

Mahua Biodiesel: An Alternative to Conventional Diesel Fuel

Yogendra Rathore¹, Dinesh Ramchandani²

¹(H.O.D., Mechanical Engineering Deptt. Govt. Polytechnic College, Raisen, M.P., India)

²(Assistant Professor, Mechanical Engineering Department, SISTec, Bhopal, M.P., India)
(¹yogendra_ap@yahoo.com, ²dvramchandani@gmail.com)

ABSTRACT: Energy is the basic need to any nation's growth. Due to energy crisis whole universe is struggling with many issues like fossil fuels are losing ground drastically, demand for energy is ever increasing, concerns to the climate changes & high energy prices are putting us on our toes in the search of alternative and cleaner fuel sources which is the biggest challenge to the energy industry & various nations. As a substitute of conventional diesel fuel, biodiesel fuel is made from renewable resources and it also has non toxic and biodegradable nature. Our country i.e. INDIA has many potential for the production of biodiesel from the seeds of edible and non edible oils. Out of many variants of oil seeds, only some variants are tested till the time. Many researchers studied on the properties part of biodiesel fuel that has shown that it is completely miscible with conventional diesel fuel. A unique property of biodiesel over conventional diesel fuel is that biodiesel releases particulate matter and gases. Amongst the potential sources of non edible oils of India, Mahua has shown very bright prospects. This paper shows the past and current progress along with other types of biodiesels, the characteristics, processing and economics available to Biodiesel industry and also it's their respective application part to automotive industry. The current paper fairly shows the studied comparison of conventional diesel fuel and Mahua biodiesel usage in view of its performance and exhaust characteristics parameters.

Keywords: biodiesel, transesterification, mahua oil, performance, emission, energy, policy.

I. INTRODUCTION

A century before, Rudolf diesel first came with the concept of diesel engine, used peanut oil (vegetable oil) for experimental evaluation, that time only it indicated that vegetable oils are appropriate to cater the needs of future. In today's century, it is assumed as per the usage data of conventional petroleum fuels that it will become very scarce & expensive to locate and manufacture, although researchers have found number of ways to increase the fuel economy but population of nations has increased many folds and also energy is the backbone of any nation's economy. Extreme exploration of crude oil deposits has been used in much type of usages, just because of sudden bursting of population around the globe. Lubricants that are in regular usage, made from mineral oils and additives which are very poisonous to water & soil due to its respective denser chemical composition and lesser biodegradability. There is always an alarming situation as far as environment is concern which pulls our attention towards natural counter parts just because of rising crude prices, inappropriate disposal methods and absence of lubricant usage across the globe [1-3].

Fuels are very important to all of us in many ways due to its useful energy which we received during its combustion and satisfy many parameters of day to day life like transportation of public and supplies. Fossil fuel provides us major boon of energy which are petroleum oil, coal and natural gas. Today fuels from fossils carries 80% of the total energy requirement, also many of the industries using diesel engines are totally dependent for its manufacturing reason. Transport sector consists of busses, trucks, cars, ships etc consuming major amount of diesel and gasoline. This way we are totally dependent on this type of source of energy to the great extent where as growing demands of population possibly will not be fulfilled by household production of raw oil. [4-5].

Fossil fuels are derivatives of plant and animal fossils that are million years' old which lies in non renewable energy sources category. The demand for energy and fuel price will never be in the declining graph. Developing countries are totally dependent on fossil fuel for their growth and development but regrettably these will be consumed in next 65 years. Emission from the combustion of fossil fuel leads to pollution in atmosphere and global warming [6-9]. Many nations are facing such pressure from outside of national territory to work on issues of global warming [10-12]. Due to these every nation is looking for clean, green and renewable alternate fuel to address the today's and tomorrow's need.

II. LITERATURE REVIEW

2.1 PETRO-DIESEL & BIO-DIESEL

Petroleum diesel/petro-diesel/fossil diesel can be produced when fractional distillation of crude oil occurs between the temperature of 2000C and 3500C with pressure of atmosphere which produces a combination of chains of carbon that carries per molecule around 8 to 21 atoms of carbon. This is particular liquid fuels which were found by fractional distillation of crude oil which is commonly called petroleum diesel [13]. Whereas animal or vegetable oil based diesel fuel is known as Biodiesel which burns and emits very less soot, oxides of carbon and particulate matter [14]. It has long chain mono-alkyl esters and can be produced by transesterification of either vegetable oil or animal fat. The process will happen when one mole of triglyceride reacts with three moles of alcohol so as to manufacture one mole of glycerine and three moles of mono alkyl esters which is also termed as Biodiesel. This carries a long chain of mono alkyl esters and could be manufactured by doing transesterification of either vegetable oil or animal fat. The reaction can be done with one mole of triglyceride reacting with three moles of alcohol. Transesterification reaction is shown in figure 1. Biodiesel is like petroleum diesel fuel consists of chains of hydrocarbons which carry neither sulphur nor any of the aromatic compounds in its composition. It is also a kind of fuel which is of renewable natures means that burns with less effect to environment in comparison with petro-diesel.

