Biodiesel conversion from high FFA crude *jatropha curcas*, *calophyllum inophyllum* and *ceiba pentandra* oil

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Abstract

Biodiesel is a renewable energy that has great potential as an alternative fuel to fossil diesel in diesel engine. The potential non-edible feedstock for biodiesel is now being taken into careful consideration for the purpose of continuing biodiesel production while not negatively affecting the food issue. The crude *jatropha curcas, calophyllum inophyllum* and *ceiba pentandra* oil have free fatty acid value which is above 2%. Therefore, a pretreatment acid catalyzed esterification process is required to reduce the free fatty acid content. It was found that *jatropha curcas, calophyllum inophyllum* and *ceiba pentandra* oil at 9:1 M ratio (methanol to oil) with preheat at 60°C and reaction at temperature 55°C for 60 minutes in the presence of 1% KOH in order to get lower acid values (0.39 mg KOH/g, 0.45 mg KOH/g and 0.40 mg KOH/g) and obtained high methyl ester yield (98.23%, 98.53% and 97.72%). This study had shown that improvement in biodiesel properties by using two stage esterification-transesterification methods. The major fuel characteristics such as kinematic viscosity, density, flash point and calorific value of biodiesel fulfilled American Society for Testing Materials (ASTM) biodiesel standards.

1. Introduction

Transportation sector is one of the major causes of globalization and has a vital contribution to the economy. Although the sector is growing quickly and providing benefits, it has caused serious negative impact to the environment [1]. Currently, many researcher focuses to non-edible oil as duel source for transportation due to the food vs. fuel problem. The non-edible oil can be used for biodiesel production such as *jatropha curcas, pongamia pinnata, calophyllum inophyllum, ricinus communis* and *ceiba pentandra* [2]. Vegetable oils are a renewable and potentially inexhaustible source of energy with an energetic content close to diesel fuel. Historically, it is believed that Rudolf Diesel himself started research with respect to the use of vegetable oils as fuel for diesel engines [3]. However, due to their high viscosity (about 11 to 17 times higher than diesel fuel) and low volatility, they do not burn completely...
and form deposits in the fuel injector of diesel engines [3]. In view of above, this study was conducted to compare the production of biodiesel with two stage esterification-transesterification processes and its fuel characterization following to ASTM D6751 standard.

2. Botanical description

*Jatropha curcas* L. is classified to *euphorbiaceae* family. It is a drought-resistant plant capable of surviving in abandoned and fallowed agricultural land. The plant is native to Mexico, Central America, Brazil, Argentina and Paraguay [4]. *Jatropha curcas* is well adapted in semi-arid conditions, low in fertility and capable to grow on marginal soils [5]. The oil contents in seed are about 55–60% respectively. The yield of oil is 1590 kg per hectare.

*Calophyllum inophyllum* L. oil is non-edible oil and its low cost makes it an important raw material for biodiesel production. *Calophyllum inophyllum* is belonging to the family clusiaceae, commonly known as mangosteen family. The tree yields 100–200 fruits per kg. The seed of *calophyllum inophyllum* tree has been reported to be 2000 kg per ha. The oil is tinted green, nutty smelling and the seed has very high oil content around 65-75% [6]. The yield of oil is 4680 kg per hectare.

*Ceiba pentandra* L. (malvaceae) is an oleaginous species native to Southeast Asia, India, Sri Lanka and tropical America [7]. *Ceiba pentandra* L. oil is viscous, dark brown nonvolatile and non-dry oil. Seeds are brownish black in color and contain about 25–28% of oil in each fruit. The average oil yield was around 1280 kg per hectare.

3. Methodology

3.1 Materials

The crude *jatropha curcas* oil (CJCO), crude *calophyllum inophyllum* oil (CCIO) and crude *ceiba pentandra* oil (CCPO) were purchased from Cilacap, West Java, Indonesia. All other chemicals and solvents used during biodiesel production, purification and analysis were purchased from Merck Sdn Bhd (Kuala Lumpur, Malaysia).

3.2 Biodiesel production

The crude oil were received and stored in a vacuum chamber to avoid oxidation in the biodiesel production. Experiments were conducted in 1 liters of necked flask with tight stopper caps and condenser connected to refrigerator cooling bath. The condenser is used to retain the vaporization of methanol during the reaction. The temperature of oil was controlled by a thermometer and regulated by an electrically heated water bath (Model: Wise Circu Model: WCR-P8). The reactor was digital mechanically (Model IKA 16 basic) stirred to assure a good mixing of the reactants. The biodiesel derived from oil was prepared by reacting 1 liters of oil, 9:1 molar ratio (methanol to oil and 1 %vol. of H$_2$SO$_4$ and 1 %wt. KOH. The reaction was carried out for 60 minutes under reflux at 55°C and 1000 rpm stirring.

4. Result

4.1 Characterization of crude oils and fatty acid composition

The crude vegetable oils used in this study were *jatropha curcas*, *calophyllum inophyllum* and *ceiba pentandra* oil. These three crude vegetable oils have high viscosity which was 28.35 mm$^2$/s, 53.17 mm$^2$/s and 34.45 mm$^2$/s for *jatropha curcas*, *calophyllum inophyllum* and *ceiba pentandra* oil respectively. Besides, the high acid values of three oils were 25.4 mg KOH/g, 46.6 mg KOH/g and 33.6 mg KOH/g respectively. Thus, a two-step catalyzed and neutralization process was needed to produce the biodiesel from crude oil. The characteristics and the physicochemical properties of these three crude oils were determined and shown in Table 1.

**Table 1** Physical and chemical properties of CJCO, CCIO and CCPO

Table 2 Physical and chemical properties of JCME, CIME and CPME

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<tr>
<td>Density at 15º C (kg/m³)</td>
<td>880</td>
<td>881.9</td>
<td>884</td>
<td>896.6</td>
<td>869</td>
<td>876.9</td>
<td>875</td>
<td>839</td>
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<tr>
<td>Kinematic viscosity at 40º C (mm²/s)</td>
<td>5.42</td>
<td>4.57</td>
<td>4.0</td>
<td>4.61</td>
<td>5.4</td>
<td>4.15</td>
<td>2.91</td>
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<tr>
<td>Acid number (mg KOH/g)</td>
<td>0.39</td>
<td>0.45</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.15</td>
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<tr>
<td>Flash point (ºC)</td>
<td>171</td>
<td>158.5</td>
<td>140</td>
<td>156.5</td>
<td>156</td>
<td>71.5</td>
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<tr>
<td>Pour point (ºC)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
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<tr>
<td>Cloud point (ºC)</td>
<td>13.2</td>
<td>4.3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
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<td>Oxidation stability at 110º C (hours)</td>
<td>39.890</td>
<td>40.104</td>
<td>41.397</td>
<td>40.493</td>
<td>36.292</td>
<td>45.825</td>
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5. Conclusion

Nowadays, production of biodiesel from non-edible feedstocks is more attractive than in the past and switch grass have emerged to be very promising feedstocks for biodiesel production. Therefore, three potential biodiesel feedstocks which are CJCO, CCIO and CCPO are proposed in this study. A two-step of acid-alkaline catalyst transesterification has been used to produce biodiesel from this feedstock. The optimum condition were methanol to oil ratio of 9:1 with 1% (v/v) of H₂SO₄ acid catalyst esterification and 1% (w/w) of KOH catalyst transesterification. The optimum methyl ester yield obtained was 98.23%, 98.53% and 97.72% for JCME, CIME and CPME respectively. It was found that most of the parameters of methyl ester comply with ASTM D6751 and EN14214 specifications. Based on these results, it is proven that *jatropha curcas*, *calophyllum inophyllum* and *ceiba pentandra* can be utilized as a feedstock for biodiesel.

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References:


