

# Exploring the role of Mahua as a functional food and its future perspectives

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## 7.1 Introduction

### 7.1.1 Nontimber forest products

In a variety of ways, forests and trees contribute to the livelihood of rural families. Forests are the main source of non-timber forest products (NTFPs) for well-being, domestic consumption, and earnings for people living in rural areas. Though NTFPs play a significant role in employment for rural people, they habitually put their hopes on potential gains generated from the marketing of NTFPs for poverty mitigation and maintenance of the natural resource base. Moreover, the NTFPs have directly influenced the economic status of the rural people (Kumar & Meena, 2018). Harvesting NTFPs can provide a safety net or green social security to billions of poor in the form of low-cost building materials, income, fuel, food supplements, and traditional medicines. Out of 20% of NTFPs, only 0.8% have been commercially utilized (Maithani, 1994). NTFP deeds hold expectations for integrated forms of growth that yield higher rural income and conserve biodiversity without competing with agriculture (Sharma, 1992). *Madhuca indica* commonly known as Mahua is an important nontimber forest product (NTFP) that is mostly found in Central and Eastern India, and it is directly linked with the tribal economic status in different ways. Although all parts of the mahua tree are used, mainly mahua seeds and flowers are collected by the tribes for self-consumption and for sale to raise money to maintain their daily life. Mahua is contributing to the economic status of the tribal society. There is a clear linkage between various socioeconomic factors that affect the level of dependency of mahua in the tribal society (Nayak & Sahoo, 2020).

### 7.1.2 Botanical description

Taxonomical classification:

Kingdom Plantae,  
Division Magnoliophyta,  
Class Magnoliopsida,  
Order Ericales,  
Family Sapotaceae,  
Genus *Madhuca*,  
Species *Longifolia*.

Mahua trees are distributed in different parts of India as well as Asian countries like Philippines, Pakistan, Sri Lanka to Australia. In central India, it is found near the river banks and in the semi-evergreen forests. Mahua trees are abundantly found in different states of India like Uttar Pradesh, Madhya Pradesh, Odisha, Jharkhand, Chhattisgarh, Andhra Pradesh, Maharashtra, Bihar, West Bengal, Karnataka, Gujarat, Rajasthan. The annual production of mahua

flowers is 45,000 million tonnes. The yield of every tree varies from 83 to 320 kg every year (Pinakin et al., 2018). Patel et al. (2012) studied that mahua is a medium-sized to large deciduous tree, usually with a short and large rounded crown found all over the green forest part of India up to an altitude of 1200 m, and the height of the tree is 12–15 m. The bark is a dark brown color and is slightly cracked. The size of the leaves is 10–30 cm and is thick and leathery. According to Bisht et al. (2018), most of the leaves are pointed at the tip, clustrescent glabred near the end of branches, epileptic or elliptic-oblong 7.5–23 cm. Flowers are small and fleshy, dull or pale white and define fascicles near the end of branches. The corolla of the flowers are tubular, freshly pale, yellow aromatic and caduceus. Fruits are 2–6 cm long, fleshy, and greenish (Jha & Mazumder, 2018).

### 7.1.3 Microscopy of mahua

The microscopic study was observed by Yadav et al. (2011) which shows that the seeds are dark brown, and the number varies from 1 to 4. The stem is cylindrical, decumbent, and branched. The fruits are fleshy, green, and ovoid type. The flowers are abundant in number and present at the ends of the branches, drooping on the pedicles. Corollas are yellowish-white whereas the tubes are fleshy. Stamens vary from 20 to 30 in number, and the anthers are hispid at the back with stiff hair. The petiole is short. The leaves are clustered at the end of the branches. Leaves and petiole are pubescent or tomentose. Leaves are coriaceous, elliptic or oblong-elliptic, shortly acuminate, and base cuneate.

### 7.1.4 Uses of different parts of mahua

#### 7.1.4.1 Flowers

Liquor is produced from corolla as it is a rich source of fermentable sugar. Per tonne of dry mahua flower gives 80–217 L of ethyl alcohol (Vimal & Tyagi, 1984). Anonymous (1962) stated that flowers can be used for the distillation of country liquor.

#### 7.1.4.2 Fruits

They can be either eaten raw or cooked. At the ripening stage, fruits are rich in starch which converts to sugar after 2–3 days of plucking (Anonymous, 1962).

#### 7.1.4.3 Seeds

An average mahua tree yields 100 kg of seeds per year. The seed kernels contain aspartic, glutamic, glycine, serine, proline, and alanine. The seed coat contains 2% of quercetin and dihydroquercetin with some tannins and thioglucosides (Banerji & Mitra, 1996).

#### 7.1.4.4 Mahua oil

It can be used washing soaps, manufacturing candles, lubricants, bathing oil, production of steric acid, etc. (Douli et al. 1968a, 1968b).

