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Traditional uses and nutritional properties of mahua (*Madhuca longifolia*): A multipurpose tropical tree grown by tribals of Odisha

Manas Ranjan Nayak, Samir Ranjan Dash, Amaresh Khuntia and Sangram Paramaguru

Abstract
Mahua (*Madhuca longifolia*) (Roxb.), also spelt Mahua, is a multipurpose tropical tree native to South Asia that is primarily cultivated or harvested in the wild for it edible flowers and oil seeds. It is widely seen in Malkangiri, Kandhamal, Nabarangapur and Koraput district of Odisha. It takes about 10 years for the tree to fully mature and continuous production can be get up to 60 years. The present paper aims to study the traditional uses and nutritional properties of *Madhuca latifolia* (Roxb.) in dominated forest areas of Odisha situated in different agroecological zones. The seed yield ranges from 60 to 80 kg/tree/year and Mahua trees are also harvested for their flowers and yield 100 to 150 kg of flower DM/tree/year. The sweet, fleshy flowers are eaten fresh or dried, powdered and cooked with flour, used as a sweetener or fermented to make country liquor. The Mahua seed contains 35% to 50% oil and the kernel contains 50% oil and Mahua oil is used to make soaps and candles and is also used as a seed preservative against pests. Mahua oil has emollient properties and is used in skin disease, rheumatism and headache. It is also a laxative and considered useful in habitual constipation, piles and haemorrhoids and as an emetic. The Mahua is being used from the tradition as different plant parts like its bark and oil have Anticancer, Anti-hyperglycemic, Antibacterial with Antioxidant activity. The different ailments treated with these parts include tuberculosis, rheumatoid arthritis, cholera, paralysis, snake-bite, debility, tonsillitis, influenza, piles, arthritic pain, helminthiasis, headache, flatulency, and infections, besides being used as a blood purifier and as an antidote to poison. Mahua seed cake is relatively rich in protein (16-29% of DM) and it is used for fish toxicant cum pond manure in inland aquaculture systems of India. Mahua and it's by product used as soil improver, soil reclamation and erosion control in India. Mahua seed cake contains Saponins (5-6%) and Tannins that reduces its use and high levels of saponins reduces palatability and have anti-nutritional and toxic effects on animals. The biodiesel obtained from Mahua oil has properties similar to the conventional diesel.

Keywords: Antioxidant, bio fuels, mahua, nutritional properties and traditional uses

Introduction
Mahua (*Madhuca longifolia*) (Roxb.), is a species of much ecological and economic importance to the people of Odisha, and therefore this species is subjected to much human pressure for extraction of its flower and seeds which in turn may lead to change in vegetation structure of this species. (Nayak and Sahoo, 2020) [17]. The two major species of genus Mahua found in India are *Madhuca* latifolia and *Madhuca longifolia*. Mahua (*Madhuca longifolia)* is a multipurpose tropical tree mainly cultivated or harvested in the wild in Southern Asia for its edible flowers and oil seeds (Fern, 2014) [11]. *Madhuca longifolia* is an Indian tropical tree found largely in the central, southern, north Indian plains and forests, Nepal, Myanmar and Sri Lanka. It is a fast growing tree that grows to approximately 20 meters in height, possesses evergreen or semi-evergreen foliage and belongs to the family Sapotaceae. It is commonly known as mahuwa or madhuka, Butter Tree, Mahua, mahwa and in Odisha it is known as Mohulo among the tribal farmers. It is widely seen in Malkangiri, Kandhamal, Nabarangapur and Koraput district of Odisha.

Distribution
Mahua is indigenous to India, Sri Lanka, Nepal and Myanmar (Fern, 2014) [11]. It is a frost resistant species that can grow in marginal areas of dry tropical and subtropical forests up to an altitude of 1200-1800 m. It can be found scattered in pastures, in crop fields in central India, and on rivers banks in semi-evergreen forests (Trees India, 2016; Orwa *et al*., 2009) [18].

It grows well where annual rainfall is between 500 mm to 1500 mm, and where temperatures are in the range of 2-46 °C. Mahua does better on deep loamy or sandy-loam soils with good drainage, but it also occurs on shallow stony, clayey and calcareous soils (Orwa *et al*., 2009) [18].

Morphology

It thrives well in deep clay soil and grows quickly with a height reaching up to 20 m with high adaptability to arid environments. It requires an annual rainfall of 550-1500 mm and a temperature of 46 °C. Mahua is a medium-sized deciduous tree, and it has a short, stout trunk, 80cm in diameter. The crown is rounded with multiple branches. The bark is grey, vertically cracked and wrinkled, exfoliating in thin scales. The leaves are alternate and clustered at the end of branchlets. The leaf blade is simple, 10-25 cm long x 6-12 cm broad, oblong-shaped, rigid, thick and firm, woolly at the lower face and exuding a milky sap when broken. Young leaves are pinkish or reddish-brown. Flowers are borne on green or pink, furry bunches, each bunch consisting of 12 fragrant cream-coloured flowers. The flowers live for only one night and then fall to the ground. Pollinated flowers develop into a fleshy, greenish ovoid fruit containing 1-4 shiny, oily brown seeds. The seeds are 3-5 cm long, elliptical and flattened on one side (Trees India, 2016). It is non-edible oil with an annual production of 60 million tonnes in India. It takes about 10 years for the tree to fully mature and continuous production can be up to 60 years (Aransiola *et al*., 2019) [1].

Uses and Economic importance of mahua

Mahua a multipurpose tree that is very important to the local economy of tribal's in Odisha, supplying a range of foods, medicines and other commodities. It is commonly harvested from the wild and is also often cultivated in the tropics. Here is a misconception about Mahua tree that it is used as liquor and harmful for health, but this is what after the fermentation process, so the present review deals with the general and chemical profile of (*Madhuca longifolia*) and its economic importance including medicinal and other uses and tried to emphasize the most potent activity (Patel *et al*., 2012) [19]. Mahua a plant of Indian origin having tremendous therapeutic and potential use but due to unawareness of people it is not fully utilized. Mahua tree have a lot of pharmacological potency for treatment of several diseases. The different ailments treated with these parts include tuberculosis, rheumatoid arthritis, cholera, paralysis, snake-bite, debility, tonsillitis, influenza, piles, arthritic pain, helminthiasis, headache, flatulency, and infections, besides being used as a blood purifier and as an antidote to poison. The *Madhuca longifolia* commonly known as Mahua is an important economic plant growing throughout the subtropical region of the indo-Pakistan subcontinent. (Siddiqui *et al*., 2010) [27].

Table 1: Active constituent present in different parts of Mahua

Parts	Phyto constituents
Bark	Flavonoids, Triterpene, Sterol
Latex	Soluble Resin, Insoluble Resin
Leaf	Leaf Moisture, Organic Matter, Minerals, Potas (K_2O) Phosphoric Acid (P_20_5) Silica, Alkaloids, Flavonoids, Protobasic Acid
Flower	Carotene, Ascobic Acid, Thiamine, Riboflavine, Niacine, Folic Acid, Biotine, Inositole
Ripe Fruit	Ripe Fruit Moisture, Protein, Fat, Carbohydrates, Minerals, Calcium, Phosphoras, iron, Carotine, Ascorbic Acid, Tannins

***Source*:** The Wealth of India, Raw Material, Council of Scientific and Industrial Research, New Delhi, Vol. 6, 2007. and Behl *et al*., 2002

Mahua flowers, fruits and leaves are edible and used as vegetables in India and other Southern Asian countries. The Mahua flower is edible and is a food item for tribal. They use it to make syrup for medicinal purposes and Mahua flowers are rich in total sugars, out of which reducing sugar are present in high amount. Sugars identified are sucrose, maltose, glucose, fructose, arabinose and rhamnose. When flowers are mature and ready to fall, there is maximum total sugar content in the flowers. The majority of dried Mahua flowers are used in the production of country liquor (Singh *et al*., 2013) and (Suryawanshi, *et al*., 2020) [32]. The Tribal people of Southern and Western Orissa, Santhals and Koya tribal of North-East Odisha and Andhra Pradesh, use the Mahua drink as part of their cultural heritage and it is an essential drink for tribal men and women during celebrations. Mahua fruit are an essential food for tribal people of Odisha and Mahua flowers are also used to manufacture jam. There are many varieties of food prepared with its fruits and flowers. Also, in Odisha people used to pray to this tree during festivals. The liquor produced from the flowers is largely colorless, opaque and not very strong. It is inexpensive and the production is largely done in home stills. The sweet, fleshy flowers are eaten fresh or dried, powdered and cooked with flour, used as a sweetener or fermented to make alcohol (Fern, 2014) [11]. The fleshy outer coat of the fruit is used as a vegetable among the tribal community. In India, during periods of scarcity, a combination of Mahua flowers and Sal seeds (*Shorea robusta*) is boiled to prepare a substitute for grain staples (Sunita *et al*., 2013) [31]. Mahua is an oil plant whose seeds yield between 35 and 47% oil (Ratnabhargavi, 2013) [24] and this Mahua oil is used to make soaps and candles and is also used as a seed preservative against pests (Orwa *et al*., 2009) [18]. Oil produced in smallholder farms is of low quality and is mainly used as a ghee substitute or adulterant (Fern, 2014) [11]. In India, potential Mahua oil production could be up to 60 million t/year (CJP, 2007) [5]. The oil cake resulting from oil extraction is used as a fertilizer, and could be used to control root-knot nematode and fungal infections because the high Saponin content reduces nematodes and phytopathogenic fungi (Orwa *et al*., 2009) [18]. Mahua is also used for its hard, strong, dense and reddish timber (Orwa *et al*., 2009) [18]. Mahua flowers produce nectar that is very valuable to honey bees in periods of scarcity (Singh *et al*., 2008) [28]. Mahua is reported to have many applications in traditional medicine, and to provide several environmental benefits. Several Mahua products are used to feed livestock. Leaves, flowers and fruits are lopped to feed goats and sheep (Singh *et al*., 2008) [28]. The Mahua oil cake (usually called Mahua seed cake in India) is used for ruminants in areas where Mahua oil production is important, but is generally considered detrimental to livestock performance due to its high Saponin content (Singhal *et al*.,

1986) [29]. Spent flowers, the by-product of alcohol production, are also occasionally fed to livestock. Native tribes also used the Mahua oil as an illuminant and hair fixer" (Trifed nic.in 2009). Farm Query, 2014 reported that Mahua oil has also been used as biodiesel. In many parts of Bihar, such as villages in the district of Siwan, the flowers of Mahua tree are sun-dried; these sun-dried flowers are ground to flour and used to make various kinds of breads. It is cultivated in warm and humid regions for its seeds (producing between 20 and 200 kg of seeds annually per tree, depending on maturity), flowers and wood. The fat (solid at ambient temperature) is used for the care of the skin, to manufacture soap or detergents and as a vegetable butter. The seed cakes obtained after extraction of oil constitute very good fertilizer. Several parts of the tree, including the bark, are used for their medicinal properties. It is considered holy by many tribal communities because of its usefulness. The alkaloids in the press cake of Mahua seeds are reportedly used in killing fishes in aquaculture ponds in some parts of India. The cake serves to fertilize the pond, which can be drained, sun dried, refilled with water and restocked with fish fingerlings. (Pillay and Kutty, 2005) [20].

Oil extraction

Mahua seeds contain up to 50% oil. In the industrial extraction process, the seeds are first broken and flaked; the resulting flakes are then steam-cooked. The cooked flakes are crushed and solvent extracted with hexane at 63 °C. The resulting Mahua oil meal contains less than 1% oil. In smallholder farms, the seeds are only crushed, resulting in an energy rich Mahua seed cake containing up to 17% oil (Ratnabhargavi, 2013 and Singhal *et al*., 1986) [24, 29].

Detoxification

Due to the low palatability and toxicity of Mahua seed cake, there have been many attempts at improving its nutritional value. The most promising seems to be washing with water, which was tested with some success for ruminants and poultry (Singhal *et al*., 1986) [29].

Forage management

Mahua trees are vegetatively propagated. Scions from the mother plant are grafted one year old seedlings in July and are planted in September at 8 m spacing intervals. Mahua responds positively to N, P, K fertilizers. The trees start bearing fruits 10 years after planting and can yield fruits for up to 60 years. Old trees are more productive than young trees. Irrigation may be useful during fruit development but should be avoided during flowering and leaf shedding. In India, fruits are harvested in May, June and July. Seed yield ranges from 60 to 80kg/tree/year. Mahua trees are also harvested for their flowers and yield 100 to 150 kg of flower DM/tree/year (Singh, 2016).

Environmental impact

Mahua and its by product used as soil improver, soil reclamation and erosion control in India. Though not a legume, Mahua develops mycorrhizal associations able to fix atmospheric N and act as a soil improver. Its extensive superficial root system binds the soil and limits erosion. In India, was used in soil reclamation on hard lateritic soils. Fallen leaves on the soil provide organic matter but they do not break down as easily compared to teak leaves or sal leaves (Bargali *et al*., 2015) [3]. Mahua seed cake is used as a fertilizer and to control root-knot nematode (Orwa *et al*., 2009) [18].

Nutritional attributes

Mahua seed cake is relatively rich in protein (16-29% of DM), the solvent-extracted meals being the richest. Press cake contains about 5-17% oil while solvent-extracted meal contains usually less than 2% oil. The crude fiber content is generally low, from 3 to 12% of DM.

Mahua spent flowers

The composition of Mahua spent flowers contains 4-12% crude protein, 2-45% crude fiber, 2-8% ether extract and 4-11% ash (Reddy *et al*., 1966) [25].

Potential constraints

Mahua seed cake contains Saponins and Tannins that reduces its use by livestock. Mahua contains high levels of saponins, which reduce palatability and have anti-nutritional and toxic effects on animals, though less so, in ruminants (EFSA, 2009) [8]. Mahua seed cake containing 5-6% Saponins and fed to rats at 10-12% of the diet caused 100% rat mortality within a month (Shanmugasundaram *et al*., 1985) [26]. Mahua saponins caused local gastro-intestinal toxicity as well as liver and kidney toxicity. At lower doses, they are responsible for feed refusal leading to starvation, with reduced body weight gain and increased mortality (EFSA, 2009) [8]. Mahua seed cake contains tannins that affect negatively its utilization in livestock feeding (Singhal *et al*., 1986) [29]. In India, Mahua trees are abundant in some areas. Farmers collect the leaves, flowers and fruits to feed ruminants like goats and sheep, and use Mahua seed cake, flowers and spent flowers to feed cattle (Sunita *et al*., 2013) [31].

Mahua seed cake as animal feed

Mahua seed cake is generally considered as a poor feed ingredient for ruminants with a negative impact on protein digestibility and performance (Singhal *et al*., 1986) [29]. However, not all results are negative and in some trials ruminants tolerated water-washed Mahua seed cake at inclusion rates up to 20% of the total diet (EFSA, 2009) [8]. The palatability of unprocessed Mahua seed cake was found to be very poor but improved notably after a period of adaptation (Singhal *et al*., 1986) [29]. In lactating Murrah buffaloes, processed Mahua seed cake was incorporated into the concentrate mixture to replace groundnut cake at 0, 25, 50, 75 and 100%. DM intake and nutrient digestibility did not differ between the 5 treatments. Milk fat, solids-corrected milk and solids-not-fat yields, percentage of fat, lactose, ash and total solids, and gross energy values of milk did not differ between the 5 groups (Tiwari *et al*., 1997) [33].

However, many trials have reported that animals fed Mahua seed cakes performed less well than those on a control diet (Singhal *et al*., 1986) [29]. 12-14 month-old crossbreed calves fed a complete diet containing 20% of Mahua seed cake had higher weight gain but lower crude protein digestibility than the control-fed animals (EFSA, 2009) [8]. The intake digestibility of nutrients and energy utilization were not altered by the Mahua seed cake (Inamdar *et al*., 2015) [13].

Mahua flowers and spent flowers

Mahua flowers are fleshy and sweet and have been used by

Indian villagers to feed their cattle (Reddy *et al*., 1966) [25]. Spent flowers (the by-product of fermentation) are also used as animal feed. They are palatable to cattle and no adverse effect on milk yield and milk composition has been observed (Singhal *et al*., 1986) [29]. Spent flowers from alcohol production were used to feed broilers and maintained performance without adverse effects at up to 8% of the diet (Reddy *et al*., 1966) [25].

Poultry Feed and Fish Feed

Untreated Mahua seed cake is toxic to chickens because of its high saponin content. In young chicks, high mortality was observed with high (35%) levels of Mahua in the diet (Mukherjee *et al*., 1966) [16]. After removing saponins by water extraction, Mahua seed cake still reduced feed consumption and growth performance of broilers, at only 5% of the diet (Dular *et al*., 2000) [7]. Unless an appropriate detoxification process is found, the use of Mahua seed cake for poultry is not recommended. Mahua seed cake cannot be used for fish feeding. However, due to the stupefying effect of saponins on fish Mahua seed cake is traditionally used in India as a stupefying for catching fish in ponds, 0.5 kg of Mahua seed cake boiled in water catching all fish in a 3 x 3 m pond (Kamalkishor *et al*., 2009) [14].

Table 2: Chemical composition and nutritional value: Mahua (*Madhuca longifolia*), seed cake, mechanical extraction

Main analysis	Unit	Avg.	SD	Min	Max	Nb
Dry matter	% as fed	92.2				1
Crude protein	% DM	19.7	5.4	16.0	29.0	6
Crude fibre	% DM	6.5	3.8	3.1	12.6	6
Ether extract	% DM	8.3	2.4	5.0	10.9	6
Ash	% DM	7.5	2.3	5.0	10.5	6
Gross energy	MJ/kg DM	19.2				
Minerals	Unit	Avg	SD	Min	Max	Nb
Calcium	g/kg DM	3.6		1.2	6.0	2
Phosphorus	g/kg DM	3.2		2.8	3.6	2
Potassium	g/kg DM	12.4				1
Magnesium	g/kg DM	3.2				1
Manganese	mg/kg DM	75		17	133	2
Zinc	mg/kg DM	32		11	52	2
Copper	mg/kg DM	38				1
Iron	mg/kg DM	890				1
Secondary metabolites	Unit	Avg	SD	Min	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	7.5		5.0	10.0	2
Ruminant nutritive values	Unit	Avg	SD	Min	Max	Nb
OM digestibility, ruminants	%	26.4				1
Nitrogen digestibility, ruminants	%	11.9				1

Medicinal and Pharmacological value of mahua

Different parts of a plant often contain a quit different active ingredients, so that one part may be toxic and another one quite harmless. They are root, bark, leaves, flowers, fruits, seeds, oil. *Madhuca longifolia* has several pharmacological activity, and potential to provide health to the society. It is used as Anti diabetic, antiulcer, hepato protective, anti-pyretic, anti-fertility, analgesic, anti-oxidant, swelling, inflammation, piles, emetic, dermatological, laxative, tonic, anti-burn, anti-earth worm, wound healing headache and many more problems. Traditionally, Mahua bark has been used against diabetes, rheumatism, ulcers, bleeding and tonsillitis. The flowers, seeds and seed oil of Mahua have great medicinal value. Externally, the seed oil massage is very effective to alleviate pain. The Mahua have several pharmacological potency and it is being used from the tradition. (Dahake and Chiratan, 2010) [6].

Anticancer activity

In Ayuevedic system of medicine it is stated that the bark of *Madhuca longifolia* is useful in the treatment of cancer at the local application (Balachandran *et al*., 2005).

Anti-hyperglycemic activity

The significant hypoglycemic effects of *Madhuca longifolia* bark in diabetic rats indicate that this effect can be mediated by stimulation of glucose utilization by peripheral tissues. The results of the study by (Srirangam and Annsmpelli, 2010) [30] clearly indicated the ethanolic extract of the bark have a hypoglycemic effect.

Antibacterial and Antioxidant activity

The Mahua flower has an antibacterial activity against the *Escherichia coli* and resist against rice pest disease. Oxidative stress is produced during normal metabolic process in the body as well as induced by a Varity of environmental and chemical factor, which cause a generation of a various reactive free radical and subsequent change in DNA and lipids (Maity and Hansda 2009) [15].

Biodiesel production and industrial use of mahua oil

Recently, biodiesel has been receiving increasing attention due to its less polluting nature and because it is a renewable energy resource as against the conventional diesel, which is a fossil fuel leading to a potential exhaustion. Mahua oil is inedible oil available in plenty in the tropical countries like India. Mahua oil is reported to have potential use in biodiesel production and also referred to as non-edible oil crop, have two main advantages over traditional edible oil crops for biodiesel production. First, because of their toxic compounds, dedicated oil crops are unsuitable for human consumption, thereby minimizing negative impacts from using edible oil on food security. Second, they are able to grow and even to produce a reasonably high yield under unfavorable conditions for agriculture (e.g., poor soil quality, inadequate rainfall and water shortage, low fertilizer level, and high temperature variation) without requiring intense cultivation practices, making their cultivation more flexible, efficient, and economical compared to edible oil crops (Bankovic-IIic, Ivana, Olivera & Vlada, 2012) [2].

Table 3: Chemical compositions of diesel fuel and biodiesel, % (m/m)

Chemical compositions of Bio diesel in Mahua oil					
Fuel	C	H	O	C/H	Empirical formula
Mahua	77.2	11.9	10.8	6.45	C19.05H34.98O2

(Ramalingam *et al*., 2019) [23].

Fresh Mahua oil is yellowish while the commercial oil is greenish yellow. The blend of Mahua oil biodiesel with conventional diesel has been found to result in lower CO, hydrocarbon, and smoke emissions as compared to pure conventional diesel (Aransiola *et al*., 2019) [1]. The seed contains 35%-50% oil and the kernel contains 50% oil, depending on the size and age of the tree. The total oil yield of Mahua oil per hectare is 2700 kg. The oil contains about 20% free fatty acids (FFAs) and a procedure for converting this oil to biodiesel is required. The biodiesel obtained from

Mahua oil has properties similar to the conventional diesel of American and European standards. Under optimized conditions, about 98% conversion of Mahua oil to biodiesel is possible. The reason for the utilization of natural or vegetable as a new source of fuel is present status of demand. Since the oil price increase of the 1970s, various alternative fuels have been investigated with the goal of replacing conventional petroleum supplies. The initial interest was mainly one of fuel supply security, but recently more attention has been focused on the use of renewable fuels in order to reduce the net production of CO_2 from fossil fuel combustion sources (Puhan and Vedaraman, 2005) [22].

Conclusion

Plants are the important economical source of a number of well-established drugs looking upon wide prospects and potential of *Madhuca longifolia* for various purposes; it is worthwhile to cultivate this plant on large scale especially on unproductive and wasteland. This will help in financial full support of poor and landless families. Generally this plant *Madhuca longifolia* is known only for its liquor making purpose, but it is time to change the thinking of unaware people. The Mahua tree is hidden from the public eyes as its medicinal point of view. As for the better potential, good quality of Mahua tree should be cultivated through plant tissue culture by means of micro propagation. The research workers have to come along with the people of rulers' area so they may have more and valuable knowledge. In coming next generation the importance of plant and Mahua tree is going to be increase because of their effectiveness, easy availability, low cost and comparatively being devoid of toxic effect. *Madhuca longifolia* has found several of pharmacological activity, yet several other activities have to be finding out.

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