Dual Bio-Fuel As An Alternate Fuel For CI Engines With Enhanced Physical And Chemical Properties

Navdeep Sharma Dugala, Gyanendra Singh Goindi

Abstract: We know that our world is heavily dependent on petroleum fuels, which leads to an increase in petroleum products price, increase in emissions with hydrocarbon, carbon dioxide, and NOX. To overcome these problems new alternative energy sources, need to be developed to minimize the dependency on fossil fuels and reduce emissions. Biodiesel is becoming one of the prominent alternate energy re-source because of the factors relating to economic growth of a country and the environmental reasons. It can be used with mineral diesel without any major engine changes or modifications. Biodiesel is mono alkyl fatty esters of animal fat, edible and non-edible oil vegetable oil. Majority of work done on biodiesel production from blending of vegetable oil with mineral diesel. But no work has been suggested in biodiesel preparation by combining two different biodiesel blends with mineral diesel at different blending ratios. In this work, Mahua and Jatropha biodiesels, obtained by the transesterification method, were used to prepare. Dual-fuel biodiesel fuels were mixed at different percentages to study the physico-chemical properties of the dual-fuel biodiesel. It was found that the properties of the cold flow of dual-fuel are optimal at 50% blends.

Index Terms: Mahua Oil Biodiesel, Jatropha biodiesel, Dual Bio-Fuel, Transesterification, Cold flow properties.

1 INTRODUCTION

In recent years the continuously accelerating use of petroleum fuel is causing the exhaustion of fossil fuel reservoirs. This is due to an increase in the human population, the ever-increasing demand for industrialization, which indirectly leads to the rise in the cost of refinery and products obtained from petroleum. The combustion of petroleum products results in HC, CO2 and NOx emissions. Due to the above-mentioned reasons the alternative energy resources are becoming more attractive as they are renewable, sustainable and produce less or no emissions as compared to conventional fuel. Biodiesel is easily renewable, eco-friendly, non-toxic, and has wide availability compared to conventional used diesel fuel[1], [2]. It is an alternate fuel derived from the vegetable oil which could be first or second generation or animal fats[3], [4]. Biodiesel is produced through different methods like Blending, Emulsification, Pyrolysis and Trans-esterification[5]. The common approach to produced biodiesel is through a simple process called transesterification, as it is the easiest way to produce biodiesel. Lots of work have been done on Jatropha, Palm and other oils which are mostly based on one oil biodiesel, i.e. just blending single biodiesel into diesel. Fewer work has been reported by combining two separate biodiesel blends with mineral diesel [6]. Hass et al.[7] have reported that using a blend of soybean soap stick biodiesel with mineral diesel in 20:80 ratio by volume could reduce CO, HC, and PM emissions by 2.40%, 27.70%, and 19.70 % respectively when comparing to standard diesel. Hifjur Rahman et al.[8] found a good fuel combustion emission and 21% fewer soot deposits by using B10 blends of Simarouba oils and Mahua oil in the ratio of 50:50 with mineral diesel oil. Srithar et al. [9] conducted an experiment using blends Pongamia pinata oil and mustard oil with diesel oil. B10 shows 0.32 kg/kWh specific fuel consumption and diesel shows 0.31 kg/kWh. Bhupendra et al. [10] have described that using Jatropha biodiesel along with engine performance, combustion characteristics, and variations in emissions. Srithar et al. [9] have stated that in the past lots of work has been done by researchers on biodiesel production from the blending of vegetable oil with mineral diesel. But no work has been reported in biodiesel preparation by combining two different biodiesel blends with mineral diesel at different blending ratios. Dual biodiesel fuel enhances the low temperature properties and reduces the emissions of the diesel engine. Hanny Johannes Berchmans et al. [11] revealed that low temperature properties of Jatropha Biofuel are better, so in this research, we’ve selected the Jatropha biodiesel and Mahua biodiesel for the preparation of the dual-fuel biodiesel. Amr Ibrahimhas [12] studied and reported that blends of 5% diethyl ether and diesel can improve the engine performance mostly at all engine loads. Senthur Prabu et al. [13] experimented on diesel and Palm oil to produced biodiesel by blending them. Biodiesel produced from Palm oil with antioxidants has shown better engine performance and reduction in emission levels for different blends. A DI diesel engine was used for testing. Nalgunwar et al. [14] have taken a combination of Palm and Jatropha biodiesel and blended it with diesel to perform an experiment on a single-cylinder direct injection diesel engine. Senthil et al. [15] used a catalytic cracking technique for biodiesel produced from Mahua oil biodiesel. Potassium hydroxide and activated red mud were used as catalysts. Activated red mud catalyst has shown a reduction in engine exhaust emission as well as consumption of fuel. Sanjid et al. [16] have performed experimentation on the 1-cylinder diesel engine to measure engine combustion, engine out emissions, noise, vibrations and harshness characteristics. Further, the power output of engine fueled by dual biodiesel of Jatropha and Palm biodiesel blends was also determined. Mahua oil has a calorific value of 5% inferior to the diesel fuel [17], [18]. Both Mahua raw seed oil and Jatropha raw seed oil have high FFA (Free fatty Acid) content which is around 19%-20% [19]. To reduce the FFA content of both crude oils, the pretreatment

