# MAHUA (MADHUCA INDICA) AS A SOURCE OF BIODIESEL IN INDIA

Pratap S Kulkarni[1], Dr Sharanappa G[2], Dr Ramesh M R[3]
1.Proudhadevaraya Inst Of Tech,Hospet,Karnataka spratapkulkarni@gmail.com 2.Reva Inst Of Tech, Bangalore gsharanappa@rediffmail.com 3.NITK Surathkal mr_ramesh@rediffmail.com

**Abstract**— The Mahua trees are indigenous to India, grow even in draught prone areas and are found abundantly over several parts of India. If the seeds fallen are collected, and oil is extracted at village level expellers, few million tons of oil will be available for lighting lamps in rural area. In some countries, Mahua oil is considered edible as it is used only for preparing ghee, but in our country it has been considered as non-edible oil. Growing Mahua trees would also help in protecting the environment and benefit the farmers as well. It is the best substitute for kerosene. Since these are spread over a large area, collection of seeds for Biodiesel manufacture is not viable. A compact plantation can support a Biodiesel plant. The oil has not yet found any significant commercial application. But due to increase in awareness and growth in research in this area the Mahua can be developed as the alternative source of fuel by replacing diesel. In the present study attempt has been made to study the scope of Mahua in India.

**Index Terms**— *Mahua, Biodiesel, Viscosity, Oilseed, plantation, extraction, commercial application*

## 1 INTRODUCTION

India ranks 6th in terms of consumption of energy *i.e.* 3.5% of the total world's commercial energy. The current consumption of diesel in India is about 40 million tonnes (MT) (40% of the total consumption of petroleum in the country) and is expected to reach 65 million tonnes (MT) by 2011-12, whereas the domestic production of crude oil and natural gas will be less as compared to the demands. There is huge gap between the demand and supply which is presently met by imports, resulting in heavy burden of foreign exchange on the country. Production of biodiesel from oil and ethanol from sugar based resources are considered as the best substitute of diesel and gasoline respectively in the country. The waste and degraded land after reclamation can be used to grow the resource, produce oil and its conversion to biodiesel. Biodiesel's are mono alkyl ester of long chain fatty acids of vegetable oil or animal fats either from plant or animal. The biodiesel, when mixed with diesel up to 20% requires very little or no modification in internal combustion engines and brings substantial reduction in the emission of unburned hydro-carbon by 30%, carbon monoxide by 20% and particulate matters by 25% with no sulphur. The biodiesel has nearly 10% more oxygen which facilitates the complete combustion and enhances the cetane number.

## 2 CULTIVATION OF OIL SEED PLANT IN INDIA

Depending on climate and soil conditions, different nations are looking for different vegetable oils as substitute of diesel fuel: soybean oil in USA, rapeseed and sun-flower oils in Europe, palm oil in south East Asia and coconut oil in Philippines. In India, the demand for biodiesel for the year 2011-2012 has been estimated as 13.38 million tonnes considering 20% blends of biodiesel with diesel. The area

required for growing the Jatropha plantation alone is about 11.19 Million hectares [1]. The use of edible oil resources like mustard, soya bean, sunflower, palm oil etc for bio-diesel production put heavy competition with food and above that, the demand of edible oils is being met by importing from other countries. The non edible oil sources seem to be the only option for cultivation, oil extraction and biodiesel production on industrial scale for engine operation.

## 2.1 GENERAL MORPHOLOGY OF PLANT AND OIL SEEDS

The general morphology of the oil plant and their seeds, the availability and combustion characteristics like density, viscosity, flash point and fire point, cetane number and calorific value of mahua oil and its blends with diesel oil under test are presented. The world's rapidly dwindling petroleum supply, their raising cost and the growing danger of environmental pollution from these fuels have led to an intensive search of alternative fuels. The use of Mahua oil (Madhuca Indica) as diesel substitute in compression ignition engine has now gained greater importance because of their large population and phenomenal growth rate. Mahua oil can easily be substituted for hydrocarbons which are scarce worldwide, and save the countries crores of rupees in foreign exchange. It is therefore necessary to develop some means for improving the fuel economy of compression ignition engines and also to investigate the suitability of Mahua oil for diesel engine operations. If the diesel engine could be fuelled on a cleaner fuel such as honge oil, Mahua oil, it may well be the most desirable engine of the future. The present researchers considered among several non edible seed oils, Mahua oil is considered because of following reasons [2, 3].

- These are non edible type oils.
- These trees are indigenous to India, grow even in drought prone area and found abundantly in all parts of India.
- These oils can be easily substituted for petroleum based Hydro Carbon fuels that are becoming extinct.
- They have assured greater importance because of their large availability and potential growth with age. In India at present theoretical potential of oils is estimated to 4, 00,000 tons per year for Mahua oil.