#### 7.1.4.5 Cake

Mahua-deoiled cake contains carbohydrates, proteins, and ash. Due to its toxic effects, it cannot be used as cattle feed, but when it is detoxified it can be given to cattle (Mitra & Misra, 1967). They are also used as wormicide and fish poison but do not decompose and nitrify in soil (Misra & Mitra, 1968). The consumption of mahua seed cake causes hemolysis due to the presence of saponin (Birk, 1969). Saponin was removed by the use of different solvents like water, ethanol, isopropanol. Detoxification was done with minimal loss of protein and carbohydrates (Sen Gupta, 1980).

## 7.2 Traditional uses

For many years, there are a lot of traditional uses for each and every part of the mahua tree. Mahua plays a vital role in the treatment and prevention of many diseases. Different parts of the tree are used to treat different types of diseases. According to Patel et al. (2012), in Ayurveda mahua flower is used as a cooling agent, acute chronic tonsillitis, pharyngitis, ulcer, and bronchitis. The flowers are used as a tonic, analgesic, and diuretic. Jha and Mazumder (2018)

clearly mentioned that the flowers have shown some activity against swelling, itching, and fractures. According to Bisht et al. (2018), bark juice is orally taken for the treatment of diarrhea, and it is also used in the treatment of chronic tonsillitis, leprosy, and fever. Sometimes the bark is used to cure rheumatism, bronchitis, and diabetes. Patel et al. (2012) cited that besides all these properties bark is a good therapy used to cure bleeding and spongy gum. Verma et al. (2014) discussed that the leaves of mahua play a significant role in the treatment of chronic bronchitis and Cushing's disease. The leaves also show several activities like wound healing, hepatoprotective, antioxidant, antimicrobial, verminosis, gastropathy, dipsia, bronchitis, dermatopathy, rheumatism, cephalgia, and hemorrhoids. Pinakin et al. (2018) quote that the fat gained from mahua seeds has many therapeutic claims such as emulscent property, used in skin infection, rheumatism, headache, laxative, piles, and sometimes as galactagogue.

According to Bisht et al. (2018), traditionally mahua is utilized in food production.

- Due to the presence of a high amount of sugar, mahua is used as a sweetener in the preparation of many food items.
- Sundried flowers are boiled with tamarind, and sal seeds and are consumed by the poor tribal people.
- Flowers that are left after fermentation and distillation are used as cattle feed to improve the health status of the cattle.
- Fermented flowers are used for the preparation of country liquor having an alcohol amount of 30%–40%.
- The seed oil is used as cooking oil.

## 7.3 Nutritional and phytochemical profiling

### 7.3.1 Nutritional analysis of mahua

- *Sugars*: The sugar contents of mahua flowers are dextrose, levulose, maltose, sucrose, etc. According to Fowler et al. (1920), when the flower is ready to fall it has high sugar content. In the flower, the amount of levulose is greater than dextrose. In the storage period, the amount of sucrose decreases, but in the shedding stage of corolla the amount of sucrose is high. Sutaria & Magar (1955a, 1955b, 1955c) have done a paper chromatographic experiment of unhydrolyzed mahua extract which revealed the presence of maltose, sucrose, arabinose, fructose, and rhamnose, but the hydrolyzed extract revealed the presence of galacturonic acid.
- *Polysaccharide*: The water-soluble polysaccharides were extracted and gel-filtered to obtain a homogeneous fraction. D-galactose, L-arabinose, L-rhamnose, D-xylose, and D-glutaric acid were found in the first fractionation. The second fractionation was done by Sarkar & Chatterjee (1984), and they reported the presence of D-glucose, L-arabinose, and D-glucuronic acid.
- *Protein and amino acid*: The nitrogen content of the underdeveloped flower is higher than the fully developed flower, that is, 0.65%–1.1%. The protein content of the flower fluctuates from 4.4% to 7% (Belavady & Balasubramanian, 1959; Jayasree et al., 1998). Sutaria & Magar (1955a) reported the presence of eleven amino acids like lysine, arginine, aspartic acid, glutamic acid, threonine, valine, tryptophan, phenylalanine, isoleucine, leucine, and proline. Jayasree et al. (1998) discussed that the protein content of mahua flower was superior when compared with groundnut protein.
- *Fat and fatty acid*: The fat content of mahua flower is very low. As reported by Jayasree et al. (1998) and Sutaria & Magar (1955a, 1955b, 1955c) the fat content differs from 0.09% to 1.3%. Sutaria & Magar (1955a) stated that mahua flowers contain linoleic, oleic, palmitic, and stearic acid.
- *Vitamins*: Different researchers have evaluated different vitamin contents of fresh mahua flowers. Ascorbic acid content varies from 36.99 to 7 mg. Thiamine content is 140.3 µg (Sutaria & Magar, 1955b). Riboflavin is found to be 878 µg (Belavady & Balasubramanian, 1959). Niacin was found to be 5.2 mg (Belavady & Balasubramanian, 1959), and folic acid content is 214 µg (Sutaria & Magar, 1955b).
- *Minerals*: Different minerals have been reported in mahua flowers such as Ca, P, Fe, Mg, Na, and K. Out of these, Na is 25.27 mg/100 g, K is 1.2 mg/100 g, and Zn is 0.926 mg/100 g (Sutaria & Magar, 1955a).
- *Enzymes*: Fowler et al. (1920) detected enzymes in different developmental stages of the flowers such as amylase, maltase, invertase, catalase, and oxidase.
- *Saponins*: It can be termed as an anti-nutritional factor, but it has both positive and negative consequences. In the positive aspects, it helps in lowering the serum cholesterol level in humans. On the negative side, it hinders the productive performance of nonruminants. They also show the toxic effect that leads to death in the rats (Goodhart & Sahil, 1980; Mulky & Gandhi, 1977).

