The effect of palm biodiesel composition on the physical properties of Calophylluminophyllum-palm biodiesel mixture

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Abstract. The increasing energy consumption and depletion of fossil fuels require the need for alternative source of fuels. Biodiesel is an alternative fuel developed and can replace or reduce the use of petroleum diesel. One of its development processes is to change fatty acid composition through the mixing of different raw materials namely Calophylluminophyllum and palm oil. Calophylluminophyllum oil is a non-edible raw, while palm oil is an edible raw material which is abundantly produced. The research was carried out by processing palm and Calophylluminophyllum oil into biodiesel using transesterification. Furthermore, both kinds of biodiesel were mixed with 11 variations of the composition. The results showed that mixing biodiesel Calophylluminophyllum and palm oil produced positive results with decreased viscosity and increased calorific value.

Keywords: biodiesel, Calophylluminophyllum, palm, fatty acid

1. Introduction
The need for biodiesel is rising as the demand for energy increases followed by the depletion of petroleum reserves. The biodiesel raw materials are vegetable oil and animal fat [1–3], but its production requires more vegetable oil. Vegetable oil comprises of triglycerides which are composed of three molecules of fatty acid and one molecule of glycerol [4,5]. It is obtained from a variety of plants, including food crops such as soybean, palm oil, coconut and non-food crops such as jatropha and Calophylluminophyllum [1]. Each vegetable oil has a different composition of fatty acids and this affects the biodiesel properties [6].

Biodiesel has biodegradable, environmentally friendly and renewable properties[2]. Its deficiencies are mainly high viscosity and relatively low calorific value[7]. The physical and chemical properties of biodiesel are strongly influenced by its fatty acids structure[6]. In accordance with its structure, a fatty acid can have either positive or negative influence on the nature of biodiesel. The composition of fatty acids also can be varied therefore, various biodiesel properties can be obtained. The alternative is to improve the properties by varying the composition of fatty acid and its constituent[8].

One potential non-food crop is Calophylluminophyllum which is an edible oil seed which belongs to the Clusiaceae family. This plant has many origins including Southeast Asia, East Africa,
India, and Australia [1]. Conversely, the food crop that is produced abundantly, especially in Southeast Asia, is oil palm. Palm oil is a tropical perennial plant and grows well in lowlands with damp places. Therefore, it can be cultivated easily in Indonesia, Malaysia and Thailand. Besides having a high level of production, its oil content is also high [1].

The combination of *Calophyllum inophyllum* and palm oil is used to indicate that changes in composition affect the physical properties of biodiesel. The purpose of this study was to determine the effect of palm oil composition on the physical properties of *Calophyllum inophyllum*-palm biodiesel mixture.

2. Methods

2.1. Material

The materials used in this research were *Calophyllum inophyllum* and palm oil. The physical properties of *Calophyllum inophyllum* and palm oil were presented in Table 1. The content of fatty acids in palm and *Calophyllum inophyllum* oil are presented in Table 2.

| Properties                      | *Calophyllum inophyllum* Oils | Palm Oils |
|---------------------------------|------------------------------|-----------|
| Density, 40 °C (kg m\(^{-3}\)) | 910.13                       | 889.30    |
| Viscosity, 40 °C (cSt)          | 49.22                        | 30.59     |
| Flash Point (°C)                | 264                          | 189       |
| Heating value (MJ kg\(^{-1}\)) | 90,547,663                   | 93,795,791 |

| Fatty acid                                   | Abbreviation | *Calophyllum inophyllum* Oil | Palm Oil |
|----------------------------------------------|--------------|-----------------------------|----------|
| Methyl Butyrate                              | C4:0         | 6.24                        | 1.21     |
| Methyl Palmitate                            | C16:0        | 11.67                       | 35.27    |
| Methyl Octadecanoate                        | C18:0        | 14.3                        | 3.84     |
| Cis-9-Oleic Methyl Ester                    | C18:1        | 36.59                       | 43.82    |
| Methyl Linoleate                            | C18:2        | 16.3                        | 12.51    |
| gamma-Linolenic acid methyl ester           | C18:3        | 1.99                        | 0.33     |
| M Cis-5,8,11,14- Eicosatetraenoic           | C20:4        | 10.12                       | 0.4      |
| Linolelaidic Acid Methyl Ester              | C18:2        | 0.52                        | <0.1     |
| Methyl Lenolenate                           | C18:3        | 2.27                        | 0.26     |

2.2. Oil pretreatment

Pre-treatment was carried out for *Calophyllum inophyllum* oil because of the presence of impurities and excess fatty acid content of more than 2%. To remove the impurities from the oil, degumming was carried by reacting *Calophyllum inophyllum* oil with phosphoric acid/H\(_3\)PO\(_4\) (0.2%
of the volume of oil) at 80°C for 15 minutes. Furthermore, washing with water and drying were carried out.

The next process was the esterification reaction to prevent saponification. Esterification was carried out by reacting *Calophyllum inophyllum* oil with methanol (22.5% of the oil volume) using a sulfuric acid (H₂SO₄) catalyst. The esterification reaction was carried out for 60 minutes at 60°C. After the settling process, washing and drying were carried out.

2.3. **Transesterification**
The transesterification process was carried out separately on *Calophyllum inophyllum* and palm oil. Oil was reacted with methanol (15% of the oil volume) using KOH as a catalyst. This transesterification reaction was carried out for 60 minutes at 60°C. The reaction produced biodiesel and glycerol. After settling for 8 hours, glycerol was separated from biodiesel.

2.4. **Washing and drying**
After the separation process, the biodiesel washing was carried out at 60°C temperature of water. Drying to remove water content was carried out by heating biodiesel at a temperature of 105°C for 10 minutes.

2.5. **Mixing**
*Calophyllum inophyllum* and palm biodiesel were mixed with composition of 1:9, 2:8, 3:7 until 9:1. Mixing was carried out for 60 minutes using a mixer equipped with a heater and stirrer. During mixing, the temperature maintained was at 90°C.

2.6. **Testing properties**
The fatty acid composition of the oil raw material was tested using Shimadzu Gas Chromatography (GC) 2010. The density measurement was carried out by measuring the biodiesel mass at a certain volume. Density was measured at 40°C. Dynamic viscosity was also measured at 40°C using the NDJ-8S Viscometer. The fuel calorific value measurement was carried out using the Bomb Calorimeter Parr 6050. Meanwhile, the flash point was measured by the Cleveland Open Cup method.

3. **Result and discussion**
Transesterification does not change the fatty acid composition of the raw material [4]. Fatty acids can be divided into saturated and unsaturated fatty acids [5]. Unsaturated are fatty acids that have double bonds. The degree of unsaturation of fatty acid indicates the number of double bonds. Furthermore, the effect on the physical properties of the biodiesel produced can be obtained based on the fatty acid composition of *Calophyllum inophyllum* and palm oil.

3.1. **Density of biodiesel blends**
Density affects the amount of mass of fuel that can be injected into the combustion chamber. Biodiesel density is influenced by the degree of unsaturation of its constituent fatty acids [9].
Figure 1. Density of Calophylluminophyllum-palm biodiesel blends

From Table 2, it can be observed that the fatty acids making up Calophylluminophyllum oil mostly have a degree of unsaturation by 1 to 4, while palm oil contains methyl palmitate which is a saturated fatty acid of 35%. The average density of unsaturated fatty acids of palm oil was lower than Calophylluminophyllum oil. Therefore, the addition of the palm biodiesel composition to the mixture with Calophylluminophyllum biodiesel will reduce the density of the mixture. Figure 1 shows that the density decreases with increasing palm biodiesel composition. These results correspond with previous studies on the jatropha mixture and waste cooking oil [10].

3.2. Viscosity of biodiesel blends
Viscosity is a very important property which affects the combustion quality. High viscosity causes poor evaporation, narrower injection spray angles, and greater fuel spray penetration in the cylinder[6]. This causes worse overall combustion and higher emissions. High viscosity also affects the fuel flow velocity through the injector which influences the process of fuel atomizing in the combustion chamber therefore, decreasing the power of the engine[11].
Figure 2. Viscosity of *Calophylluminophyllum*-palm biodiesel blends

The viscosity change of biodiesel mixture is shown in Figure 2. The higher the percentage of palm oil the lower the viscosity. Viscosity is influenced by the length of fatty acid carbon chains [6]. Table 2 informs that the fatty acids of *Calophylluminophyllum* oil mostly have carbon chains of 18 and 20, while palm oil has 35% methyl palmitate with carbon chains of 16. The average carbon chains of fatty acids of palm biodiesel are shorter than the *Calophylluminophyllum* biodiesel. This causes the viscosity of palm oil biodiesel to decrease. Therefore the addition of palm biodiesel composition in the mixture with *Calophylluminophyllum* biodiesel will reduce the viscosity of the mixture. These results also correspond with the study on jatropha-soybean biodiesel blends [12].

3.3. Calorific value of biodiesel blends

Figure 3. Heating value of *Calophylluminophyllum*-palm biodiesel blends
Calorific value is the amount of energy found in a fuel. It is also influenced by the structure of fatty acid in the fuel. One of the structural features of fatty acids that affect the calorific value of fuel is the degree of unsaturation. Furthermore, a higher degree of unsaturation of fatty acids causes a reduction in the heating value [6].

The change in calorific value of *Calophylluminophyllum* and palm biodiesel blend is shown in **Figure 3**. The calorific value and palm biodiesel composition have a direct variation. This is due to the degree of unsaturation of fatty acids in *Calophylluminophyllum* biodiesel which is higher than palm biodiesel. Mixing palm biodiesel causes an increase in the calorific value of the *Calophylluminophyllum*-palm biodiesel mixture. This increase in calorific value also occurs in mixing jatropha biodiesel from waste cooking oil [10].

### 3.4. Flash point of biodiesel blends

The lowest temperature at which a fuel produces an amount of steam sufficient for ignition is called the flash point. The higher the flash point value, the less flammable the fuel becomes. Fuels with high flash point tend to be safe in storage [13].

**Figure 4** shows the change in flash point mixture of *Calophylluminophyllum* and palm biodiesel. Flash point decreases with increasing palm biodiesel composition. Palm biodiesel has more fatty acids with shorter carbon chains therefore, reducing the flash point temperature. These results correspond with research reported by Carareto that flash points are influenced by fatty acid structures [14].

### 4. Conclusion

*Calophylluminophyllum* and palm oil have different fatty acid compositions. Palm oil is dominated by palmitic acid (C16:0) and cis-9-oleic methyl ester (C18:1) while the fatty acids in *Calophylluminophyllum* oil mostly have carbon chain lengths of 18 and 20. Mixing biodiesel from both materials produce different physical properties from the original raw material. This indicates that fatty acid structure affects biodiesel properties. Based on the perspective of
Calophylluminophyllum oil as a non-edible feedstock, mixing with palm biodiesel produced positive results with decreased viscosity and increased calorific value.

5. References
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