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Mahua (Madhuca Indica) oil: A potential source for biodiesel production in India

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Abstract: The economic development of a country is highly dependent on the supply of fossil fuels which are constrained by its limited availability and pollution characteristics. India is among the world's fourth-largest petroleum consumer due to which the vehicular emissions increased eight times over the last two decades. Due to the environmental awareness and depletion of fossil fuel reserves, attention has been given to find an alternative energy source. Among the alternatives existing, Biodiesel is the one which is less polluting and eco-friendly. So it can be used in industrial, commercial, agricultural and other sectors as a substitute for diesel. Biodiesel can be produced from crude vegetable oil, non-edible oil, frying oils (waste), animal tallow and algae by a process of chemical reaction called Transesterification. Biodiesel is also known as methyl or ethyl esters of the feedstock from which it is produced. It is miscible with diesel oil which allows the use of blends of petro diesel and biodiesel in any percentage. The C.I. engines fuelled with biodiesel perform more or less in the same fashion as that with the conventional fuel. Comparative to diesel, biodiesel has high Cetane number and lower compressibility. Additionally, the heat release rate of biodiesel is slightly lower than diesel owing to low calorific value, low volatility and high viscosity. The problem of high viscosity can be eradicated by transesterification process and by adding additives which help us to store the biodiesel for a longer duration of time without any decay. Exhaust emissions are significantly reduced with the use of biodiesel or its blends. The present paper investigates the potential of Mahua (Madhuca Indica) oil for biodiesel production as it can be extracted from seeds of Mahua tree which are indigenous to India. It can grow even in dry regions and are found abundantly in several parts of India.

Keywords: Madhuca Indica, Mahua, Free Fatty Acid (FFA), Transesterification.

1 Introduction: Dr. Rudolf Diesel, invented the Diesel Engine in 1895, used only bio-fuel in his engine. His statement was "The application of vegetable oils as engine fuel may seem insignificant today, but such oils may become in course of time, as important as products of petroleum and coal of present time". The above prediction came true today as more and more biodiesel is being used all over the world. Scientists E. Duffy and J. Patric conducted the process of Transesterification of a vegetable oil in the early 1853, years before the first diesel engine became operating. On August 31, 1937, G. Chavanne of the University of Brussels (Belgium) was given a patent for the transformation of vegetable oils for their uses as fuels. The use of biodiesel was recognized much earlier and became technically relevant only after the energy crisis in the year 1973 and afterward. Vegetable oils have high viscosity due to large molecular weight and bulky molecular structure. High viscosity liquid fuels affects the flow properties and also sprays atomization, vaporization, air/fuel mixture formation. Higher viscosity has an adverse effect on the combustion of vegetable oils in diesel engines. Temperature greatly affects the viscosity of vegetable oils.

Mahua oil is obtained from the kernel of Mahua seed (Madhuca Indica) which have 50 - 55% oil. The oil contains fatty acids similar to those in cooking oils as oleic acid, Linoleic acid, Stearic acid and Palmitic acid. The specific gravity of Mahua oil is 9.11% higher than diesel. The kinematic viscosity of Mahua oil is 15.23 times more than diesel at temperature of 40ºC. The kinematic viscosity of Mahua oil decreases considerably with increase in temperature up to 80ºC and by increasing the ratio of diesel in fuel blends **[1 - 7]**.

2. Characteristics of Mahua Oil:

As per standard methods, the physical and chemical properties of Mahua oil are determined in Department of Chemical Engineering, B.I.T., Mesra – Ranchi. Table 1 shows the comparison between Pure Mahua oil properties with Diesel. The properties like Kinematic viscosity, flash point, fire point and density of Mahua oil is higher than diesel. The calorific value of the oil is observed to be lower than diesel. Viscosity is determined in Redwood Viscometer and other properties like flash and fire point is determined by using Cleveland Open cup apparatus in the above-mentioned laboratory. Determination of calorific value is carried out in a Bomb calorimeter in Aerospace Engineering Department, B.I.T., Mesra. The density of Mahua oil is found to be 0.87g/cc at 20°C which is higher than diesel. The Flash and Fire point are found to be 360°C and 368°C respectively which are very higher than Diesel. The % FFA (Free Fatty Acid) content of oil is determined by the method of titration.