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process is required for that. The yield percentage of the oil depends upon the various parameters like reaction temperature, the temperature of oil, the ratio of oil to alcohol, kind of catalyst used and concentration taken and also the purity of reactants used to obtain biodiesel. Methanol is used instead of the Ethanol for the preparation of the biodiesel as methanol has better reactivity than the ethanol. Acid catalyst (H₂SO₄) is used during the pretreatment process and base catalyst (KOH) is used during the transesterification process. The reason for this is the high percentage of the FFA content in the seed oils because if we directly use the base catalyst the reaction will not take place properly instead the formation of soap takes place and the catalyst is no longer available for the reaction. Mahua biodiesel and Jatropha biodiesel has better combustion and emissions properties than that of the conventional mineral diesel as it found out by various researchers in the past. Cold flow properties of Jatropha biodiesel are better than Mahua biodiesel as it has higher value for pour and cloud point. To improve the low temperature properties of the Mahua biodiesel, we blended the Mahua biodiesel with Jatropha biodiesel in different blending ratios, in order to find out optimum blending ratio for dual fuel. Studies have found that the thermal stability of biodiesel and vegetable oils is better than standard diesel fuel [20]. In this experimental research, we have prepared the dual-fuel biodiesel with non-edible vegetable oil in order to achieve better cold flow properties of the biodiesel and which conforms to the ASTM standards.

2 MATERIAL AND METHOD

The raw Mahua seed oil and the raw Jatropha seed oil were purchased from the Himani International, Delhi and the methanol (99% pure) was purchased from the Oswal scientific stores, Chandigarh. The acidic catalyst used for the pretreatment was H₂SO₄ (Sulfuric acid), the base catalyst used for the trans-esterification was KOH (Potassium hydroxide) which is present in the pellet form. The experiment was conducted in the chemical laboratory at Chandigarh University. The experiment was conducted using laboratory scaled equipment and glassware.

2.1 Preheating

The raw Mahua seed oil and the raw Jatropha seed oil was preheated separately at a temperature of 90°C-100°C for 30 minutes and was stirred manually with the help of glass stirring rod at the time interval of 5 minutes regularly to eliminate the any water content and to remove any unwanted dust particles and then filtered the heated oil using the 5-micron filter paper.

2.2 Pretreatment

The reasons behind opting for the two-step process for biodiesel production is that as both Mahua and Jatropha oil have about 19% FFA content which is very high and after the pretreatment process the FFA fall under 1% which will result in better yield of the oil. Each sample of both the raw oil was made using different alcohol to oil ratio.

Sample1: Raw Mahua oil

Preheated Mahua oil is used for the pretreatment process, 75% v/v alcohol to oil and 1.5% v/v H₂SO₄ which act as an acidic catalyst is used for the process. All the reactants were poured in a glass beaker and the reaction was carried out for the 2 hours in the water bath, the temperature of the water bath was kept at 60°C-80°C and the mixture was stirred at an interval of 5 minutes manually with the help of glass rod. After the reaction, the mixture was poured into the separating funnel and given a settling time of 1 hour.

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R^1\text{COOH} + \text{ROH} = R^1\text{COOR} + \text{H}_2\text{O}
\]

Sample2: Raw Jatropha oil

Preheated Jatropha seed oil was used for the pretreatment process, 50% vol. /vol. methanol to oil and 1% v/v Sulphuric acid which act as an acidic catalyst is used for the process. All the reactants were put into the chemistry lab glass beaker and then the reaction was allowed to happen for 1 hour 30 min. in the water bath, the water bath temperature was kept approximately in the range 60°C-80°C and the mixture was stirred at an interval of 5 minutes manually with the help of glass rod. After the reaction, the mixture was settled into the separating funnel giving it a settling time of 1 hour.

![Fig. 1 Pretreatment process](image-url)
For sample 2: Jatropha raw seed oil

For the second step to produce biodiesel we followed the same process as we followed during the preparation of Mahua biodiesel. For the preparation of methoxide solution, 20% oil to methanol, 1%w/v base catalyst Potassium Hydroxide (KOH) which is present in pellet form is used. Methanol and KOH are mixed in a conical flask with the cork on top and stirred vigorously until the pallets of the KOH get dissolved in the methanol. After adding this methoxide solution to the pretreated oil, the reaction is carried for 1 hour at a temperature which varies from 60°C-70°C in a water bath. The mixture is being stirred manually by using the glass rod at every 5 minutes. The mixture is then let to settle for an overnight in the chemistry lab separating funnel and then the layer of biodiesel and glycerol is bringing separated out.

2.4 Distillation
After separating out the biodiesel from the glycerol, some amount of glycerol could still be present due to cold weather conditions. In order to remove the unwanted amount of glycerol hot water washing method is used. We added the hot boiled water in the methyl ester which was kept inside the separating funnel and remove the layer of glycerol after mixing it with the methyl ester from the bottom by opening the outlet valve. Keep repeating this process until we get a clear layer of water at the bottom. In the end, again heat the methyl ester up to 100°C in order to remove any water moisture left.

3 IMPROVING THE COLD FLOW PROPERTIES
Biodiesel production from feedstocks like animal fats, edible and non-edible vegetable oils that are high in fats especially the saturated ones, creates problems during the cold weather conditions. In the cold running conditions, biodiesel faces some cold flow problems like gelling, chocking the injectors, etc. These low temperature properties of biofuel obtained can be solved by mixing another biodiesel into it, to get the desired biodiesel properties that overcome the cold flow problem. As to overcome these problems we use some additives to get the desired cold weather properties of the biodiesel. Mahua biodiesel doesn’t have good cold flow properties. For improving the low temperature properties of biofuel, we blended Mahua biodiesel with Jatropha biodiesel which is known for its good cold flow properties. The transesterification method used in biodiesel production slightly reduces the
viscosity and enhances the calorific value[9]. Different blends of dual-fuel were prepared of Mahua biodiesel and Jatropha biodiesel, a blend of 50%v/v i.e. Mahua biodiesel and 50% Jatropha biodiesel demonstrate the desired physico chemical properties of biodiesel which could bear the cold weather conditions.

4 METHODOLOGY
In order to determine whether the biodiesel has the physico chemical properties within the permissible limit, it is necessary to find out the cold flow properties of samples using the required lab experiments. Cloud point is the temperature at which the gel-like crystals start forming in the sample and pour point is that minimum temperature for which the sample becomes half solid and has a minimal tendency to flow.

