Comparative Evaluation of Edible and Non-Edible Oil Methyl Ester Performance in a Vehicular Engine

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Abstract

This paper examines the performance and emission characteristics of biodiesel produced from edible oil source (palm) and non-edible oil source (Jatropha) and compared that with fossil diesel fuel. Only 20\% palm and 20\% Jatropha biodiesel (described by PB20 and JB20 respectively) were examined because it has been suggested by the commercial company that up to 20\% biodiesel can be used in a diesel engine without any engine modification. The physical and chemical properties of PB20 & JB20 are also presented and compared with diesel fuel (B0). The performance of these fuels and their emissions were measured in a multi-cylinder diesel engine at different engine speeds and at full load condition. The test results indicated that both PB20 and JB20 fuels produce slightly lower brake powers and higher brake specific fuel consumption compared to diesel fuel. Engine emission results indicated that the PB20 and JB20 fuel reduces the average emissions of carbon monoxide (CO) and hydrocarbons (HC). However, the PB20 and JB20 fuels slightly increases nitric oxides (NO) emissions compared to diesel fuel. Although PB20 have slightly better emission performance than JB20 biodiesel, JB20 biodiesel should be used in unmodified diesel engines to meet the global energy demand and to reduce emissions into the atmosphere because it does not create food versus fuel conflict.

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1. Introduction

Transportation system has a great importance for social and economic development of any country. The rising issue for transportation sector is the energy, which is mainly fulfilled by gasoline and diesel fuel. Globally 1.1\% in average energy consumption is increased in the transportation sector every year. The transportation sector accounts for the largest share (63\%) of the total growth in world consumption of...
petroleum and other liquid fuels from 2010 to 2040 [1]. There are about 22% global GHG (greenhouse gas) emissions come from the transportation sector due the increasing demand of vehicles. Rapid growth of the number of vehicle industry in the world has resulted increase of exhaust emissions to the environment. Vehicular emissions such as particulate matter (PM), hydrocarbon (HC), carbon dioxides (CO$_2$), carbon monoxides (CO) and nitrogen oxides (NOx) are hugely responsible for the air quality deterioration [2]. The International Energy Agency (IEA) forecasts that the emissions of CO$_2$ from transport sector will increase by 92% between 1990 and 2020 [3]. Also it is estimated that 8.6 billion metric tons of CO$_2$ will be released to the atmosphere from 2020 to 2035 [3]. The consumption of both petrol and diesel has been increasing rapidly with growing motorization and increasing the GHG emission worldwide.

It is very urgent to find out alternative fuels for transportation sector as this sector is emitting higher GHG emission and contributing to the rapid growth of global oil demand [4]. Recently, attention has been drawn to develop cleaner alternative fuels from renewable sources to reduce the harmful emission to air and to reduce the dependency on the petro-diesel fuel [5]. The most clean alternative fuel for vehicles being considered globally is biodiesel [2]. Biodiesel is produces from available resources like vegetable oils (palm, soybean, peanut, sunflower, rape, coconut, karanja, neem, cotton, mustard, Jatropha, linseed and castor), animal fat (from pork, chicken) and greases (used cooking oils and restaurant frying oils) through a chemical process known as transesterification [6-8]. Biodiesel have several advantages over fossil fuel such as smoother engine operation by enhancing better lubricity and better combustion characteristics. Though biodiesel has some disadvantages, such as the higher production cost and the poor cold flow properties of biodiesel to use it in colder climate. Biodiesel can reduce greenhouse gas emission to the atmosphere by lowering CO, HC and particle matters etc. Many research projects around the world are now conducted to ensure the effectiveness of biodiesel addressing these problems including the utilization of biodiesel and by product of bio-diesel (glycerol) [9]. In this investigation, a comparison of engine performances (power, fuel consumption) and emissions (unburnt hydrocarbons, carbon monoxide and nitric oxide) of diesel engine using two different bio-diesels namely PB20 and JB20 and diesel fuel is performed.

