. New Delhi: Directorate Council of Scientific and Industrial Research: LM. VI: Council of Scientific and Industrial Research. 1962:207-15.
91. Abhyankar VS, Narayana N. Reports on preparation of sugar syrup from dry mahua flowers which can be further use as a sweeting preliminary note on the preparation of syrup from mahua flowers. Poona Agric Coll Mage. 1942;33:168-72.
92. Reuther W, Webber HJ, Batcher LD. Citrus Ind. 1967:407-9.
93. Patel M, Naik SN. Biochemical investigations of fresh mahua (*Madhuca indica*) flowers for nutraceutical. PhD [thesis]. New Delhi, India: Centre for Rural Development and Technology, Indian Institute of Technology. 2008.
94. Patel M, Pradhan RC, Naik SN. Physical properties of fresh mahua. Int Agrophys. 2011;25:303-6.
95. Banerji R, Mahua MR (*Madhuca species*): Uses and potential in India. J Appl Bot. 1996:260-77.
96. Patel M, Naik SN. Flowers of *Madhuca indica* J.F. Gmel: Present status and future perspectives. Indian J Nat Prod Resour. 2010;1:438-43.
97. Yadav P, Garg N, Diwedi DH. Effect of location of Cultivar, fermentation temperature and additives in the physico-chemical and sensory qualities of mahua (*Madhuca indica* J.F. Gmel) wine preparation. Nat Rad. 2009;8:406-18.
98. Fowler GJ, Behram JDE, Bhate SR, Hassan HK, Mahdihassan S, Inuganti NN. Biochemistry of Mahua flower. J Indian Inst Sci. 1920;3:81-118.

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