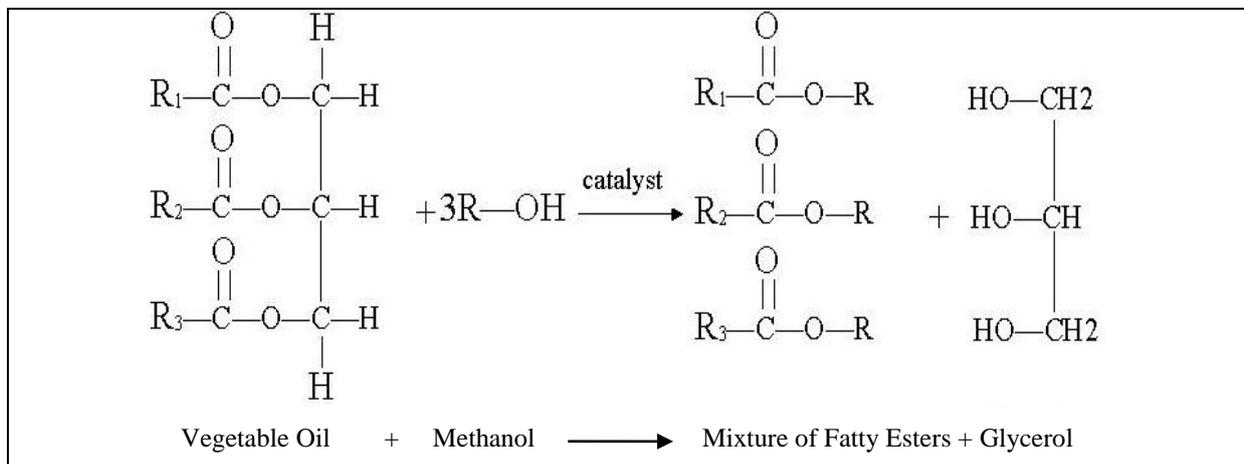


Fig. 1. Transesterification Reaction

2.2 ADVANTAGES & DISADVANTAGES OF BIODIESEL

Biodiesel is a kind of fuel which is atmospherically pleasant and renewable and that is the main quality which has got all the appreciation all around the world. The merits with biodiesel as fuel are discussed as follows:

- Its emissions are not dangerous to our atmosphere.
- It is being capable of being agriculture, non-hazardous and recyclable and a renewable fuel.
- It carries high cetane number, low in sulphur content, low in volatility and availability in oxygen atoms per molecule of fuel.
- Use of biodiesel would create high job opportunities in developing countries in view of sector of agriculture where currently level of employment is very low [15].

Whereas the disadvantages of using biodiesel are listed as follows:

- It has high nitrogen oxides in emissions which results the formation of smog and acid rain.
- In view of comparison between the output in energy amongst biodiesel and petroleum diesel, requirement of biodiesel is relatively high for producing same amount of energy.
- Usage of precious farming land for biodiesel crop cultivation would result in increase in food cost all around and also could increases scarcity of food as well.

2.3 CURRENT SCENARIO

Thus, in terms of end usage, energy demand across the transport sector is greatest. Roads, being one of the dominant infrastructures for transport, carry as estimated 85 to 90 Percent of the country’s passenger traffic and 65 percent of its freight. Traffic on roads is growing at the rate of 7 to 10 percent per year; while the vehicle growth is of the order of 8 to 10 percent per year. In view of demand of petrol in comparison with diesel, diesel is five times demanded than petrol. India ranked fifth for consumption of primary energy and fourth as consumer of petroleum products and landing after ranking of U.S., China and Japan.

During last ten years, production of biodiesel has reached creditable figures which shows the increase in demand and its continuous increase in production figures are shown in Fig. 2 [16]. The escalation in the economy of India during 2009-10 is 8% as on 31 Jan 2011; during 2010-11 it is 8.6% as on 07 Feb 2011 [17].