**Table 1: Fuel properties of crude oils, biodiesel and diesel fuel**

<table>
<thead>
<tr>
<th>Properties</th>
<th>Standards</th>
<th>CPO</th>
<th>CJO</th>
<th>PB20</th>
<th>JB20</th>
<th>B0</th>
<th>ASTM D6751</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic viscosity at 40°C (mPa.s)</td>
<td>ASTM D445</td>
<td>36.30</td>
<td>31.52</td>
<td>2.92</td>
<td>3.03</td>
<td>2.69</td>
<td>-</td>
</tr>
<tr>
<td>Kinematic viscosity at 40°C (mm$^2$/s)</td>
<td>ASTM D445</td>
<td>40.40</td>
<td>34.93</td>
<td>3.47</td>
<td>3.63</td>
<td>3.23</td>
<td>1.9-6</td>
</tr>
<tr>
<td>Density (kg/m$^3$)</td>
<td>ASTM D1298</td>
<td>898.4</td>
<td>902.5</td>
<td>840.1</td>
<td>834.9</td>
<td>827.2</td>
<td>-</td>
</tr>
<tr>
<td>Viscosity index</td>
<td>N/A</td>
<td>192.1</td>
<td>204.5</td>
<td>149.8</td>
<td>159</td>
<td>90</td>
<td>-</td>
</tr>
<tr>
<td>Cold Filter Plugging Point (°C)</td>
<td>ASTM D6371</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Cloud Point (°C)</td>
<td>ASTM D2500</td>
<td>8</td>
<td>-2</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td>Pour Point (°C)</td>
<td>ASTM D97</td>
<td>9</td>
<td>-3</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>ASTM D93</td>
<td>165</td>
<td>220</td>
<td>78.5</td>
<td>84</td>
<td>68.5</td>
<td>130 min</td>
</tr>
<tr>
<td>Calorific value (MJ/Kg)</td>
<td>ASTM D240</td>
<td>39.44</td>
<td>38.66</td>
<td>43.99</td>
<td>44.19</td>
<td>45.30</td>
<td>-</td>
</tr>
<tr>
<td>Acid value (mgKOH/g oil)</td>
<td>ASTM D664</td>
<td>3.47</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0.5 max</td>
<td>-</td>
</tr>
</tbody>
</table>
2. Experimental Materials and Methods

Crude Palm oil (CPO) and Crude Jatropha oil (CJO) were collected from Forest Research Institute, Malaysia (FRIM). All other chemicals, reagents and accessories were purchased from local markets. Table 1 shows the properties of CPO and CJO. Biodiesel from those crude oils were produced using transesterification process described by Mofijur et al. [9]. The physico-chemical properties of the produced biodiesel were characterized according to the ASTM D6751 standards. Then the test fuels were blended with diesel for 20 minutes using a homogenizer operated at 2000 rpm to be used in the engine. A Mitsubishi Pajero (model 4D56T) multi-cylinder vehicular engine was used to perform the performance and emission test. Fig. 1 shows the schematic diagram of engine test bed. Table 2 shows the details specification of the engine. A BOSCH exhaust gas analyzer (model BEA-350) was used to measure the NO, HC and CO emissions from the engine.

![Schematic diagram of engine test bed](image)

Table 2: Details specification of the test engine

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine type</td>
<td>4 cylinder inline</td>
</tr>
<tr>
<td>Displacement (L)</td>
<td>2.5</td>
</tr>
<tr>
<td>Cylinder bore x stroke (mm)</td>
<td>92 x 96</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>21:1</td>
</tr>
<tr>
<td>Maximum engine speed (rpm)</td>
<td>4200</td>
</tr>
<tr>
<td>Maximum power (kW)</td>
<td>55</td>
</tr>
<tr>
<td>Fuel system</td>
<td>Distribution type jet pump (indirect injection)</td>
</tr>
<tr>
<td>Lubrication System</td>
<td>Pressure feed</td>
</tr>
<tr>
<td>Combustion chamber</td>
<td>Swirl type</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Radiator cooling</td>
</tr>
</tbody>
</table>

3. Results and discussion

3.1 Engine Performance Study

3.1.1 Brake Power (BP)

Fig. 2 compares the engine brake power (BP) output of PB20, JB20 and B0 at different engine speeds. For all tested fuels, the brake power increased steadily with the engine speed up to 3500 rpm then it decreased due to the higher frictional force. At all test speeds, the average brake powers of the B0, PB20
and JB20 fuels were 28.72, 26.73 and 26.35 kW, respectively. Compared to diesel fuel, the PB20 and JB20 fuels produced lower brake powers (6.92% and 8.25%, respectively) due to their lower calorific values and higher viscosities (Table 1), which influenced combustion [10,11].