## 2.2 MAHUA TREES

Mahua oil is obtained from dried seeds of the mahua plant. Mahua plant shown in **Figure 1** is a large deciduous tree growing widely under dry tropical and sub tropical climatic conditions. It is an important tree for the poor, it is greatly valued for its flowers and its seeds. The tree has religious and aesthetic value in the tribal culture. In some

countries, Mahua oil is considered as edible as it is used only for preparing ghee, but in our country it has been considered as non-edible oil. Its botanical name is Maduca Indica and common English name is Maduca or Butter tree. In Indian languages it is called Mahua or mauwa in Hindi, Hippe in Kannada, and Ippe in Telugu. The trees in Karnataka are tall and reach a height of 20 – 25 ft. flowering of mahua occurs in February – April. The fruits ripen in June – July and fall off soon ripening. In northern India harvesting takes place between April and July. In southern India the harvesting period is between August and September [4]. The tree starts giving flowers and fruits between $10^{th}$ to $15^{th}$ years after plantation. An average sized tree yields about 50 to 100 kg of flower in a season that lasts around a month. Mahua tree has an annual average yield of 62.5 kg of flower and 59 kg of gully as per one study. Collection of Mahua seed, which is also an important source of oil, is capable to generate employment worth 3 million person days a year. Mahua trees are widely grown in Uttar Pradesh, Madya Pradesh, Gujarat, South India, three district of Karnataka (Mysore, Tumakur and Bidar) and Monsoon forest of western Ghats.

Figure 1 Photograph of Mahua Tree

## 2.3 MAHUA SEEDS

Mahua seeds are collected during May to July. During a bumper season a person can collect up to 15 kg of tori per day. Local tribal extracts 250 ml of oil from 1kg of seed. Oil is usually kept for domestic consumption. In market they sell seeds at Rs 12/- per kg. The seeds should be de-shelled by pressing and then dried to get the kernel. The amount of oil extracted is 20-30 % of weight of kernels when crushed in ghanis, 34-37 % in expellers and 40-43% when extracted by solvents. Fresh mahua oil from properly stored seeds is yellow in color with an unpleasant taste. Commercial oil is generally greenish yellow in color with an offensive odor and disagreeable taste. The light yellowish brown colored ripe fruit is shown in **Figure 2** and the brownish colored dry seeds are shown **Figure 3.**

**Figure 2 Photograph of Mahua ripen fruits**

**Figure 3 Photograph of Mahua seeds**

## 2.4 APPLICATIONS

It is used mostly in manufacturing of soaps, particularly the laundry field. It is also used for edible and cooking purpose. Refined oil is used in manufacturing of lubricating greases. The oil is used for candles a batching as a raw material for production of fatty alcohol and stearaic acid. The tribal commonly consume the tori oil that contains 40-45% oil. The oil cake is also used as pesticide and manure. It contains 16% of protein. The oil cakes are profitably utilized as bio-fertilizers or cattle feed or sold to solvent extraction plants, where still more oil is extracted.

Medically the tree is very valuable. Flowers are prepared to relieve coughs, biliousness and heart- trouble while the fruit is given in cases of consumption and blood diseases. Mahua flowers show anti-bacterial activity against Escherichia coli. The honey from flowers is edible and reported to be used for eye. The bark is used in treating of rheumatism, ulcers, itching, bleeding and spongy gums, tonsillitis leprosy, heal wound, and diabetes mellitus. The root base is applied to ulcers.

## 2.5 DETAILS OF CONSTITUENTS AND QUALITY CHARACTERISTICS

Mahua oil is obtained from the kernel of mahua seed (Madhuca Indica) and contains 50-55% oil. The unrefined but filtered crude mahua oil is greenish yellow in color. The oil itself contains a number of fatty acids similar to those in cooking oils such as oleic acid, linoleic acid, stearic acid and palmitic acid. The fatty acid profile and characteristics of mahua oil is given in **Table1**. The quality of oil extracted from the seeds, depends largely on the conditions under which they have been stored. Even under the best conditions the concentration of fatty acid increases. The oil from fresh seeds has an acid value as low as 3.5 while the

value for oil obtained from old and badly stored seeds may be as high as 60. Mahua oil has 21% free fatty acids (FFA) [5, 4].

