Review Article

A review on Phytochemicals and biological attributes of *Madhuca longifolia*

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Abstract

Madhuca longifolia (mahua) is commonly known as the Honey tree and butter-nut tree belongs to the family Sapotaceae. Mahua is an economic plant growing throughout the subtropical region of India, Nepal, Australia, and Sri Lanka. It is about 17m in height and wild as well as commercially cultivated by villagers as it is a good source of employment for many people. Phytochemical study of mahua shows that it is rich in sugar, vitamin, protein, glycosides, alkaloids, tannins, flavonoids, steroids, terpenoids, saponins, and phenolic compounds which are responsible for different pharmacological properties such as anti-inflammatory, antioxidant, analgesic, antihyperglycemic, spasmolytic, hepatoprotective, anticonvulsant, anticancer, anthelmintic, antiulcer, antitumor, neuropharmacological and dermatological activities. Mahua flowers are widely used in the manufacturing of liquor as well as different types of food products. This may increase employment and help to raise potential income source for the nation. Commercial utilization of mahua flowers in different types of food products may increase employment and help to generate potential income source for the nation. This review mainly focuses on the traditional uses of various parts of a plant, phytochemical constituents along with their chemical structures, and reported pharmacological activities.

***Keywords*:** *Madhuca longifolia*, traditional uses, phytochemistry, pharmacological profile, marketed formulation

Introduction

Madhuca longifolia is the botanical name of the Mahua tree which belongs to the family Sapotaceae. Medicinally each part of the plant has specific importance and hence is cultivated for its medicinal use. The English synonym for Mahua is The Honey Tree. It is also been worshipped by tribal and has relevance in their norms and traditions (Saif et al., 2020). Mahua is also termed as a tree of Butter-nut and has many other synonyms in various languages like Atavimaduka in Sanskrit; Mohua, Mungli in Hindi; Ippa, Madhukamu in Telugu; Iluppai, Kattillupi in Tamil; Mohuka, Mohulo in Odia; Illuppa, Iruppapu in Malayalam; Doddippa, Halippa in Kannada; Mahuva in Urdu; Moha, Mhowra in Marathi; Mahudo in Gujarati; Mahula, Kochra in Bengali (Jha and Mazumder, 2018; Khare et al., 2018). It is mainly native to Asian and Australian forests, Sri Lanka, and Burma.In India, it is widely distributed in deciduous forests of West Bengal, Orissa, Punjab, Madhya Pradesh, Uttar Pradesh, Bihar, and sub mountainous region of the Himalaya.It is also cultivated in the northern parts of India. The tree is drought-resistant, requires a large amount of light, and cannot thrive well under shady places. The tree grows best in sandy soil but can also grow in other varieties of soils such as shallow, boulders, clay, and calcareous soil. It is generally found up to an altitude of 1200 m, with a mean annual maximum temperature of 28-50°C and rainfall from 550-1500 mm (Singh et al., 2017). The tree of Mahua is a medium to a large-sized deciduous tree, cracked bark, and rusty-tomentose with a bunchy top which provides an ample amount of shade. It grows up to a height of 17-18m (Bhaumik et al., 2014; Singh et al., 2014). Leaves are coriaceous and are present in the form of bunches at the endings of branches, shortly acuminate, elliptic, shortly acuminate band base cuneate (Bhaumik et al., 2014). They are pointed tips and have a thick texture, they have a hairy surface on the beneath, have strong nerves (Singh et al., 2017; Yadav et al., 2011). Flowers are numerous, white in color, fascicled and they are present at the branch endings, drooping on pedicels (Bhaumik et al., 2014; Singh et al., 2014). They have a sweet flavor and are fleshy in texture (Singh et al., 2017). Fruits are green and fleshy which contain 3-4 brown colored ellipsoidal

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seeds having shiny coat (Marikkar and Yanty, 2012).

The tree has been gifted with many chemical constituents, which make it a potent medicine. It also provides various products of edible purposes (Khare et al., 2018). The tree is important to mankind for its oil-bearing seeds and flowers, which are also being used for alcoholic beverage production. Being a good source of edible fats, seeds of Mahua are of economic importance (Gaikwad et al., 2009). Flowering of Mahua tree occurs from March to April. Collection of seeds generally performed in May, June, and July by villagers using a hand-picking method or bamboo sticks. For oil expelling, the indigenous methods could be used (Khare et al., 2018). The tree of mahua contains a large number of secondary metabolites which are useful in preventing and act as an ailment to cure various chronic diseases and also has antimicrobial, cardioprotective, antifungal, antiulcer, antiparasitic, antiviral, anti-allergic, anticancer, antispasmodic, antihyperglycemic, anti-inflammatory, and immunomodulatory pharmacological responses (Gaikwad et al., 2009).

Traditional uses

Madhuca longifolia has been used since ancient times by people to satisfy their needs in the form of food, medicine, additives, and as fodder for animals. Leaves of Mahua are used as an expectorant and to treat chronic bronchitis, Cushing's disease. The bark of the tree is used in itching, fractures, poisoning due to Snakebites, and Diabetes mellitus. Flowers are used to treat chronic bronchitis and eye diseases; a mixture of flowers and milk helps in impotency and general debility. Also, the juice of flowers is used to cure many skin diseases, which is used as a nutritious tonic (Bhaumik et al., 2014). It gives relief from discomfort due to pitta, and can be used as a nasal drop (Dahake et al., 2010). The seeds of Mahua are a rich source of oil, which is generally used to cure inflammation, skin infections, and also as a laxative. Flowers of Mahua are known since ancient times as a cooling agent, tonic, aphrodisiac, astringent, and also as a demulcent. The bark of the tree is used as an ailment to cure rheumatism, ulcers, and tonsillitis (Singh et al., 2014). Tuberculosis, rheumatoid arthritis, cholera, flatulency, debility, influenza, paralysis, piles, arthritic pain, helminthiasis, low semen count, headache are some diseased conditions which can be cure by various parts of mahua plant.Also, being used as a blood purifier and as an antidote to poison (Sangeetha and Devi, 2016). Leaves of Madhuca are boiled and used to treat Orchitis (Inflammation of testis). The decoction prepared from the bark is effective against diabetes. Chronic constipation can be cured by seed oil of Mahua which also acts as a laxative, cure piles. Leaves of Mahua are also helpful in the treatment of eczema by coating the leaves with sesame oil and heating over a flame and by applying on the locally affected area to get relief from eczema. The liquid extract obtained from the bark of mahua diluted with water helps to heal spongy and bleeding gums. Flowers and seeds of Madhuca are used to elevate the production of milk in feeding mothers (Mishra and Pradhan, 2013). Freshly obtained pieces of stems are used to eliminate foul smell in the mouth and also help to strengthen gums. For ladies suffering from amenorrhoea are administered with the decoction prepared with extract of the inner bark of Mahua. The juice of mahua leaves is applied to the body to get rid of any muscular pains. Dysuria can be treated with dry petal juice of the flowers of Mahua. Also, wine prepared from fermented petals is given to women during child delivery, which also helps in curing cough and cold. Buffaloes are given oil extracted from kernels to improve the digestive process. In children to cure constipation, seed powder is given. Smelling seed powder can help cure throat discomfort, cough, cold, and hysteria. Juice obtained after rubbing germinated seed in water is administered as a nasal drop to cure chronic headache (Patil et al., 2004). LATTA, a preparation obtained by mixing the same amounts of flowers of mahua and roasted grains of maize is proved to be effective to cure to pain in arthritis (Gaikwad et al., 2009).

Nutritional properties of Mahua

(a) Nutritional aspects of flowers of Madhuca

Flowers of Mahua contain 50.6% of Reducing sugars, 3.43% of Cane sugar, 6.37% protein, 8% Calcium, and 2% Phosphorous (Mishra and Pradhan, 2013).

(b) Nutritional aspects of Seed oil of Madhuca

Madhuca longifolia is one of the versatile plant which has medicinal as well as nutritional value (Mishra and Pradhan, 2013; Marikkar and Yanty, 2012). Seed oil of Madhuca plant consist of many nutritional constituents which are shown in Table No.1.

Seed oil of Madhuca has Refractive index of about 1.452-1.462, Saponification value of 187-197, Iodine value 55-70, Unsaponifiable matter (%) 1-35, Palmitic Acid C 16:0 (%) 24.56, Stearic Acid C 18:0 (%) 22.77, Oleic Acid C 18:0 (%)37.08, Linolic Acid C 18:2 (%) 14.3.

Table 1. Nutritional aspects of *Madhuca longifolia* seed oil

S. No.	Parameters	Value
1.	Refractive index	1.452-1.462
2.	Iodine value	55-70
3.	Saponification value	187-197
4.	Unsaponifiable matter (%)	1-35
5.	Palmitic Acid C 16:0 (%)	24.56
6.	Stearic Acid C 18:0 (%)	22.77
7.	Oleic Acid C C18:0 (%)	37.08
8.	Linolic Acid C18:2 (%)	14.3

Table 2. Chemical constituents and uses of *Madhuca longifolia*

Plant Parts	Chemical Constituents	Uses	Ref.
Leaves	B-carotene, xanthophylls, D-glucosides, erthrodiol, palmitic acid, Protobassic acid, myricetin, quercetin, oleanolic acid, n-hexacosanol, 3-O-L-rhamnoside, 3β-caproxy and 3β-palmitoxy- olean-12-en- 28-ol, 3-O-β-D-glucoside, quercetin and its3-galactoside, myricetin and its 3-O-arabinoside, n-octacosanol, β-sitosterol and its 3-O-β-D-glucoside	Orchitis, Eczema, Chronic Bronchitis, Cushing's Diseases	Khare et al., 2018; Singh et al., 2014
Bark	α- and β- amyrin acetates, Ethylcinnamate, Betulinic acid, α-terpineol and sesquiterpene alcohol, 3β- monocaprylic ester of erythrodiol and 3β-capryloxy oleanolic acid.	Used to cure bleeding spongy gums, ulcer, and tonsillitis, skin diseases, epilepsy,rheumatism, pneumonia, and piles	Khare et al., 2018; Sangeetha and devi, 2016.
Flowers	Vitamins like A & C, quercetin, β- amyrindecanate, betulinic acid, tannins, β-amyrin acetate, stigmasterol andβ -amyrin cinnamate	Used as tonic,analgesic, (aphrodisiac, demulcent)and diuretic	Singh et al., 2017; Mishra et al., 2013.
Seeds	Arachidic acid, oleic acid, linolenic acid, aspartic acid, Protobassic acid, lysine, Myristic, palmitic and stearic acids, isoleucine, cysteine, α-alanine, glycine, and leucine, methionine, proline, threonine, myricetin, serine, quercetin, Mi-saponin A and saponin B, Madlongiside A, B, C, D	Fat obtained from seeds is used to treat skin diseases, rheumatism, headache, laxative, piles, Galactagogue etc.	Yadav et al., 2012.
Fruits	n-hexacosanol, β-sitosterol, and its 3β-D- glucoside, quercetin, dihydroquercetin, and α- and β- amyrin acetates	Used in Tonsillitis, as an astringent, and in pharyngitis	Kumar et al., 2015.

Chemical constituents

The Mahua tree has been gifted with many chemical constituents which make it a potent medicine. The chemical constituents and chemical structures of these constituents with their respective plant parts are mentioned in table no.2 and table no. 3 respectively.

Pharmacological activities

Anti-hyperglycemic activity

The anti-diabetic activity by *Madhuca longifolia* may be reported due to the differences in glucose utilization (Jha and Mazumder, 2018). Diabetes mellitus involves a group of metabolic diseases that are characterized by hyperglycemia, hypertriglyceridemia, and hypercholesterolemia which may be either a result of insulin action or secretion or at times both. Recently bark of *Madhuca longifolia* is used to treat diabetes, arthritis, ulcers, bleeding, and tonsillitis. Diabetes can be grouped into two types which have greater possibilities of morbidity and mortality which are of the following two types of Insulin-dependent diabetes mellitus (IDDM) and Non-insulin-dependent diabetes mellitus (NIDDM). The present studies indicate that the methanolic extract of the bark of *Madhuca longifolia* exhibits hypoglycemic activity when tested on STZ induced diabetic rats, Hence, can be supposed to be a potent anti-hyperglycemic agent (Dahake et al., 2010; Mishra and Pradhan, 2013). Significant hypoglycemic activity exhibited by the bark of *Madhuca longifolia* in diabetic rats depicts that this pharmacological effect can be administered by stimulation of glucose utilization with the medium of peripheral tissues (Srirangam et al., 2010). Hydroalcoholic leaf extracts also showed the Anti-hyperglycemic activity against diabetic rats induced with Alloxan, oral administration of a single dose of ethanolic bark extract of *Madhuca longifolia* caused a significant decrease in serum glucose level in normal rats only (Jha and Mazumder, 2018; Ghosh et al., 2009).

Anti-inflammatory activity

Inflammation is regarded as an indication of the response to the external stimuli. Various studies reveal that the ethanolic extracts of both bark and seed exhibit anti-inflammatory response. On the other hand, a crude alkaloidal extract of *Madhuca longifolia* also exhibits an anti-inflammatory response. The generalized mechanism of action was noted that the constituents of Madhuca brought about inhibition of the synthesis of prostaglandin along with its mediators in synthesis, another possible mechanism includes reducing the expression of intercellular cell adhesion molecule-1 which gets induced by TNF-α (Jha and Mazumder, 2018). Good anti-inflammatory activity was exhibited by seeds of mahua fruit against cotton pellet granuloma. Saponins extracted from mahua and ethanolic extract of mahua functioned as efficient anti-inflammatory agents against carrageenan-induced edema (Khare et al., 2018). The aerial parts of *Madhuca longifolia* are used to treat inflammation. Madhuca plant has been reported to bring about significant inhibition of COX, which makes it a potent anti-inflammatory agent (Verma et al., 2014). The residual seed cake after extracting oil is densely loaded with

Table 3. Chemical Structures of active ingredients of *Madhuca longifolia*

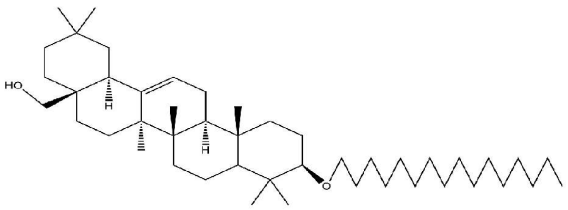
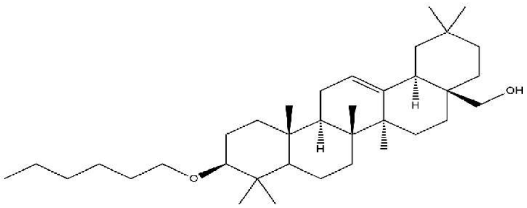
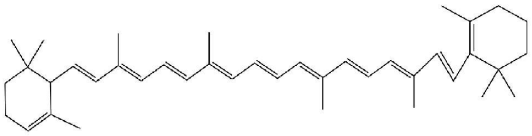
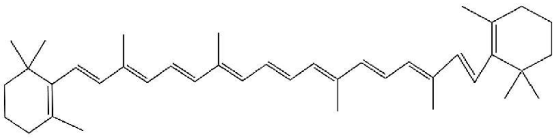
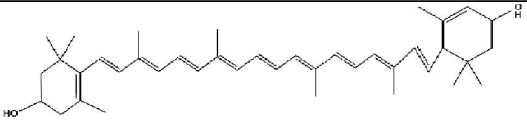
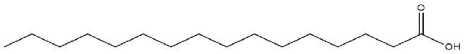
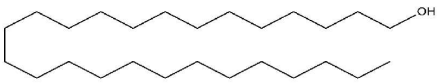
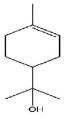
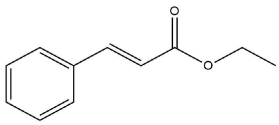
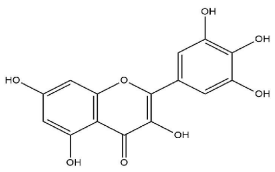
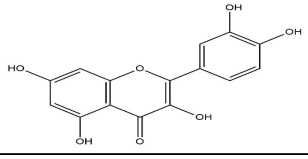
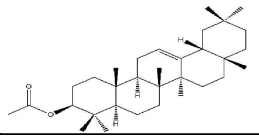
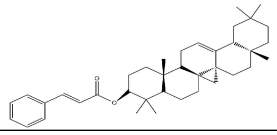
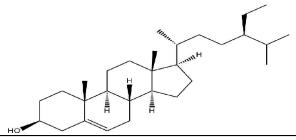
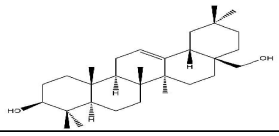
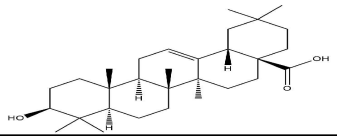
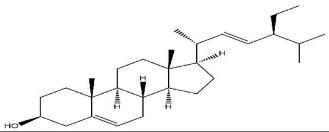
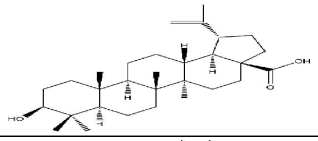
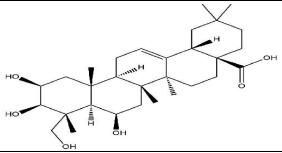
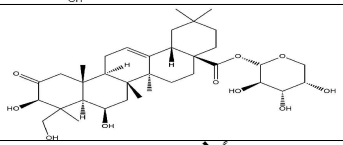
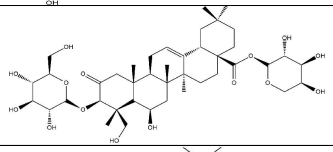
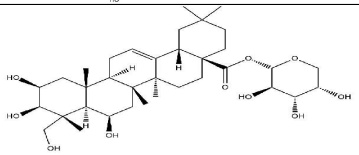
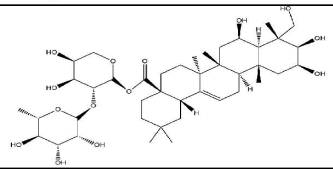
No	Name	Chemical Structure	Plant part
1.	3-beta- palmitoxy-olean-12-en-28-ol		Leaves
2.	3-beta-caproxy-olean-12-en-28-ol		Leaves
3.	Alpha-carotene		Leaves
4.	Beta-carotene		Leaves
5.	Xanthophyll		Leaves
6.	Palmitic acid		Leaves, Seeds
7.	n-hexacosanol		Fruit
8.	Alpha-terpineol		Bark
9.	Ethyl cinnamate		Bark
10.	Myricetin		Leaves, seeds
11.	Quercetin		Leaves, seed, flower, fruit

Table 3. Continue .....

No	Name	Chemical Structure	Plant part
12.	Beta-amyrin acetate		Bark, Flower, Fruit
13.	Beta-amyrin cinnamate		Flower
14.	Beta-sitosterol		Leaves, Fruit
15.	Erythrodiol		Leaves, Bark
16.	Oleanolic acid		Leaves, Bark
17.	Stigmasterol		Flower
18.	Betulinic acid		Bark, Flower
19.	Protobassic acid		Leaves, seeds
20.	Madlongiside A		Seeds
21.	Madlongiside B		Seeds
22.	Madlongiside C		Seeds
23.	Madlongiside D		Seeds

saponins,hence due to the presence of saponins finds more scope as an anti-inflammatory agent (Gaikwad et al., 2009). Acetone extract of Mahua exhibits a significant anti-inflammatory response (Chakma 2011).

Larvicidal and Ovicidal activity

The aqueous extract of oil cakes of Madhuca exhibit significant larvicidal and ovicidal activities against *Meloidogyne incognita*. The cakes of mahua showed activity against the larval growth of egg-sacs of cyst nematodes (Verma et al., 2014; Lanjewar and Shukla, 1986).

Spasmolytic activity

The saponins extracted from leaves of Madhuca exhibit significant spasmolytic activity, also saponins present in seeds exhibited remarkable spasmolytic activity on isolated ileum of guinea pig (Khare et al., 2018).

Spermicidal activity

The presence of steroids and triterpenoid saponins in seeds make them act as spermicidal agents (Khare et al., 2018). Reduction in sperm count was observed after administering the male mice with natural contraceptives, the interference in testicular spermatogenesis lead to infertility and raised abnormality of sperms, hence spermicidal activity was noted (Verma et al., 2014).

Insecticidal and pesticidal activity

Cake of mahua exhibits insecticidal and pesticidal activity against Phyto nematode and as a remarkable pesticide against Tetranychusurticae (Khare et al., 2018).

Antimicrobial activity

Mahua showed good antimicrobial activity against strains of bacteria such as *E. coli, Pseudomonas, S. aureus, Penicillium* and 3 fungal strains. Its activity was more potent against *S. aureus E. coli* (Khare et al., 2018). Fresh stems of Madhuca are used to eliminate foul smell in the mouth, hence used as toothbrushes (Lanjewar and Shukla

Table 4. Various Pharmacological properties of *Madhuca longifolia* Linn.

Sr. No	Activities	Plant Parts	Solvents	References
1.	Anti-hyperglycemic	Bark	Methanol	Dahake et al., 2010
		Leaves	Hydro-ethanol	Ghosh et al., 2009
2.	Anti-inflammatory	Bark	Ethanol	Jha, 2018
		Seed	Ethanol	Jha, 2018
		Overall plant	Acetone	Chakma, 2011
3.	Larvicidal and Ovicidal	Seed cakes	Aqueous	Verma et al., 2014; Lanjewar 1986
4.	Spasmolytic activity	Leaves	Crude Extract	Khare et al., 2018
		Seeds	Crude Extract	
5.	Insecticidal and Pesticidal activity	Seeds	Crude Extract	Khare et al., 2018
6.	Antimicrobial activity	flowers, leaves, stem and stem bark	Ethanol, Acetone, Water	Singh et al., 2018; Jagram, 2016
7.	Antibacterial	Bark,stem,flowers,leaves	Alcoholic	Khare et al., 2018
8.	Antifungal	Leaves, Flowers	Alcoholic	Kalaivani, 2013
9.	Analgesic	(Flowers, Leaves)	Methanol	Verma et al., 2014
10.	Hepatoprotective	Flowers	Methanol	Singh et al., 2017.
11.	Anti-oxidant	Bark	Ethanol	Verma et al., 2014
		Leaves	Ethanol	Khare, 2018
12.	Dermatological uses	Leaves	Ethanol	Khare et al., 2018
		Bark	Ethanol	
13.	Anti-convulsant/ Anti-epileptic	Bark	Methanol	Palani et al., 2010
		Leaves	Ethanol	
14.	Anti-cancer	Leaves	Ethanol	Jagram, 2016
15.	Anthelmintic	Flowers	Ethanol Methanol	Singh et al., 2017
16.	Anti-Ulcer	Flowers	Alcohol	Kalaivani, 2013.
		seed	Ethanol	Seshagiri et al., 2007
17.	Anti-tumor	Leaves	Acetone	Sangameswaran et al., 2012.
18.	Neuropharmacological Response	Leaves	Methanol	Ingankal, 2012

1986). Acetone and water extracts of the plant were reported to exhibit antibacterial activity to a better extent. The methanol extract of flowers, leaves, stem, and stem bark *of Madhuca longifolia* had been reported to have antimicrobial activity (Yadav et al., 2012). Acetone extract of *M.longifolia* exhibits significant anti-microbial activity (Chakma 2011). *Madhuca longifolia* was treated against two different bacteria namely Escherichia coli and Staphylococcus aureus and hence significant antimicrobial activity was reported by SEM analysis. Hence, the leaves of Madhuca also exhibit proficient antimicrobial activity (Subanithi and Swarnalatha, 2018; Singh et al., 2018; Jagram and Dhanraj, 2016).Hence, herbal medicines can be effectively used as antimicrobial agents by replacing them with synthetic ones (Karpagam and Manonmani, 2019).

Anti-bacterial activity

Dried bark of Mahua exhibited good antibacterial activity against some species such as E coli, B subtilis, Staphylococcus and Epidermidis with the help of Disc diffusion technique. The flower of Madhuca exhibit antibacterial activity against Escherichia coli and resists the disease of rice pests (Verma et al., 2014). Study showed that biological compounds like 2-Furan methanol, 4H pyran 4-one, 2,3-dihydro 3,5-dihydroxy-6-methyl, Thiophene, 2-Furancarboxyaldehyde-5-(hydroxymethyl), and 1,4-tetradecanediolwere responsible for antibacterial activity of alcoholic extracts of mahua leaves and flowers (Kalaivani and Jegadeesan, 2013). Silver nanoparticles synthesized using mahua flower extract showedpotential antibacterial activity against Gram-positive and Gram-negative pathogens (Maheshkumar et al., 2018).

Anti-fungal activity

Saponins were responsible to exhibit the anti-fungal activity against plant pathogenic fungi. The remnant seed cake is used for its anti-fungal property which was generally collected after defatting of mahua seeds (Khare et al., 2018). Antifungal activity of alcoholic extracts of leaves and flowers of *Madhuca longifolia* was reported due to the presence of biological compounds like 2-Furan methanol, 4H pyran 4-one, 2,3-dihydro 3,5-dihydroxy-6-methyl, Thiophene, 2-Furancarboxyaldehyde-5-(hydroxymethyl), and 1,4-tetradecanediol (Kalaivani and Jegadeesan, 2013).

Analgesic activity

Both aqueous and alcoholic extract obtained from flowers of *Madhuca longifolia* possess analgesic property (Singh et al., 2017).Analgesic activity is encountered by taking into consideration the reduced number of abdominal constrictions. A comparison was made between control mice and mice treated with methanolic extract of *Madhuca indica* and there was a positive effect, i.e. analgesic activity was reported. Anti-analgesia is a loss of sensation of pain and hence Madhuca plays a role as an analgesic agent too (Verma et al., 2014).

Hepatoprotective activity

It was shown by methanolic extracts obtained from flowers against hepatotoxicity induced by paracetamol (Singh et al., 2017). Significantly lowered serum levels of Glutamate Pyruvate Transaminase (SGPT), Serum Glutamate Oxaloacetate Transaminase (SGOT), Serum bilirubin, and Serum alkaline phosphate (SALP) were noted, hence exhibiting a protective effect. As a result, the methanolic extract of bark of *Madhuca indica* exhibits hepatoprotective property (Verma et al., 2014). Studies demonstrate the potential use of the ethanolic extract of *Madhuca longifolia* can be considered as a novel therapeutic agent useful for hepatoprotective and nephroprotective activity due to the presence of flavonoids and alkaloids (Palani, 2010). Hepatoprotective activity may have been reported due to stimulation of lipid peroxidation due to which destruction and damage to the cell membrane occurs. It also affects on cellular leakage which causes loss of functional integrity of the cell membrane in liver cells (Mishra, 2019; Roy et al., 2015).

Anti-pyretic effect

Pyrexia is defined as an elevation in body temperature beyond the normal range, *M.longifolia* is known for exhibiting febrifuge activity (Mishra, 2019). The anti-pyretic effect was observed in mice by measuring the rectal temperature in mice and hence also plays a major role in decreasing body temperature; hence Mahua can be used as an antipyretic agent (Chandra, 2001).

Anti-oxidant activity

Anti-oxidant activity depends on two mechanisms one is Prevention of oxidation by oxidizing itself and another is creating a protective layer over the material.

The ethanolic bark extract of Madhuca exhibits reducing property by donating a hydrogen atom. The presence of ample amounts of phenolic compounds makes it a significant reduction or an antioxidant. As phenolic compounds directly behave as anti-oxidants and show the presence of hydroxyl groups, they act das potent antioxidants (Verma et al., 2014). The methanolic extract of Mahua leaves exhibits anti-oxidant activity. The anti-oxidant activity was reported as a result of the presence of Madhucic acid (the active constituent in *Madhuca longifolia*). The anti-oxidant activity was observed by superoxide radical scavenging techniques, Hydroxyl radical scavenging activity, etc (Khare et al., 2018). Oxygen species which are active and free radicals play a major role in the development of various diseases. Hence, potent anti-oxidants can be used to cure several diseases by targeting the root cause. Reactive oxygen species (ROS) including

superoxide anions and hydroxyl radicals contribute to various degenerative diseases namely hypercholesterolemia, atherosclerosis, carcinogenesis, diabetes mellitus, ischemic reperfusion cardiac injury, and digestive system disorders which include hypersecretion and gastric mucosal damage (Chidrewar et al., 2010; Jose et al., 2018). Ethanolic, Methanolic and Aqueous leaf extract of *M.longifolia* showed potent antioxidant activity using different in-vitro assays and Pharmacological model study in wistar albino rats (Peter SJ et al, 2020).

Dermatological use

Synthetic lotions and creams these days are sufficient to accomplish every skin related issue rising these days, but also cannot be neglected as they have certain side effects including rashes, itching, etc. Taking into consideration the various demerits of synthetic lotions, plants can be considered to be reliable sources to substitute synthetic skin formulations. Allergic reactions on the skin can be effectively treated using seed oil of mahua. Itching and ulceration can be treated by using a decoction obtained from the bark of Madhuca (Verma et al., 2014). There was observed reduction in epithelisation time on the application of a methanolic extract of leaves and bark of *Madhuca longifolia* when applied topically and hence showed wound healing property, hence can be used topically to heal wounds (Khare et al., 2018). The juice of the flowers of Madhuca is used for oleation in cases of skin diseases (Singh et al., 2017).

Anti-convulsant / Anti-epileptic activity

Epilepsy is a chronic disorder that can be characterized by dysfunction of the brain and usually affects an individual's consciousness (Patel et al., 2011). The methanolic extract of bark & heartwood of mahua is noted to exhibit anticonvulsant activity. Results demonstrate that *Madhuca longifolia* comprises several biologically active constituents which may contribute to the anticonvulsant activity of *Madhuca longifolia*. Sedations and Drowsiness are also characteristic of methanolic extracts of leaves of *Madhuca longifolia* (Palani et al., 2010). *Madhuca longifolia* possesses specific biological constituents that function as anti-convulsant agents, hence acting as anti-epileptic (Patel et al., 2011; Thakare and Upasani, 2018).

Anti-cancer activity

Studies report that extracts obtained from leaves of *Madhuca longifolia* act as potent anti-cancer agents by reducing tumor volume, cell count in a tumor, tumor weight and enhances the average survival time. It has also been encountered to be effective against Ehrlich Ascites Carcinoma [EAC] in mice (Murthi et al., 2013). Local application of bark extracts of *Madhuca indica* exhibits anticancer activity (Fawzy et al., 2006). Hence, proves to be good to a moderate anti-cancer agent. Leaf extract of *Madhuca longifolia* act as a potent anticarcinogenic agent against breast cancer and are also assumed to exhibit chemopreventive activity. The results obtained from the in-vitro studies reveal that ethanolic extracts of seed and fruit of *M.longifolia* elicited considerable anti-cancer activity when HeLa (Human cervical adenocarcinoma) cell lines were used. Also, cytotoxicity levels were appreciably reported (Bhaumik et al., 2014). The leaves of *Madhuca longifolia* were experimentally studied and can be used in the treatment of mammary carcinoma by oral administration. Quercetin is one of the potent chemotherapeutic agent which is used in the treatment of breast cancer which is reported to be present in leaves of *Madhuca longifolia*, hence due to the presence of such bioactive phytoconstituent carcinoma can be treated, but has not been confirmed yet (Chinnadhurai and Otaibi, 2019). The bioactive phytoconstituents present in leaf extract of *M.longifolia* are responsible for the anti-cancer activity which include hamnetin-3-Glucoside-4′-Glucoside, Myricitrin, and Hirsutrin (Sarkar et al., 2018). There was reported no anti-cancer activity in liver cancer cells, on the other hand, maximum activity as anti-cancer was reported on colon cancer cells. The ethanolic extract of Mahua was seen to exhibit anti-cancer activity (Jagram and Dhanraj, 2016).

Anthelmintic activity

Ethanolic and methanolic extracts of flowers showed anthelmintic activity against Indian Earthworm, Pheretimaposthuma. Comparatively methanolic extract was encountered to be a more potent anthelmintic activity (Singh et al., 2017).

Anti-ulcer activity

Ethanolic extract has been reported to exhibit significant anti-ulcer activity (Singh et al., 2017). Results show that ethanolic extract was significant in protecting pylorusligation-induced gastric ulcers and was much effective (Yadav et al., 2012). Flavonoids also avoid the development of ulcers by enhancing microcirculation and increased capillary resistance. The methanolic extracts of *M. longifolia* were reported with both gastroprotective and healing ulcer pharmacological property in rats (Chidrewar et al., 2010; Mohod and Bodhankar, 2013). Also, the alcoholic extract of flowers of *Madhuca longifolia* exhibited an appreciable gastroprotective effect. The presence of secondary metabolites such as flavonoids (quercetin), alkaloids, tannins, saponin glycosides, and phenolic compounds could be responsible for a significant increase in the antiulcer activity of *Madhuca longifolia*. Flavonoids being the cytoprotective materials exhibit anti-ulcerogenic agent. The presence of flavonoids confirms *Madhuca longifolia* as a potent anti-ulcerogenic agent (Kalaivani and Jegadeesan, 2013).

Anti-tumor activity

Acetone extract of leaves of *Madhuca longifolia* possessed anti-tumor activity against Ehrlich Ascites Carcinoma (EAC) in mice (Sangameswaran et al., 2012).

Table 5. Marketed formulations of *Madhuca longifolia* (Khare et al., 2018; Mishra, 2019)

Name of the formulation	Dosage form	Cures
Madhukasava	liquid	Bleeding, Emaciation, Tiredness, Diseases of skin
Abhayarishta	liquid	Constipation, Piles
Chandanasava	liquid	Burning sensation, Burning micturition, Spermatorrhoea
NyagrodhadiChurna	powder	Diabetes, Urinary disorders
Lakshmanarishta	liquid	Gynecological disorders like:Heavy and irregular periods Metrorrhagia, Menorrhagia
PanchaSaarapanaka	liquid	Burning sensation, Burning micturition, Thirst
StanyajananaRasayana	powder	Enhances milk production, provides strength to lactating mothers
Kutajarishta	Liquid	Amoebiasis, Bacterial dysentery, Amoebic dysentery, Blood diarrhea

Neuropharmacological activity

Generally, the sedative activity of a drug can be measured by spontaneous motor activity. Research studies illustrate that the methanolic extract of leaves of Madhuca induce sedation and lead to drowsiness. Hence, CNS depressant action was reported and the neuropharmacological response was recorded (Ingankal and Swamy, 2012).

All Pharmacological activities of *Madhuca longifolia* with respective plant parts were mentioned in table 4.

Marketed formulations

The Ayurvedic Pharmacopoeia of India has suggested many therapeutic formulations of *madhuca longifolia Linn.* These are Svasa, Daha, Ksaya, Trsna, Srama. Following are the formulations available in market as shown in table 5.

Conclusion and future perspective

Medicinal plants are the local heritage with global importance. *Madhuca longifolia* is one of those multipurpose forest tree species that provide food, fodder, and fuel along with medicinal properties. Hence more focus should be given on the commercial cultivation of *Madhuca longifolia* in the future. Also, investigating more and more bioactive ingredients that are responsible to treat various diseases and their safety and efficacy testing with proper validation is the need for the current international pharma market.

In this review, we have discussed traditional uses, morphology, geographical source, collection and cultivation, phytoconstituents of *Madhuca longifolia* along with various pharmacological activities which will help to explore the mahua plant further and also to expand the existing therapeutic potential of *Madhuca longifolia*. This will provide convincing support to its future pharmacotherapeutic use in a clinical set-up.

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