**TABLE 7.1** Phytochemical screening of mahua flower extract.

Sl. no	Phytoconstituents	Tests	Ethanollic extract	Methanolic extract	References
01	Proteins	Biuret test	+ve	–ve	Mishra & Usha (2019), Patel et al. (2019)
02	Carbohydrates	Molisch's test	+ve	+ve	
03	Amino acids	Ninhydrin test	–ve	–ve	
04	Volatile oil	Sudan test	–ve	–ve	
05	Alkaloids	Tannic acid test	+ve	+ve	
06	Flavonoids	Alkaline reagent test	–ve	–ve	
07	Tannins	Lactic acid test	+ve	+ve	

### 7.3.2 Comparative nutritional profile

As per the report of [Gopalan et al. \(2004\)](#) and [Jayasree et al. \(1998\)](#), the amount of protein content of dry mahua flower was 6.67% which is much higher when compared with other common fruits like apple, banana, mango, and raisins. Likewise, it has a lower amount of fat, that is, 0.09%. Carbohydrate content of fresh mahua flower is 68%. Calcium content is found to be 139%. From the different reviewers, it can be said that fresh and dry mahua flowers are having all the essential nutritional compounds.

### 7.3.3 Effect of geographical distribution on the flower composition

According to [Elworthy \(1887\)](#), there is an effect of climatic changes on the sugar composition of mahua flowers. The flowers were collected from Hyderabad, Jabalpur, Gujarat, and Mirzapur. The cane sugar % was found to be maximum, that is, 17.1% in the flower collected from Hyderabad. The inverted sugar % of the flowers collected from Gujarat was 45.3%. Dextrose % of the flowers collected from Mirzapur was 43.6%, whereas the total sugar % of the flowers from Hyderabad was 57.1%. According to [Roy & Rao \(1959\)](#), flowers collected from the Mandla district of Madhya Pradesh were found to contain reducing sugar (57.3%), nonreducing sugar (9.4%), starch (3.6%), protein (6.8%), ash (4.5%), and other components (18.4%), respectively.

Phytochemical screening of mahua plant extract was studied by different researchers who have studied the presence or absence of different phytoconstituents. The detailed study of phytochemical screening of mahua flower extract is depicted in [Table 7.1](#).

Phytochemical profiling of different parts of mahua plant was done. In [Table 7.2](#), reviewers have found the presence of various chemical constituents which were also responsible for different biological activities.

GC-MS analysis of seed, leaf, bark, and flower was done by [Ranjana et al. \(2018\)](#). Certain important phytochemicals were found such as hexylcyclohexane, octylcyclohexane, E-14-hexdecenal, pentadecan-8-one, 8-octadecanone, dibutyl phthalate. [Annalakshmi et al. \(2013\)](#) did the GC-MS and HPTLC analysis of leaf extract of mahua, and they found that there were several known and unknown bioactive compounds present which were mainly responsible for the treatment of different diseases.

## 7.4 Pharmaceutical uses and pharmacological importance

### 7.4.1 Industrial uses

[Patel et al. \(2019\)](#) observed a lot of traditional utilization of mahua tree. Mahua can be used industrially which can upgrade the economic status of the country. Flowers that are used for the preparation of country liquor can be fermented to obtain spirits, ethanol, acetone, lactic acids, vinegar, etc. Soon after the alcohol production, the remaining pulp and other ingredients are used for the production of biofertilizer. According to [Mishra & Poonia \(2019\)](#), mahua biofertilizer can be said as a good fertilizer as there is a presence of nitrogen, phosphorus, and potassium along with calcium. After the removal of oil from the seed, the seed cake may be used for cattle feed ([Ramadan et al., 2016](#)). Many researchers