| Properties | Values |
|---|---|
| Refractive index | 1.452-1.462 |
| Saponification value | 180-195 |
| Iodine value | 50-70 |
| Unsaponifiable matter, % | 1-3 |
| **FATTY ACID COMPOSITION** | |
| **Fatty acid** | **(%)** |
| Palmitic $C_{16:0}$ | 23.7-24.7 |
| Stearic $C_{18:0}$ | 19.3-29.9 |
| Arachidic $C_{20:0}$ | 2.0 |
| Oleic $C_{18:1}$ | 36.32-43.3 |
| Linoleic $C_{18:2}$ | 11.60-15.8 |

## 2.6 AVAILABILITY AND SPREAD

This tree is well distributed in India, especially in the moist deciduous forests. Madhya Pradesh along with Orissa accounts for nearly 80 % of Mahua trees in India. As per various estimates, the undivided state has 3 to 5 million trees of Mahua. Mahua tree can be found in forests, revenue, and private land; more in the latter two. Two types of this tree are found in South India. In Andhra Pradesh, the trees have a spread out canopy and the leaves are broad and oval in shape. The fruits have a hard outer rind and are not edible. The trees in Karnataka are tall and reach a height of 20-25 feet. The leaves are oblong in shape and the terminal leaves are pink in color. The fruits resemble sapota fruits and are edible [6].

## 2.7 PHONOLOGY AND SILVICULTURE

Flowering of Mahua occurs in February- April. The fruits ripen in June- July and fall off soon after ripening. A large evergreen tree with numerous branches, the fleshy cream colored sweet petals fall soon after flowers open out. During the flowering season, large quantities of petals are collected. The season for collecting Mahua flowers is short and in absence of organized harvesting, a considerable portion of the crop is lost during monsoon. The tree has a short bole and round spreading crown. The bark is nearly smooth, grey or brown with vertical cracks. The tree starts giving flowers and fruits between the 10th and 15th year after planting. An average size tree yields about 50-100 kg of flower in a season that lasts around a month. It is said that low rainfall in the previous year adversely affects flower production. One Mahua tree has an annual average

yield of 62.5 kg of flower and 59 kg of gully as per the study. It has been observed that good flowering in Mahua occurs every alternate year or once in every three years. The reason for this is said to be fluctuations in rainfall, temperature and other climatic factors. According to a group of people,major causes for poor flowering is seen due to the damage caused to the tree while beating it with bamboo for tori collection [5, 4, 6].

### 2.8 COLLECTION AND PROCESSING

Mahua seed is collected during May to July. In this season when Mahua tree flowers more, seed production is low. The villagers go to forests early in morning to collect fruits using bamboo sticks (or hand pick) to pluck the fruits. During a bumper season a person can collect up to 15 kg of tori per day. Local tribal use their indigenous knowledge for extraction of oil from seed. 250 ml of oil is extracted from 1 kg of seed. Oil is usually kept for domestic consumption. In the market they sell at Rs 8/- a kg. After collection of fruits, the seeds are separated from them and tribal people use the pulp for their food. After removal of pulp, seeds are washed and soaked in water for 3 days so that the seed coat softens. Thereafter the covering is removed either one at a time or many together by crushing the seeds through grind stones by applying minimum pressure. The seeds should be de-shelled by pressing and then dried to get the kernel. The amount of oil extracted depends on the efficiency of the equipment employed for crushing; it is 20-30% of the weight of kernels when crushed in ganas 34-37% in expellers and 40-43% when extracted by solvents. Fresh Mahua oil from properly stored seeds is yellow in color with unpleasant taste. Commercial oil is generally greenish yellow in colour with an offensive odour and disagreeable taste. Groups can set up advance dealing, directly with the oil expellers, if they are located nearby. Indigenous methods for oil expelling could be utilized and gully oil may be sold to soap manufacturers after vacuum purification. Mahua gully is prone to fungal attack if not preserved properly. It is kept in an airtight earthen pot with its mouth sealed or in baskets with wet mud and leaf coating. Mouth of the basket is covered with mahul or palas leaves. This indigenous technique is useful for storing the guli for sufficiently longer time before onset of monsoons [4, 6,7].