Property	Unit	Pure Mahua Oil	Diesel
Density at 20°C	g/cc	0.87	0.80
Kinematic Viscosity at 40°C	Cst	51.85	3.80
Calorific Value	MJ/Kg	38	42
Flash Point	°C	360	68
Fire Point	°C	368	73
Pour Point	°C	13	-18
Cloud Point	°C	12	-15
Acid Value	mg KOH/mg	38	0.35
Free Fatty Acid	%	19	0.17

Table1: Comparison of Pure Mahua oil and Diesel characteristics.

2.1 Required Properties of Mahua Oil as Fuel:

The diesel and Mahua oil performance on the Diesel Engine is quite similar as per the experiments conducted by the researchers **[8 - 10]**. The properties of good vegetable oil as a substitute for diesel are;

- Viscosity: High viscosity of oil can lead to problems like increased system pressure, injection problem, cold starting problem whereas the lower viscosity oil causes internal leakages.
- Calorific Value: The calorific value of various vegetable oils lies in the range of 30-40 MJ/Kg. For vegetable oils, the calorific value nearer to diesel oil is desirable.
- Flash Point and Fire Point: The higher values of flash point and fire point are desirable because of safety point of view. For smooth working the temperature should be high.
- Pour Point and Cloud Point: For cold weather operations, the satisfactory working is possible only when the pour and cloud point values are below the freezing point of the oil used.

- Blending with Diesel: The proper mixing of vegetable oil and diesel in different proportion is desirable. As the temperature increases the percentage blend of diesel decreases. As a result, of which we can run the engine on pure vegetable oil.

2.2 Demerits of Mahua Oil as Fuel:

a. The high viscosity of vegetable oils causes atomization and pumping problems in the injection system, as it creates filter plugging and cold starting.
b. Vegetable oil mixes with the lubricant oil and forms sludge's on all parts of the engine.
c. After combustion, a large amount of carbon deposition on the injection nozzle tips and in the combustion chamber.
d. The poor volatility causes vegetable oil difficult to ignite and vaporize.

2.3 Ways to Overcome the Demerits:

a. Starting problems can be overcome by starting aids like glow plugs and fuel heaters.
b. Modification of fuel such as Pyrolysis, micro-emulsification, dilution and transesterification.
c. Filter plugging is minimized if crude oils are made gum free by passing through a filter (four micrometer).

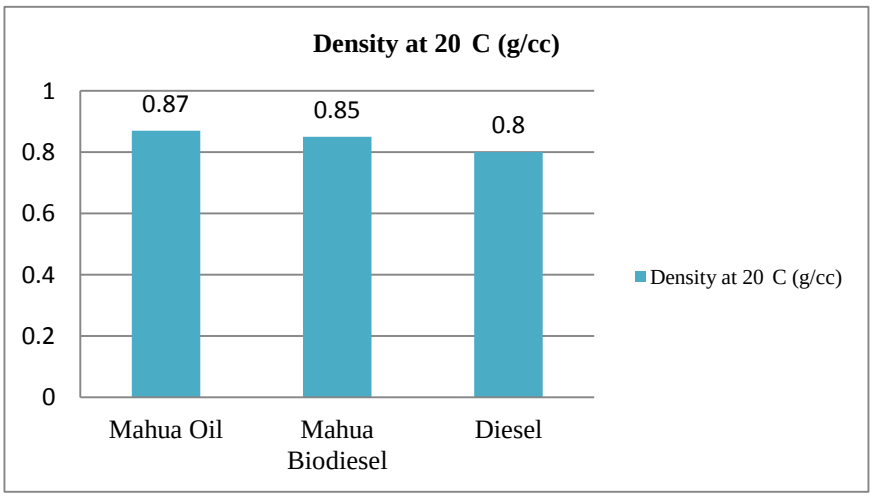
2.4 Methodology:

For the treatment of oil, the methods used are Pyrolysis, micro-emulsification, dilution and transesterification. Among all the methods transesterification reaction is a most preferred method as found in the literature **[1, 7, 8]**, as it is a less expensive way of transforming vegetable oil to biodiesel. Transesterification is also known as alcoholysis. It is the removal of alcohol from an ester by another alcohol same as the process of hydrolysis. This process is mainly used to reduce the viscosity of oils (triglycerides). Triglycerides are easily transesterified in the presence of the alkaline catalyst at atmospheric pressure and at a temperature of 60°C to 70ºC with an excess of methanol. The transesterification works well when the initial oil is of high quality. But, quite often low-quality oils are used for biodiesel preparation. In which the free fatty acid content is above 1%, difficulties arise by the formation of soap which promotes emulsification during the water washing stage. FFA content above 2% the process becomes unworkable.

In this investigation, the theoretical value of %FFA for Mahua oil is quite higher. So, the two-step process of esterification in the presence of acid catalyst and Transesterification in the presence of a basic catalyst is carried out to reduce the %FFA to less than 1 which makes it comparable to Diesel.

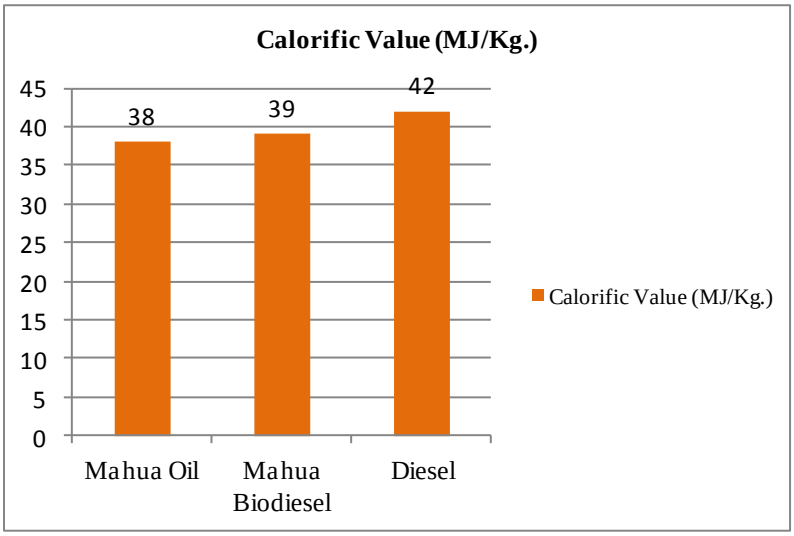
3. Results and discussion:

3.1 Density: As shown in Graph1, the density of Mahua oil at 20°C is observed to be 0.87g/cc, which is higher than that of Diesel. But it is reduced down to 0.85g/cc after Transesterification reaction.