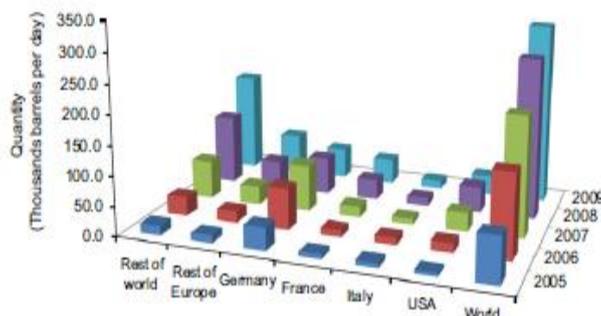


Fig. 2. Production of biodiesel in world [16].

The equation of rising demand in oil sector against production levels (Fig. 3) showing increase in dependency on imports to meet the total demand [18].

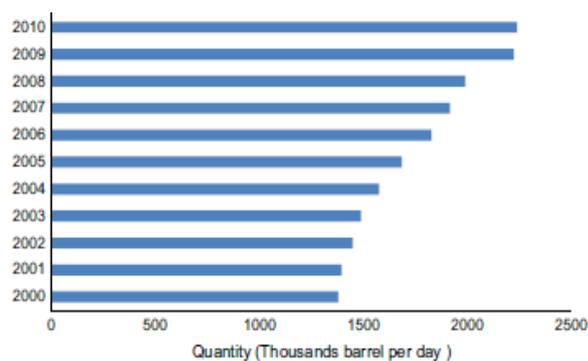


Fig. 3. Differentiation between production and consumption figures of oil in India [18].

India is one of the top 10 oil consuming countries in the world. The country’s existing annual crude oil production is at about 32 million tonnes as against the demand of about 110 million tonnes [19]. In India, bulk of the freight (over 60%) and passenger traffic (over 80%) is carried by road; and diesel and petrol contribute to 98% of the energy consumed in the transport sector[20]. Oil imports during April– May 2007 were valued at US\$ 9165.20 million and the oil import bill is expected to rise to \$120 billion in 2011–2012 [21]. This fact is well established by the production and import data of edible oil (Fig. 3) [22]. It is estimated that proportionate consumption of petroleum products in India are as follows:-

India is listed in world’s top 10 oil consuming nations. Our crude oil production figure in a year is around 32 million tonnes against the demand of around 110 million tonnes [19]. In our nation, freight includes 60% plus and passenger includes 80% plus is carried by road and collectively diesel and petrol figures around

98% of the energy is utilized in transport sector [20]. Imports of oil during April-May 2007 were calculated as US\$ 9165.20 million and import of oil is expected to increase to \$120 billion in 2011-12 [21].

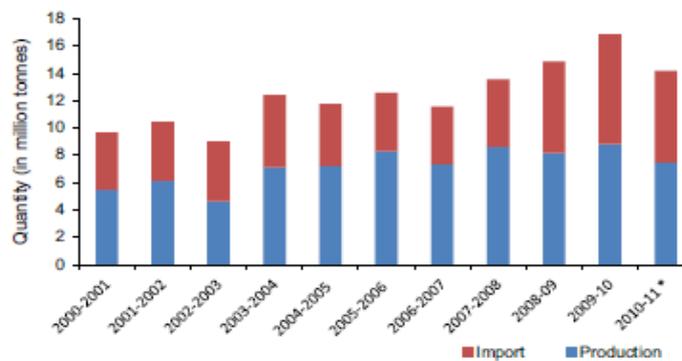


Fig. 4. Production and Import of edible oil in India [22].

Transport (Petrol, Diesel, CNG, and Aviation Fuel)	: 51 percent
Industry (Petrol, Diesel, Fuel Oil, Naphtha, Natural Gas)	: 14 percent
Commercial and Others	: 13 percent
Domestic (LPG and Kerosene)	: 18 percent
Agriculture (Diesel)	: 4 percent

That's why in regards of usage, demand of energy is greatest amongst transport sector. Roads are very important parameter in nation's infrastructures for transport which is 85-90% in passenger & 65 % in freight. Growth in road's traffic and vehicle growth is 7-10% and 8-10% every year respectively.

III. MAHUA

The properties like high oiliness, viscosity and indices, higher flash points, less evaporative loss and low full accounting cost (includes operational and nature replenishment cost) are technical in nature which gives competitive edge and hence they are preferred even after some inferior traits like reduced oxidation and thermal stabilities, poor cold flow properties, lower shelf life, but researches are working on these parameters and can be improved by applying some modification in techniques and systematized research [23-27]. There is large numbers of varieties in oil (Edible & Non Edible), only some are short listed as far as their potential is concern. Edible oils are used by all the population because of their food dependency, some non edible oils are also useful for food but mostly are not used and hence has low usage in food and hence low dependency as far as food parameter is concern that's why due to this only non edible oils could be utilized as alternative fuels having untapped potential and also multiply to the rural economy. Even after showing promising benefits very few attempts have been taken by previous researchers [28-32]. Non edible oils are the main source of making biodiesel in India and Mahua is taken as probable oil seed feed stock for the production of biodiesel. [33-34].

3.1 MAHUA LITERATURE

In India, we can find Mahua plant in many states like Orissa, Chattishgarh, Jharkhand, Bihar, Madhya Pradesh and Tamil Nadu and for getting successfully mature. It uses waste and dry land which is not at all useful for any kind of other vegetation. Its plant does not require any special or specific kind of attention as it is easily adaptable in any weather condition, resulting maximum height attains 20 m, wide spreading roots and branches along with circular crown & nice appealing structure. Fruits look like egg shaped berries and mature seeds can be drawn from June to July [35]. Moving ahead to its plantation part, its tree have been very useful in Indian economy, mostly carries the rural one. Season of flower ranges from February to April, rich in sugar content (73%) just next to cane molasses. It also carries basic raw material for alcohol fermentation and in one tonne of

its dried flower carries 450 liters of alcohol yield. 50 % of oil contained by kernel of mahua fruit and its fresh oil is yellow in color where as its commercial oil is normally greenish yellow in color. The mahua tree takes 8 to 15 years to become mature and can draw fruits up to 60 years of age. As discussed it has highly spreaded roots which withholds the soil and all these happens on waste land which helps our rural people to grow along with national economy [36].

3.2 MAHUA BOTANICAL FEATURES

The botanical name is *Madhuca Indica* which represents the Sapotaceae family with common names as

Sanskrit:	Madhuka
Andhra Pradesh:	Yappa
Gujarat:	Mahuda
Hindi:	Mahua, Mohwa,
Karnataka:	Hippe
Kerela:	Ponnam
Maharashtra:	Mahwa
Orissa:	Mahula, Moha
Tamil Nadu :	Illupei
West Bengal:	Mahwa, Maul
English:	Butter tree.

A deciduous tree, 10 to 15m tall and with a spreading, dense, round, shady canopy. Bark is rough, brown in colour, slightly cracked and fissured, inner bark red, exudes white, milky sap when cut. Leaves elliptic, 15-25 x 8-15cm, tip pointed, base angled, texture thick, hairy beneath, nerves strong, about 12 pairs, tertiary nerves oblique, and margin entire but may be wavy. Stalk 2-4cm, reddish. Flowers in bunches at the end of the branches, white, 2cm long, pointed, sweat scented, fleshy. Fruits ovoid, fleshy, 2-4cm across, greenish, 1-4 seeded. Seeds elongate, 2 cm long, brown shining [36].

3.3 MAHUA AS FUEL

As far as Mahua's fuel property are concerned it is comparable with diesel fuel and is available in good quantities that too underutilized. Its calorific value is 96.30% on volume basis of diesel. It does not have any significant change if we mix mahua oil by 20% in diesel in terms of power output, brake specific fuel consumption and brake thermal efficiency. By using mahua oil blends, performance of engine improved which enhance compression ratio from 16:1 to 20:1. With above results it is found that mahua oil can be treated as substitute of diesel but with proper care and can show profitability when it could be taken to large scale production. Table 1 Shows the characteristics of fat & Table 2 Shows the fuel properties of Mahua oil and Diesel. Stage wise concern is required like in sowing season along with latest agro techniques, proper pest control and post harvesting management [36].

TABLE 1. Characteristics of Fat [36]

S. No	Characters	Characteristic / valve
1	Colors	Pale Yellow
2	Consistency	Plastic
3	Refractive Index at 40 degree	C1.451 to 1.463
4	Specific gravity at 15 degree	C 0.857 to 0.871
5	Iodine valve	58.00 to 70.00
6	Specification valve	188 to 195
7	Un specification valve	1.00 to 3.00

TABLE II. Fuel properties of Mahua oil and Diesel [36]

S. No	Properties	Unit	Diesel	Mahua Oil	IS Limits for Grade A and B diesel
1	Specific Gravity		0.829	0.905	
2	Kinematic viscosity at	C & T			
3	40 deg Celsius		2.45	37.19	2.0 - 7.5 at 38°C grade A
4	80 deg Celsius		0.67	11.67	2.5 - 15.7 at 38 °C grade B
5	Calorific Value	mj/kg	44.02	38.964	
6	Pour Point	°C	-5	15	6 max grade A 12-18 max grade B
7	Flash Point	°C	47.5	238.4	55 min grade A 66 min grade B
8	Carbon Residue	%	0.034	0.4216	0.2 max grade A 1.5 max grade B
9	Ash Content	%	0.0065	0.022	0.01 max grade A 0.02 max grade B
10	Water Content	°C	Trace	Trace	0.05 max grade A 0.25 max grade B
11	Distillation temperature IBP		Trace	90	
12	90% Recovery		365	285	366 °C for grade A

3.4 USES OF MAHUA

Madhuca Indica oil is not properly utilized vegetable oil which is available in bulk in India. Properties of MI oil fuel are shown in the limits of specification of many countries and is comparable with pure diesel. Fuel properties of diesel, mahua oil and blends are comparable. The calorific value of mahua oil was found as 96.30% on volume basis of diesel. It was found that mahua could be easily substituted up to 20% in diesel without any significant difference in power output, brake specific fuel consumption and brake thermal efficiency. The performance of engine with mahua oil blends improved with the increase in compression ratio from 16:1 to 20:1. Based on this study, it has been observed [36].

3.5 MAHUA YIELD

If we think biodiesel as the industry we have to face feed stock supply as top challenge because producers are looking for such type of non-food crop that too from non-agricultural land means with cheaper feed stock. It can also sustain in any type of weather conditions that means it is matching all the requirements of the market. Mahua will yield at Maturity as high as +3 tons oil with proper nutrition, and irrigation. Table 3 shows approximate yield/hectare of Mahua oil. This is totally an extraordinary amount of oil from an agricultural crop [36].

TABLE III. Approximate Yield/hectare [17]

S. No	Optimal yield	
1	Seed yield	10.0 tons
2	Oil (36% of Yield) ton	3.60 ton
3	Biodiesel ton	3.60 ton
4	Plantation cost	US\$ 250.0/ha
5	Maintenance cost	US\$100.0 /ha
	UNDER COC TECHNOLOGY	
6	Crop cultivation & care cost	US\$ 1250.0/ha
7	Oil Production	6.00 tons

3.6 MAHUA OIL EXTRACTION & PURIFICATION OF MAHUA OIL

Mahua Oil extraction process can be done with or without seed coat; also if we choose appropriate and efficient oil extraction method, we can enhance the yield by more than 5%. Like in case of *Jatropha*, by using mechanical de hulling system so as to take out coat of seed, we can get 10 % increased yield. In cold pressing where temperature is less than 60°C, up to 88% and in hot pressing where temperature is 110 – 120°C, up to 90% efficiency is achieved. The solvent extraction method increases the efficiency till 99% but it carries disadvantage too, with the solvent extraction is that the quantity of phospholipids in solvent extracted oil is double as high as compared to pressed oil. It requires then a further step of oil de gumming before trans-esterification. Oil extraction methods are also being developed based on fermentation hydrolysis. In this process, cell walls of the oil plant seeds are destroyed followed by the release of the oil present within the cells [37]. Table 4 shows comparison of fatty acid and composition (%) of various seed oil [38].

TABLE IV. Comparison of Fatty Acid Composition (%) of Various Seed Oil [38]

S. No.	Fuels	Palmitic Acid	Stearic Acid	Oleic Acid	Linoleic Acid	Arachidic Acid
1	Mahua Seed Oil	16-28.4	20.00-25.00	41.0-51.0	10.00-14.00	0-3.31
2	Cotton Seed Oil	20.00	2.00	35.00	35.00	----
3	Coconut Oil	8.00-11.00	1.00-3.00	5.00-8.00	0-1.00	0-0.50
4	Karanja Seed Oil	3.74-7.92	2.41-8.91	44.51-71.34	10.81-18.32	2.21-4.72
5	Rape Seed Oil	1.51	0.41	22.0	14.3	----
6	Castor Seed Oil	2.00	1.00	7.00	5.00	----
7	<i>Jatropha</i> Seed Oil	12.00-17.0	5.00-9.50	37.5-63.5	19.0-41.0	0.31

3.7 PROPERTIES OF MAHUA OIL

Table 5 Shows Comparative Data of Mahua oil with oils of Different Origin & Pure Diesel.

TABLE V. shows properties of Mahua oil & its comparison

S. No.	Properties	Diesel	Mahua Oil	<i>Jatropha</i> Oil	Karanja Oil
1	Calorific value [MJ/kg]	42.9	39.3	39.12	38.11
2	Density [kg/m ³]	841	911	879	88.6
3	Viscosity [cSt]	3.62	5.91	4.77	5.82
4	Flash Point [oC]	63.5	130.5	163	190.5
5	Fire Point [oC]	75.5	146.5	176	192.5

IV. ECONOMIC EVALUATION & POTENTIAL RETURNS

To become environmentally sustainable fuel, it must have three criteria that are social, technical and commercial. In Northern India i.e. in Bihar, Madhya Pradesh and Orissa, rural people are getting 40% economy which is based on mahua seeds and flowers. Its tree requires little attention when root is nicely holding the soil; seed gives yield from 20 to 200 kg/tree annually and it has its own socio-economic value. On the commercial platform these trees can be planted on either of the road sides, railway tracks, canal banks or any other tribal/rural areas. In many countries researchers have found that Madhuca Indica Oil has properties within biodiesel limits, hence it can be termed as renewable fuel. The tree has the quality to reduce the level of carbon dioxide and hence reduces the level of green house gas (GHG). This kind of projects will give income generation opportunities to the rural/tribal people and in our nations favour resulting successful implementation of mahua oil as substitute to diesel on larger scale that too with non-agricultural land.

V. FUTURE OF BIODIESEL (NON-EDIBLE OILS) IN INDIA

India is also well known as agricultural country but it also has the immense potential to produce biodiesel from non-edible oils. Non-edible oils are being produced from the wasteland and as per Government of India did the economic survey, the report says in statistics that about 175 million hectares are marked as waste and degraded land and this gives us the regulator to maintain the supply of feed stocks for the large scale project. We need to erect the mechanism with a certain utilization path which will gear up at national level like other countries are doing across the globe. Industries along with proper government plans have to play an important role in defining a clean supply chain policy which exercises the Life Cycle Analysis on biodiesel production.

VI. CONCLUSION

With the above results, we can wrap up that mahua tree is very useful, economical and each part is used by the local residents. Leprosy can be cured by using bark mahua and also wounds can be healed. We can collect fresh mahua flowers in the morning and which is financially viable in nature. Using mahua flowers we can prepare many dishes with fresh and dried ones, also one can eat fresh flowers as well. In tribal regions, liquor made of mahua is very famous and could be prepared by doing distillation of dried mahua flowers and its fruit pulp can also be used for preparation of alcohol.

Alcohol from the flowers of mahua capitulates 340 litres per tonne of flowers. These flowers and fruits after segregating pulp could be used as farm stock to cattle's. Its flowers has certain medicinal impacts and tribal's use it to get relief from cardiac diseases, biliousness and throat infections where as its fruit provides medicinal affects in which blood diseases can be cured. Matured fruit is nourishing in nature and can be eaten raw or cooked.

Mahua seeds are of profitable in nature with every aspect like extraction of oil, its oil is also used for skin allergies and for the making of soap and detergents. Mahua seed contains oil which varies from 33-43% of the weight of kernel. It also reduces the cholesterol level of heart because of linoleic acid. Unfortunately we have scarcity of proper marketing of mahua flowers and seeds to the market that's why it remains only a product of forest with tribal people for local purpose, just a local person is purchasing the same from villagers and supply it to actual market of oil expellers. Table 3 shows the fatty acid composition aspects of many other non edible oils, their properties and characteristics which help us to judge better or best biodiesel. Density, Viscosity, flash point and fire point of mahua oil are on greater side with less calorific value which is in the range of 86% in comparison with pure diesel.

With these we can think for mahua as fuel oil and our nation has such a vast land area fertile and unfertile. Unfertile land is huge and can be taken for commercialisation of mahua crop so as to get the fuel oil. It has property as good fertilizer and villagers are also drawing oil but commercially it will definitely reduce our dependency on petroleum oils which are imported to meet our nation's demand, also thereby saving lots of foreign exchange to enhance nation's economy. Concluding with all the above facts, it has seen that there are many probabilities to make biodiesel from non edible oil sources which will help us to capitalise the manufacturing of biodiesel.

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