**TABLE 7.2** Phytochemical profiling of mahua.

Sl. no	Plant part	Chemical constituents	References
01	Leaves	D-glucoside, stigmasterol, $\beta$ -carotene, xanthophylls, erythrodiol, palmitic acid, myricetin, 3-O-arabinoside, 3-O-L-rhamnoside, quercetin, 3-galactoside; 3 $\beta$ -caproxy and 3 $\beta$ -palmitoxy-olean-12-en-28-ol, oleanolic acid, $\beta$ -sitosterol, 3-O- $\beta$ -D-glucoside, 3 $\beta$ -caproxyolcan-12-en-28-ol, $\beta$ -carotene, n-octacosanol, sitosterol, quercetin, $\beta$ -sitosterol- $\beta$ -D-glucoside, n-hexacosanol. 3-O-arabinoside, xanthophylls, 3-O-L-rhamnoside, n-octacosanol, 3 $\beta$ -caproxyolcan-12-en-28-ol, $\beta$ -sitosterol and 3-O- $\beta$ -D-glucoside and sitosterol	Verma et al. (2014), Khare et al. (2018), Mishra & Pradhan (2013)
02	Seeds	Myristic, palmitic, and stearic acids, $\alpha$ -alanine, aspartic acid, cystine, glycine, isoleucine and leucine, lysine, methionine, proline, serine, threonine, myricetin, quercetin, Mi-saponin A, saponin B, arachidic, linolenic, oleic, quercetin	Verma et al. (2014), Khare et al. (2018), Mishra & Pradhan (2013)
03	Fruits	n-Hexacosanol quercetin and dihydroquercetin, $\beta$ -sitosterol and its 3 $\beta$ -D-glucoside, $\alpha$ - and $\beta$ -amyrin acetates	Verma et al. (2014), Mishra & Pradhan (2013)
04	Flower	Vitamins A and C	Verma et al. (2014)
05	Bark	$\alpha$ - and $\beta$ -Amyrin acetates, 3 $\beta$ -monocaprylic ester of erythrodiol and 3 $\beta$ -capryloxy oleanolic acid, ethylcinnamate, $\alpha$ -terpineol, and sesquiterpene alcohol	Khare et al. (2018), Mishra & Pradhan (2013)
06	Nut-shell	n-Hexacosanol quercetin and dihydroquercetin, $\beta$ -sitosterol and its 3 $\beta$ -D-glucoside	Mishra & Pradhan (2013)

and reviews suggest that mahua flowers and mahua-deoiled cake can be used as cattle feed to provide proper nutrition to the cattle at an affordable rate. A cream formulated from mahua oil is nontoxic, less expensive, and biodegradable. So it could be used as an effective emulsifier for formulating cream (Mahajan et al., 2017). Because of lots of uses, mahua is giving employment and opportunity to the tribal people. They collect every part of the mahua tree and sell it in the local market, and in return they get money. But the amount is not sufficient for survival. Some government schemes should be provided for all such people who are completely dependent on mahua for their livelihood.

#### 7.4.2 Biodiesel

Ghadge & Raheman (2006) optimized the biodiesel production using a surface methodology. The surface methodology process gave a yield of 98% mahua biodiesel that satisfies the properties of both American and European standards of biodiesel. Puhan et al. (2005) stated that mahua can be used as a source of renewable energy in India. They observed that in mahua oil methyl ester has lower emission compared with other esters. Raheman & Ghadge (2007) observed that the blend of mahua oil with high-speed diesel can be used as an alternative fuel that causes low pollution. Due to the increase in the price of oil, mahua oil can be used as a lubricant for maintenance purposes. Apart from the environmental benefits, Suhane et al. (2013) experimentally revealed that the addition of mahua oil with 90T oil showed good wear-riding traits. Goud et al. (2006) developed epoxides by using hydrogen peroxides using mahua oil. (Kapilan & Reddy, 2008) concluded that an engine ran effortlessly with methyl ester of mahua oil and B20, but there was a heavy emission when only mahua oil was used as a fuel.

#### 7.4.3 Biological activity

- **Therapeutic property:** Mishra & Usha (2019) reported that from ages mahua has a lot of therapeutic potentials. Different parts of the plants have different therapeutic and pharmacological uses. Decoction of mahua flowers is used to quench the thirst. It is used as a cooling agent, and it is also used to treat tonsillitis, bronchitis, and inflammation. It has astringent properties so sometimes it is used in the treatment of piles, diarrhea, and colitis. The flowers are used to treat eczema, skin diseases, eye diseases, and arrest bleeding. It is also used to treat burning sensations, heart diseases, and ear complaints. The flower extract is used to increase the quantity of seminal fluids.

- **Anti-inflammatory activity:** The inflammation is caused due to the release of several chemicals like histamine and serotonin from the damaged cell. Inflammation is a self-protective mechanism of the body (Yadav et al., 2012). The vital mechanism of the anti-inflammatory drugs is reflected due to the inhibition of PG synthesis at the site of injury. According to Gaikwad et al. (2009), the potential of anti-inflammatory drugs is measured by their effectiveness to prevent COX. The anti-inflammatory activity is directly proportional to the inhibition of COX. The aerial parts of the *M. indica* are used in the action of inflammation. The aerial part was extracted by using Soxhlet apparatus. The extract was concentrated under vacuum-sounding apparatus for 30 minutes. The result was satisfactory when the solution was given to male Wistar rat.
- **Analgesic activity:** Pain killer can also be used for the word analgesic. Analgesic are the group of drugs that are used to give relief from pain without disturbing the consciousness. *Madhuca longifolia* exhibited the analgesic effect from both methanolic and ethanolic extracts. The activity was assessed on acetic acid writhing. Six animals were orally given the methanolic extract of *M. longifolia*. The number of writhing during the subsequent 30 minutes was witnessed after acetic acid injection (Verma et al., 2014). Anti-analgesia is expressed as the decrease in the number of abdominal constrictions between control animal and mice pretreated with the extract. The analgesic effect was also screened through the tail flick, hot plate, and chemical graded doses of both aqueous and alcoholic extract of *M. longifolia* (4.0–64.0 mg/kg, *i.m.* for 3 days) produced a dose-dependent analgesic effect in all the three nociceptive methods carried out either in rats or mice (Patel et al., 2012).
- **Antipyretic activity:** Antipyretic can be defined as a term that works against fever. The prostaglandin is responsible for fever, and the antipyretics causes the hypothalamus to override the prostaglandins which results in a reduction in fever (Khare et al., 2018). In animal experiments, the mahua extract was found to reduce fever (Patel et al., 2019).
- **Antihyperglycemic activity:** The important hypoglycemic effects of *Mahua* bark in diabetic rats specify that this effect can be facilitated by stimulation of glucose consumption by peripheral tissues. The consequences of the study specified the ethanolic extract of *Mahua* bark to have a hypoglycemic effect on STZ-induced diabetic rats. In all groups except for glibenclamide, at 30 minutes of initiating the glucose tolerance test, blood glucose concentration was higher than at zero time but decreased significantly from 30 to 120 minutes (Yadav et al., 2012). Methanolic extracts were improving glucose operation; thus the blood glucose level was expressively reduced in glucose-loaded rats. Methanolic extract of *Madhuca* has considerably reduced the serum glucose level in streptozotocin and STZ-NIC-induced diabetic rats. According to Patel et al. (2012), the crude methanolic extract of *Mahua* leaves confirmed dose-dependent reductions in serum glucose level succeeding administration in glucose-loaded mice. The serum glucose levels were found to be considerably reduced at doses of 100, 250, and 500 mg extract per kg body weight.
- **Antiulcer activity:** Ulcer is considered as a common complaint of gastrointestinal tract (Patel et al., 2019). Due to the imbalance in the defensive and attacking factor of GIT, there is a result in ulcer. The alcoholic extract of mahua flower is used to study the antiulcer activity. The experiment was conducted with the help of Wistar rats by pylorus ligation method, and the standard drug used was ranitidine. The alcoholic extract of mahua and the standard drug were given simultaneously 2 days before pylorus ligation, and the gastric juice was measured. The increase in the amount of gastric juice could be due to the inhibition of histamine which exaggerates acid release (Mohod & Bodhankar, 2013).
- **Antioxidant activity:** Free radicals are the cause of various diseases such as aging, cancer, heart disease, etc. Generally, antioxidants protect our cells from free radicals (Verma et al., 2013). Higher the phenolic content, more the antioxidant activity because the phenol groups donate the hydrogen atom. The antioxidant power of a drug depends upon two mechanisms, first to prevent oxidation by oxidizing itself or second by generating a layer of protection over the material. The methanolic bark extract of mahua showed antioxidant activity, that is, capable of donating hydrogen atoms (Khare et al., 2018).
- **Antifertility activity:** Some studies revealed that mahua has antifertility activity. The term antifertility means a substance that inhibits the ability to produce offspring (Verma et al., 2014). Male and female mice were taken for the study, and the study revealed that the percentage of fertility in the case of males and females has decreased in atropine-induced mice. It decreases the sperm count and reduced the spermatozoa density (Patel et al., 2012).
- **Dermatological activity:** As the condition of the environment is changing, there are a lot of skin-related problems people are facing in their daily life (Verma et al., 2014). There are several marketed cosmetic products which sometimes cause skin irritation, itching, etc. Mahua seed oil could be used as an alternative for the treatment of various skin-related problems. Traditionally, the tribes of many states use the mahua oil as a lotion (Patel et al., 2019).
- **Hepatoprotective activity:** To study the hepatoprotective activity, the albino rats were injected with  $\text{CCl}_4$  or carbon tetrachloride. Mahua methanolic extract has shown hepatoprotective activity (dose-dependent 300 mg/kg body weight) (Patel et al., 2019). The methanolic extract was proved to be effective against lowering the serum level of serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), serum alkaline phosphate (ALKP), and total bilirubin. It has also increased the level of total proteins and albumin (Yadav et al., 2012).

- **Antibacterial activity:** According to Khare et al. (2018), the flower extract shows antibacterial activity against *Escherichia coli* and has the ability to resist rice pest disease. By disk diffusion method, the methanolic extract of dried bark shows a significant effect against *Bacillus subtilis*, *Staphylococcus aureus*, *Staphylococcus*, *E. coli*. Patel et al. (2019) also informed that the ethanolic extract showed to be having good antibacterial activity. For the treatment of diarrhea, the methanolic extract of mahua flowers showed effective results against *S. aureus*, *Salmonella typhi*, *Bacillus pumilus*, *Proteus vulgaris*, *E. coli*, *B. subtilis*, *Candida albicans*, *Pseudomonas aeruginosa*, and *Micrococcus luteus*. The methanolic extract of mahua was used to study the antimicrobial study by disk diffusion method in which three fungal strains and three bacterial strains were taken, that is, *E. coli*, *Pseudomonas*, *S. aureus*, *Aspergillus niger*, *Penicillium* spp., *Scytalidium* spp. All of them showed positive results (Patel et al., 2012).
- **Antiepileptic activity:** Verma et al. (2014) and Patel et al. (2012) revealed that *M. longifolia* retains significant anti-epileptic activity as it amplified the onset time of seizure and reduces the period of seizures. The methanolic extract of mahua has shown antiepileptic activity. The mouse was induced with pentylenetetrazol-induced seizures (PTZ), and diazepam has been used as a standard drug. The researchers have successfully studied the involvement of benzodiazepine and opioid receptor.
- **Antinociceptive and antidiarrheal activity:** Khare et al. (2018) and Patel et al. (2019) studied that diclofenac sodium was used as a standard drug for the comparison of the response. The mice showed antinociceptive and antidiarrheal activity in the alcoholic extract of the bark. Mahua bark extract showed to be effective in monitoring the writhing reflex induced by acetic acid at a dose of 250 and 500 mg/kg of body weight by oral route.
- **Anthelmintic activity:** Mahua plant has numerous phytochemical constituents in it. It contains protein, starch, phenols, flavonoids, tannins, terpenoids, and many more (Khare et al., 2018). The study was done by in vivo method, and *Pheretima posthuma* (adult Indian earthworm) was used in the study. Metronidazole was used as a standard drug. The alcoholic and hydroalcoholic extract has shown anthelmintic activity due to the presence of tannins and other phytochemical constituents (Patel et al., 2019).
- **Immunomodulatory activity:** The alcoholic extract of mahua showed significantly good immunomodulatory activity. Cyclophosphamide-induced myelosuppression in mice was tested. The mahua extract improved the DTH response and antibody titer value and also triggered the renovation of total leukocyte count (TLC) and differential leukocyte count (DLC) (Khare et al., 2018).
- **Larvicidal and ovicidal activity:** Not only the mahua oil but also the mahua seed cake have shown larvicidal and ovicidal activity against *Meloidogyne incognita*, and they were also effective against larval growth from the egg sacs of cyst nematodes (Khare et al., 2018).
- **Antidiabetic activity:** Yadav et al. (2012) reviewed that the alcoholic extract of mahua leaf and bark was used for the study of the antidiabetic property. The albino Wistar rat was induced by streptozotocin, and after 30 days, it was compared with insulin-treated rat. The experiment showed a decrease in blood sugar level.
- **Spasmolytic activity:** Saponin is responsible for the spasmolytic activity in the alcoholic extract of mahua. The saponins extracted from mahua leaves influenced a major spasmolytic activity. The saponins existing in the leaves, and seeds of *M. longifolia* possessed spasmolytic property on isolated guinea pig ileum (Patel et al., 2019).
- **Spermicidal activity:** Khare et al. (2018) studied the steroid and triterpenoid saponins existing in *M. longifolia* seeds which influenced clear spermicidal activity.
- **Insecticidal and pesticidal activity:** Mahua cake influenced an important insecticidal and pesticidal action against phytonematode. Mahua has shown pesticidal activity against *Tetranychus urticae* (Khare et al., 2018).
- **Wound-healing activity:** According to Yadav et al. (2012) and Jha and Mazumder (2018), methanolic extract of mahua bark was used to treat the wound of the mice. Betadine was used as a standard drug. Mahua extract-treated animals showed a substantial decrease in wound area and period of epithelization. Mahua extract showed a faster wound-healing activity than the standard drug.
- **Nephroprotective activity:** Against acetaminophen-induced nephrotoxicity, the alcoholic extract of mahua possesses nephroprotective activity. There was an increase in the levels of serum urea, hemoglobin (Hb), total leukocyte count, creatinine, filled cell volume, DLC, mean corpuscular volume, and upraised body weight sideways with condensed levels of neutrophils, mean corpuscular Hb content, mean corpuscular hematocrit, granulocytes, uric acid, and platelet concentrations (Khare et al., 2018; Patel et al., 2019).
- **Neuropharmacological activity:** For the study of neuropharmacological activity, tramadol hydrochloride, diazepam, and chlorpromazine were used as a standard drug against Swiss albino male mice. The activity was measured via phenobarbitone sodium-induced sleep and their antagonistic regaining righting effects by mahua extract. Actophotometer was used for spontaneous motor activity. There was a decrease in sleeping time and a reduction in spontaneous motor activity with the use of actophotometer (Patel et al., 2019).

- *Rheumatic arthritis*: Patel et al. (2019) considered that arthritis can also be called as an inflammatory disorder which is usually caused by a lack of synovial fluid. Lack of synovial fluid can cause loss of lubrication which in turn may cause severe pain in the joints. Mahua oil was used for the action of rheumatic arthritis.
- *Anticancer activity*: According to Yadav et al. (2012), the cytotoxic activity against Ehrlich ascites carcinoma cell lines using different in vitro cytotoxic assays at 200 µg/mL was shown by the alcoholic extract of mahua leaves. Patel et al. (2012) found that both extracts revealed important cytotoxic action, but greater cytotoxic activity was found in ethanol extract.
- *Toxicity*: A combination of saponins from *M. longifolia* seed did not disclose any cholinergic action, though it was shaped at an advanced concentration (Patel et al., 2019). The saponin is tremendously toxic after it has been induced parentally, and LD<sub>50</sub> by the IV route was found to be 50–70 times higher than the oral route. In the root of *M. indica*, the extreme quantity of phenol was detected, that is, 46.0 mg/g dry weight. These complexes showed an important part in the precursor of toxic constituents. Patel et al. (2012) also described having toxic biochemical such as aflatoxine in *M. indica* seed oil. Rajgor et al. (1986) took 24 albino rats and fed them with ordinary boiled and pressure-cooked mahua flowers which showed that there was no change in food intake. But the organ weight was significantly lower in the ordinary-fed group compared to the pressure cooker fed. Bora & Singh (1994) observed the feeding of dried mahua as a substitute for maize. They concluded that dried flowers can be incorporated into the gill ration as a substitute for maize. Kotwal (2000) studied the feeding diet of processed (without saponin) and unprocessed (with saponin) mahua syrup on the biochemical and histopathological status of albino rats. According to the findings, the unprocessed syrup showed some desirable changes in the parameters, but the processed syrup does not show any changes.

## 7.5 Mahua as a functional food

### 7.5.1 Processing of flowers

#### 7.5.1.1 Collection of flowers

The primary collectors or usually the tribal families collect the fresh flowers in the early morning (Mishra & Poonia, 2019). A bamboo stick is used to pluck the flowers from the trees. Before the collection of flowers, the ground is cleaned, and the floor is cleared from leaves and grass (Bakhara et al., 2016; Chandel et al., 2018). The time required for the collection of flowers may vary because the mahua flowers are collected manually from the ground.

#### 7.5.1.2 Preprocessing

The flowers are preprocessed to increase their shelf life (Mishra & Poonia, 2019). The preprocessing methods include washing, stamen removal, and blanching with preservatives. Sometimes, the stamen is removed manually or mechanically. To reduce the rate of spoilage, the flowers are free from moisture which includes shed drying, sun drying, and tray drying (Kumari et al., 2018).

#### 7.5.1.3 Drying

Before drying pretreatment was given to the mahua flower with 4.1 minutes of blanching, 1285 ppm KMS, and 0.77% citric acid concentration (Pinakin et al., 2018). The tribals used to dry the flowers by spreading them in a clean dry place for 3–4 days under the sun (Chandel et al., 2018). After the flowers are completely dried, the stamen is detached from the flowers manually. Stamen removal is necessary because it gives a bitter taste which is mostly disliked by the customers (Bakhara et al., 2016).

**Storage:** The dried flowers are stored in dark rooms packed in gunny bags. But the flowers absorb moisture easily from the earthen floor or roof which is more prone to bacterial and fungal spoilage (Bakhara et al., 2016; Mishra & Poonia, 2019).

#### 7.5.1.4 Postharvest spoilage of flowers

Due to the lack of storage facility, about 30% of the flowers get spoiled. Fresh flowers are highly nutritious and have high moisture content which leads to bacterial and fungal spoilage (Behera & Swain, 2013). The bacteria that involve in the spoilage are *Bacillus*, *Micrococcus*, *Siderococcus*, *Nocardia*, and *Pseudomonas*, and the fungi that are involved in the spoilage include *A. niger*, *Aspergillus flavus*, *Penicillium*, and *Rhizopus* (Mishra & Poonia, 2019). Due to bacterial and fungal spoilage, the amount of sugar and ascorbic acid decreases. Certain insects and larvae are also involved

in the spoilage of the flowers which belong to the family of Noctuidae, Anthocoridae, Cucujidae, Bostrychidae, Tephritidae, and Formicidae (Behera & Swain, 2013).

### 7.5.1.5 Methods of preservation

Since mahua is a multipurpose tree having high moisture content and is rich in nutritional compounds, it is more likely to have spoilage. One of the spoilage is caused by *Fusarium solani* (Verma et al., 2014).

The spoilage of the flowers is mainly due to its high moisture content, lack of storage facilities, and inadequate knowledge of further processing.

- Moisture content of the flowers can be reduced by the use of modern machinery such as oven drying, hot air drying, tray drying, solar drying, cabinet drying, etc. Reduction in moisture content is an unfavorable environment for the growth of microorganisms. Humectants are used to keep moisture away from the flowers.
- To check the spoilage, the flowers are treated with UV and certain antibiotics. The flowers should be kept in a controlled atmosphere. Government warehouses should be built-in tribal areas so that the poor can avail the facilities and can keep their raw materials in a good condition.
- Das et al. (2010) found that the proper use of liquid nitrogen to powder the flowers can lead to a decrease in spoilage, and deep-freeze flowers are found to be less prone to microbial growth.