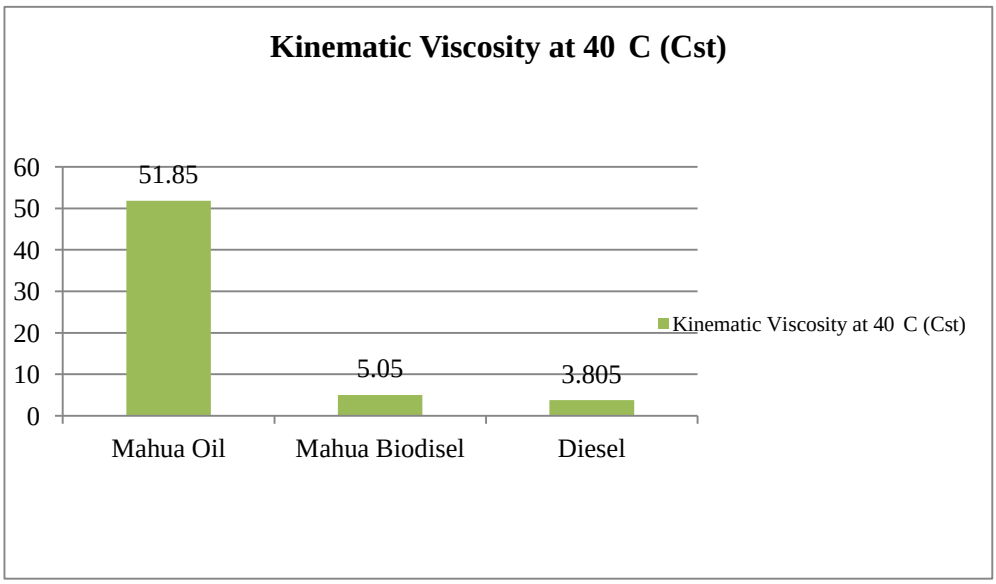
Graph1: Density of Mahua oil, Mahua Biodiesel and Diesel

3.2 Calorific Value: As shown in Graph2, the calorific value of Mahua oil is observed as 38MJ/Kg. which is lower than that of Diesel. But the value increased to 39MJ/Kg. after Transesterification process and becomes comparable to Diesel.



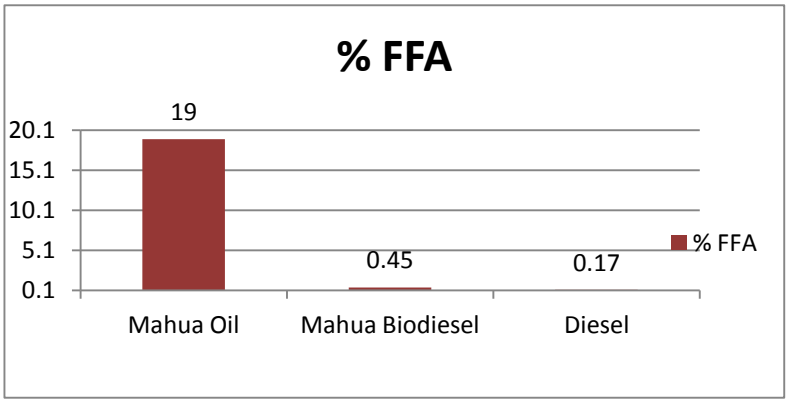
Graph2: Calorific Value of Mahua oil and Diesel.

3.3 Kinematic Viscosity: As shown in Graph 3, the Kinematic viscosity of Mahua oil is observed as 51.85Cst which is quite higher than that of Diesel. The kinematic viscosity of Mahua oil is further reduced to 5.05Cst by Transesterification process which becomes comparable to diesel.



Graph 3: Kinematic Viscosity of Mahua oil, Mahua biodiesel and Diesel.

3.4 %FFA: As shown in Graph4, the theoretical value of Mahua oil in comparison to Diesel is found to be 19% which is much higher than diesel. The experimental value of %FFA is reduced to 0.45 by Transesterification process which becomes comparable to diesel.



Graph4: % FFA of Mahua Oil, Mahua Biodiesel and Diesel.

4. Conclusions: The important parameters like Density, Calorific Value, Viscosity, Flash Point, Fire Point, Pour Point, Cloud Point and %FFA are determined in this study. As evident, properties of Mahua oil are comparable to diesel except viscosity and %FFA which is later reduced and made comparable to diesel by two-step process of esterification and transesterification. Since the oil is indigenously produced from seeds of Mahua trees which are found abundantly in rural areas of India, its application in C.I. engine will reduce the degradation of the environment and shall also reduce our dependency on foreign imports.

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