![Fig. 2: Variation of brake power with speed](image)

3.1.2 Brake Specific Fuel Consumption (BSFC)

Fig. 3 illustrates the variation of the BSFC values for all fuels at different engine speeds. Biodiesel blended fuels gave higher BSFC values than diesel fuel due to some factors such as volumetric fuel injection system, the fuel density, the viscosity and the lower heating value [12, 13]. At all speeds, the average BSFCs for the B0, PB20 and JB20 were 385.71, 406.42 and 413.32 g/kWh, respectively. Compared to diesel fuel, the BSFCs were 5.42 and 8.39 higher for the PB20 and JB20, respectively. The blends’ BSFCs were higher for the biodiesels because their densities and viscosities are higher, and their energy densities are lower, than diesel [14]. Both the viscosity and the density of the JB20 were higher than for PB20 (Table 1).

![Fig. 3: Variation of brake specific fuel consumption with speed](image)

3.2 Engine emission study

3.2.1 CO emissions

The variation of CO emissions with diesel and biodiesel blends is shown in Fig. 4. Over the entire range of engine speeds, the average reduction of CO emissions was by 36.68% and 27.23% for PB20 and JB20.
relative to B0, respectively. Similar result was reported by Hirkude and Padalkar [15]. This reduction of CO emissions is attributed to the higher oxygen content and cetane number of biodiesel fuel. The higher oxygen content of biodiesel allows more carbon molecules to burn, and fuel combustion is complete. Thus, CO emissions are lower when diesel engines burn biodiesel fuel.

![Fig. 4: Variation of CO emission with speed](image)

### 3.2.2 HC emissions

The variation of HC emissions for diesel and biodiesel blend fuels is shown in Fig. 5. For the PB20 and JB20, the unburned HC emissions are lower than for diesel fuel. Over the entire range of speeds, the average reductions in HC emission for the PB20 and JB20 are 30.26% and 19.78% relative to B0, respectively. These reductions are attributed to the high oxygen contents of these biodiesel fuels. Biodiesel contains more oxygen and less carbon and hydrogen than diesel fuel, which guarantees more complete combustion [5].

![Fig. 5: Variation of HC emission with speed](image)

### 3.2.3 NO emissions

The variation of the NO emissions for diesel and biodiesel blend fuels is shown in Fig. 6. The NO values are higher for biodiesel blends than diesel fuel. On average, the PB20 and JB20 produce 6.91% and
15.10% higher NO emissions, respectively, than diesel fuel over the entire range of speeds. This result can be attributed to the higher adiabatic flame temperature. Biodiesel fuels that contain more unsaturated fatty acids have higher adiabatic flame temperatures, which cause higher NO emissions [16].

![Fig. 6: Variation of NO emission with speed](image)

### 4. Conclusions

In this study, biodiesel was produced from crude Palm and Jatropha oils, and 20% biodiesel by volume blends were evaluated in a diesel engine. It can be concluded that, the performance of PB20 and JB20 biodiesel is comparable with diesel fuel. Even though PB20 have better performance than JB20 biodiesel but JB20 biodiesel reduce exhaust emission in a great extent than diesel fuel and JB20 biodiesel doesn’t complete with food. So JB20 can replace diesel fuel in unmodified engines to reduce the global energy demand and exhaust emissions into the environment.

### References


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**Biography**

M.A. Hazrat is currently enrolled in PhD program in the School of Engineering & Technology, Central Queensland University, Australia. He has a keen interest on applied engineering analysis in the areas of thermo-fluid, thermodynamics and energy engineering. At present, he is pursuing research on alternative fuel processing, properties determination and application in the automotive engines.