## 7.5.2 Value-added food products

Sugar syrup is the oldest food product that is prepared by researchers. Sugar syrup was prepared by Abhyankar & Narayana (1942) in which they found that there is 75%–87% of reducing sugar present in the flowers. In the process of preparing the sugar syrup, they extracted 90% of the sugar with hot water. The syrup was clarified with the addition of slacked lime followed by superphosphate. The syrup was passed through activated charcoal and evaporated to a consistency of 70–75° Brix.

Shrivastava et al. (1970) extracted the sugar syrup in two different ways. The first method includes the extraction process directly from fresh water, and the second method was the extraction done from the previous extraction. The second method was more effective and economical that takes less time.

Chand & Mahaptra (1983) prepared the sugar syrup from dried mahua flowers. The syrup was first clarified using lime, and pH was maintained by adding citric acid solution. The addition of 50 ppm of metabisulphite to the syrup has increased the shelf life.

Since mahua is rich in sugar, it has the potential for making good-quality fermented products. Soni & Dey (2013) observed that the fermented mahua when added with guava improved the flavor of the wine. The addition of guava has increased the antioxidant activity. Singh et al. (2013) investigated that mahua flower juice has a maximum yield of ethanol at 25°C with a pH 4.5 after 14 days of fermentation. The alcoholic beverage developed by Singh et al. (2013) has the characteristic flavor and aroma of mahua flowers. Dushing & Surve (2019) developed wine from mahua flower extract and pomegranate fruit juice. The result showed that *S. cerevisiae* (NCIM-3215) produced better results after 7 days of fermentation, and the wine was acceptable at a proportion of (20:80). Yadav et al. (2009) standardized a pre-treatment condition for mahua wine. They have optimized that a dip of KMS for 10 minutes leads to a decrease in microbial population, and heating at 100°C and 500 ppm KMS sulphitation are required for self-stable mahua flower juice. Patel et al. (2016) introduced an antioxidant-rich beverage from mahua flower and amla. Several blends were prepared, but a blend of 40° Brix mahua having 50% amla was best of all. Singh et al. (2018) developed cupcakes from mahua flower syrup which has 100% replaced sugar, and the product was also acceptable by the panelist. Likewise, Ravat & Dixit (2017) developed gluten-free biscuits incorporated with mahua powder as natural sugar. The gluten-free biscuits had a shelf life of 60 days. According to Pinakin et al. (2018), several researchers have developed value-added products from mahua flowers such as puree and sauces, juice, mahua jam, jelly, marmalade, mahua bar, mahua candy, mahua toffee, mahua cake, mahua squash, mahua laddoo, mahua RTS. The seed oil can be used as food supplements having proper health benefits (Yadav et al., 2011). The chemical composition of mahua oil is the same as other edible oils. Rukmini (1990) compared mahua oil with groundnut oil which showed maximum similarities in the nutritional properties.

Other uses:

- Mahua yeast was extracted from the alcohol factory that contains some vitamins in it. The yeast extracted from mahua was far better than distillery yeast (Daver & Ahmed, 1944).

- A new type of yeast *Zygosaccharomyces mahuae* was isolated by Lender (1992).
- Organic manure was prepared by adding mahua to the waste organic matter (Fowler & Gilber, 1930).
- The role of molasses, mahua flower, and mannitol in nitrogen fixation was reported by Patel & Kibe (1951).
- Hasan et al. (1928) reported that when the cattle were given mahua there was an increase in the health status and quality of the milk.
- A new agar medium for the fungal culture was developed by Saha & Singh (1991).

### 7.5.3 Health benefits of mahua

According to Mishra & Pradhan (2013), there are several health benefits of mahua. It can be used to clear chronic bronchitis problems and can be used as a remedy for cough and tonsillitis. For testis inflammation, mahua leaves are used. A decoction of bark in water is taken orally for the relief of rheumatism. Sometimes oil is also used in the affected area to get relief. It can be used for the treatment of diabetes. Mahua seed oil has laxative properties so it can be used for constipation and piles. Mahua leaves are effective against eczema and bleeding gums. Mahua leaf ash is used to cure itching. The feeding mothers consume mahua flowers to increase lactation.

## 7.6 Current trends and future perspectives

After the study of all the information available, we can conclude that the mahua tree is a boon to our environment. Nature has gifted us with this tree which is a rich source of natural sugar and different phytochemical constituents. Mahua is a perfectly balanced and fully synchronized plant that gives traditional, pharmacological, and economic benefits. Besides its utilization as food, fodder, and fuel, it has antibacterial, anticancer, hepatoprotective, antihyperglycemic, analgesic activities, etc., with certain health importance which helps to treat bronchitis, cough, piles, eczema, bleeding gums. It has also certain important chemical constituents which include flavonoids, glycosides, alkaloids, tannins, and terpenoids. For a long time, mahua is being used in the production of country liquor, but if the tribes are trained with available food technologies, they can market the mahua food products which in turn can raise their standard of living. To increase the commercial utilization of the flowers, there should be an implementation of advanced technologies by which they can make different value-added food products. Government and NGOs should aware people of the utilization of mahua flowers by conducting different entrepreneurship programs by which there will be an enhancement of income sources among the poor people.

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