5 RESULT AND DISCUSSION

Table 1 Physico chemical properties of raw Mahua oil and raw Jatropha oil

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Property</th>
<th>Raw Mahua Oil</th>
<th>Raw Jatropha Oil</th>
<th>Mineral Diesel</th>
<th>ASTM (6751-02)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density (kg/m³)</td>
<td>950</td>
<td>985</td>
<td>830</td>
<td>850-870</td>
</tr>
<tr>
<td>2</td>
<td>Specific Gravity</td>
<td>.950</td>
<td>.985</td>
<td>.830</td>
<td>.850-.870</td>
</tr>
<tr>
<td>3</td>
<td>Kinematic Viscosity(cSt)</td>
<td>24.99</td>
<td>24.76</td>
<td>2.60</td>
<td>1.8-6.0</td>
</tr>
<tr>
<td>4</td>
<td>Cloud point (°C)</td>
<td>12</td>
<td>2</td>
<td>-3</td>
<td>_</td>
</tr>
<tr>
<td>5</td>
<td>Pour point (°C)</td>
<td>8</td>
<td>-3</td>
<td>-8</td>
<td>_</td>
</tr>
<tr>
<td>6</td>
<td>Flash point (°C)</td>
<td>235</td>
<td>230</td>
<td>50</td>
<td>130 min</td>
</tr>
<tr>
<td>7</td>
<td>Fire point (°C)</td>
<td>245</td>
<td>240</td>
<td>60</td>
<td>135 min</td>
</tr>
</tbody>
</table>

Table 2 Physico chemical properties of Mahua biodiesel, Jatropha biodiesel and Dual biodiesel

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Property</th>
<th>M.B.D</th>
<th>J.B.D</th>
<th>Dual Biodiesel (M50J50)</th>
<th>ASTM (6751-02)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density (kg/m³)</td>
<td>875.4</td>
<td>920</td>
<td>905.3</td>
<td>850-870</td>
</tr>
<tr>
<td>2</td>
<td>Specific Gravity</td>
<td>.875</td>
<td>.920</td>
<td>.905</td>
<td>.850-.870</td>
</tr>
<tr>
<td>3</td>
<td>Kinematic Viscosity(cSt)</td>
<td>3.57</td>
<td>3.16</td>
<td>3.4</td>
<td>1.8-6.0</td>
</tr>
</tbody>
</table>

4. Cloud point (°C) 6 -2 3 __
5. Pour point (°C) 2 -5 -2 __
6. Flash point (°C) 180 185 172 130 min
7. Fire point (°C) 190 195 182 135 min

5.1 Density
The density of raw Jatropha oil is higher than the other fuels. The density is calculated at room temperature (20°C). Density, viscosity, and CV of oils can affect the output parameters of the compression ignition engine[21].

5.2 Specific Gravity
The specific gravity of the Jatropha oil is higher than the other fuels.

5.3 Kinematic Viscosity
Kinematic viscosity of raw Mahua oil is greater than the other fuels, it is calculated at 40°C with the use of Redwood Viscometer.
5.4 Flash Point
It is the minimum temperature at which the fuel vapors catch fire when ignited. Flash point of the Mahua seed oil is higher than the others, flash point is calculated with the help of Pensky Martens closed cup apparatus.

5.5 Fire Point
It is that minimum temperature at which the fuel will start to burn continuously for at least 5 seconds, Mahua seed oil has the highest fire point among the other fuel samples. Pensky Martens apparatus is used to find the fire point.

5.6 Cloud Point
Jatropha biodiesel has lower cloud point than Mahua biodiesel and the cloud point of M50 J50 is better than Mahua biodiesel which results in better cold flow properties.

5.7 Pour Point
Jatropha biodiesel has a better pour point than Mahua biodiesel, the pour point of the M50 J50 is better than Mahua biodiesel. As the pour point of M50 J50 is better it would lead towards better cold flow properties.

6 CONCLUSIONS
In the research work, we've found out various results which are as follow:

- The raw seed oil of Mahua and Jatropha have such a higher free fatty acid content that to improve their physico chemical properties they are required to be processed through pretreatment before the actual transesterification process.
- Jatropha and Mahua biodiesel have better-compensating physico chemical properties so they can be blended to produce dual fuel.
- M50 J50 has better cold flow properties than the Mahua biodiesel and other blends.
- The Low temperature properties of the blended dual fuel come out to be 39.28% better than Mahua biodiesel.
- Low temperature properties of biodiesel can be enhanced by the blending of another biodiesel into it.
This work can be further extended to the testing of the dual fuel on the single-cylinder diesel engine to analysis the combustion behavior and emissions characteristics.

7 REFERENCES