## 3. CHARACTERIZATION OF MAHUA OIL

The important physical and chemical properties of mahua oil are determined as per Indian standard (IS) methods in Bangalore Test House. It is observed that the properties like density, flash point, fire point and viscosity of mahua oil is high and calorific value is lower as compared with diesel. **Table 2** shows the comparison of properties of crude mahua oil with diesel. Tests for determination of density, cal-

orific value and viscosity of mahua oil are carried at Bangalore Test House Bangalore. Tests for flash point and fire point are carried out using Able's apparatus. The comparison shows higher density, viscosity, flash and fire point but, lower calorific value of mahua oil. Density of mahua oil under test is 0.904 g/ml, lower than that of diesel. Viscosity of oil is 38.86 Centistokes, higher than that of diesel. Flash point and fire point of oil is 220$^0$C and 234$^0$C respectively. Calorific value of oil under test is 37,735 KJ/Kg, which is in the range of 86% of that of diesel. Cetane number of mahua oil under test is less than that of diesel.

| Properties | Diesel | Raw Mahua |
|---|---|---|
| Density (kg/m$^3$) at40$^0$C | 828 | 904 |
| Specific gravity at 40$^0$C | 0.828 | 0.904 |
| K.V.(cSt) at 40$^0$C | 4.4 | 38.86 |
| Calorific Value (KJ/kg) | 43910 | 37735 |
| Flash point ($^0$C) | 45 | 220 |
| Fire Point ($^0$C) | 63 | 234 |

## 3.1 REQUIRED CHARACTERISTICS OF VEGETABLE OIL AS FUEL

Vegetable oils provide diesel engine performance similar to that obtained with diesel oil as per the experiments carried out by the research teams. The following are the important characteristics of good vegetable fuels required to substitute diesel oil [3].

- Ignition quality: Satisfactory diesel combustion demands self-ignition of the fuel as it is sprayed near the TDC into the hot, swirling compressed cylinder gas. Long ignition delay is not acceptable as it leads to knocking. Therefore, cetane number of the substitute fuel should be high enough, i.e., in between 40 to 60.
- Viscosity: Too low viscosity can lead to excessive internal pump leakage whereas high viscosity can increase system pressure to unacceptable levels and will affect injection during the spray atomization.
- Heating value: Although, the diesel combustion system can accept wide variations in heating value, practical systems are most suitable when calorific value of fuel is high. This helps to reduce the quantity handled and to maximize equipment operating range. It is always desirable for vegetable fuels to have calorific value nearer to diesel oil.
- Pour Point, Cloud Point and Flash Point: The first two properties are important for cold weather operation. For satisfactory working the values of both should be well below freezing point of the oil used. Flash point is important from safety view point and this temperature should be as high as practical value.

- Sulfur, Carbon Residue and Ash: These properties are responsible for corrosion and forming the residue on the engine parts which affects the engine life. These values should be as small as possible. Practical values are 0.5% sulfur, 0.27% Carbon residue and 0.01% ash.
- Miscibility with diesel: Vegetable oil should mix with diesel at various proportions and kept untouched for 24 hours.
- Aniline point*:* Aniline point is the lowest temperature at which the oil is completely miscible with an equal volume of aniline. For a good quality of diesel, aniline point is greater than 21º C.

## 4. PRODUCTION, PRICING AND ECONOMIC ASPECTS AND CULTIVATION PACKAGE

Seeds that are procured during the months of June/July cultivate this tree. The fleshy pulp is separated and seeds sown in poly bags containing sand, soil and FYM. Germination starts after 15 days and continues till 40 days. They can then be transplanted in the field during the late rainy season after they are two-three months old. The growth of the seedling is slow during the first two years. Setting up a small size oil mill as a Small Scale Industry would cost Rupees 1 to 1.25 Lakhs (at 1997 prices) including filtration set up required at a central (may be a block) level. Khadi Village Industry Commission has schemes that could help setting up of a Small Scale Industry. Assuming that 3 kg of ripe gully will result in 1 kg of oil and average price of oil as Rupees 27 per Kg, the returns to the primary collector per kg of gully would be Rupees. 7per Kg again assuming a Rupees 2 per kg of processing cost of the gully. The current prices of oils for first grade is Rupees 2900 and oil second grade is Rupees 2850 for a quintal. **Table 3** shows the potentially the trees available in India.

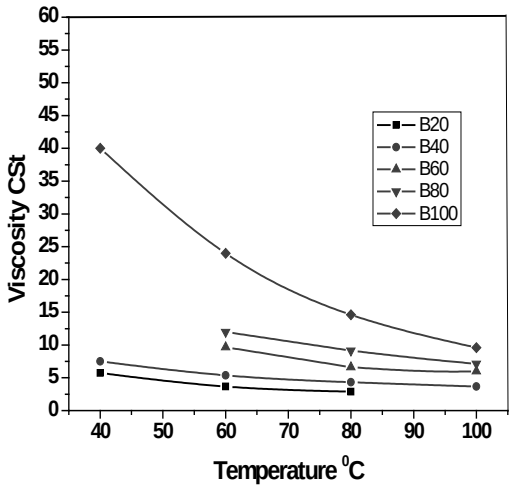
| **Region** | **No. of Trees** |
|---|---|
| Northern India | 8023000 |
| South India | 1325000 |

## 5 SUITABILITY AND PROBLEMS OF MAHUA OIL AS FUEL

### 5.1 EFFECT OF TEMPERATURE ON VISCOSITY OF MAHUA OIL AND BLENDS WITH DIESEL

**Figure 4** shows the variation of viscosity of diesel, mahua oil (MO 100) and its blends with diesel at 20 % (MO20), 40 % (MO 40), 60% (MO 60), and 80% (MO 80) with temperature. Viscosity of mahua oil and its blends decreases with increase in temperature. Blend containing 20% of mahua and 80% of diesel is close to that of diesel at $50^0$C and does not require any preheating. To reduce the viscosity of mahua oil and its blends before injecting into combustion chamber has to be preheated up to $130^0$C depending on

blend ratio.




## 5.2 SUITABILITY

The Mahua (vegetable) oil has some properties, which makes replacement of diesel fuel. Cetane number of mahua oil is generally in the higher range of diesel fuel. Heat content of vegetable oils are nearly 90 % that of diesel fuel. Long chain saturated, unbranched hydrocarbons are especially suitable for conventional diesel fuel. The long, unbranched hydrocarbon chains in the fatty acids meet this requirement.

## 5.3 PROBLEMS

The problems involved with vegetable oils can be listed as below

- Diesel fuel has a chain of 11-13 carbon, and fresh vegetable oil has a chain of about 18. To burn in an engine, the chain needs to be broken down to be similar in length to diesel
- The high viscosity and the polyunsaturated nature of the oils
- In complete combustion but characterized by nozzle coking, engine deposits, lube oil dilution, ring sticking, scuffing of the cylinder liners, injection nozzle failure and lubricant failure due to polymerization of the vegetable oil.
- To a lesser extent, operational problems, unreliable ignition and misfire, and degraded thermal efficiency.
- Neat vegetable oils are reported to cause engine deposits. Attempting to solve these problems by using methyl esters (Biodiesel) cause operational problems at low temperatures. Furthermore, problems related to combustion and emissions remains to be solved.
- Both cloud and pour points of esters are significantly higher than those for diesel fuel. These high values may cause problems during cold weather.

## 6. CONCLUSIONS

The general morphology of the mahua oil, its availability and combustion characteristics like density, viscosity, flash point and fire point, and calorific value are determined. Effect of blending vegetable oil with diesel on viscosity, and variation of viscosity with temperature for vegetable oil and their blends are studied and presented. From above investigations the following conclusions are drawn. The production of these oil seeds can be increased by necessary development in high yielding, high-breed variety of these

plants so that their yield may be accelerated to meet the higher demand.

Mahua oil is mainly used in the manufacturing of soaps, particularly laundry soaps. Refined oil finds use in manufacture of lubricating greases and fatty alcohols. The oil is used also for candles, as batching oil in jute industry and as a raw material for the production of stearic acid. Mahua cake is used as manure. Mahua flowers are used in the preparation of distilled liquors. Flowers are used for the preparation of vinegar.

Since the mahua oil is made domestically even in village, it reduces the dependence on imported petroleum based oils saving considerable foreign exchange for better national economy. The properties like density, viscosity, flash and fire point of mahua oil under test are higher, and calorific value is lower, and are in the range of 86% that of diesel.

## REFERENCES

J. [1] Kureel R.S. (2007). "Bio-fuel scenario in India." Renewable Energy Akshay Urja, 3(2), 12-17.

[2] Radhakrishna, P. "Candidates for Bio-diesel and Prospective shareholders to accelerate program specific economic activity."All India seminars on National Policy on Non-conventional energy sources, Renewable Energy Science Series XII.

[3] Mahajan, V.V. (2003). "Sustainable development through Biodiesel: an overview" Consultative workshop on Scientific strategic for production of non edible oils for use as biofuels, SuTRA(Sustainable Transformation of Rural Area), Indian Institute of Science, Bangalore, India, 9-15.

[4] Pringi, N.V. "Non-Traditional oil seeds and oils in India". Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, India, 143-166.

[5] Ajay Kumar, I S Singh.(1991), "Chemical evaluation of Mahua ( Madhuca Indica) seed." Journal of food Chemistry, 40(2), 221-228

[6] Consultative workshop on (2003). "Scientific strategic for production of non edible oils for use as biofuels", SuTRA (Sustainable Transformation of Rural Area), Indian Institute of Science, Bangalore, India.

[7] Rudramurthy, "Review of research and development activities on Bio-diesel as an alternative fuel", Renewable energy science series XII.per, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper.