Fuel Properties of Two Types High-Speed Diesel Blending with Palm Oil Biodiesel in Indonesia

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Abstract. Biodiesel from palm oil (Elaeis guineensis) is one of the promising renewable sources in Indonesia. Biodiesel is renewable transportation fuel and nowadays is being used as a blend with high-speed diesel (HSD). There are two types of HSD in fuel specification of The Indonesian Government, HSD with Cetane No. 48 and HSD with Cetane No. 51. This paper investigates the fuel properties of HSD 48 and HSD 51 blends with palm oil biodiesel with composition 90:10 (B10), 80:20 (B20), and 70:30 (B30). The experimental investigation shows that the fuel blending HSD 48 and HSD 51 with biodiesel up to 30% improve HSD quality, such as increasing cetane number by 10%, increasing lubricity by 10-18%, and decreasing sulfur content by 35%. Furthermore, biodiesel addition to HSD has a negative effect that increases the acid value and water content, decreasing heating value and cold-flow performance, such as cloud point, pour point, and cold filter plugging point. This can be improved by tightening up the quality of biodiesel. However, the addition of palm oil biodiesel up to 30% (B30) is the potential to promote renewable fuels with tolerable characteristics with HSD fuel specification by improving the quality and specification of biodiesel and blends.

Keywords: biodiesel; fuel properties; fuel blend; high-speed diesel.

1. Introduction

Biodiesel is used as a renewable resource, contains methyl esters of fatty acid. Nowadays, biodiesel is increasingly becoming an alternative fuel as substituted for diesel fuel by reducing the consumption of petroleum and engine gas emissions are environmentally safer [1]. Biodiesel is generated from different sources, such as vegetable oils from palm, soybean, waste cooking oil, and animal fats. Vegetable oil has a mixture of various types of saturated and unsaturated fatty acids. These various resources give different basic properties, controlled by alkyl ester structures in biodiesel synthesis [2]. Oxidation stability and cold flow behavior were opposing characteristics because both depend on the compositions of saturated and unsaturated fatty acids [3]. Biodiesel can be used neat or blended with existing diesel fuel without significant modification to the engine. Generally, biodiesel from vegetable oil has higher density, cetane number, viscosity, cloud point, and lower oxidation stability and heating value comparing to commercial high-speed diesel (HSD) [4][5].
Fuel properties of biodiesel-diesel blends are important to meets the standard specifications for diesel fuels. Fuel properties of biodiesel-diesel blends determined by high-speed diesel and biodiesel properties [6]. Therefore, Indonesia has two types of HSD on fuel specification, based on types of cetane number. There are two types of HSD, HSD with Cetane No. 48 (HSD 48) with a sulfur content maximum of 2500 ppm, and HSD with Cetane No. 51 (HSD 51) with a sulfur content maximum of 500 ppm. Palm oil biodiesel is dense, slightly more viscous, and has a narrower boiling interval than diesel fuel due to the fatty acid methyl esters in biodiesel have similar boiling points. Diesel fuel is composed of a wide variety of hydrocarbons with different volatilities. This is the primary reason for the similar but different properties of biodiesel and diesel fuel [7], [8]. Meanwhile, palm oil biodiesel's most critical property is its high cloud point due to its high content of long-chain, highly saturated methyl esters [9].

Verifying biodiesel blend ratio levels is one crucial thing since government regulatory issues may depend on them. In 2020, the Indonesian government implemented a mandatory 30% biodiesel to diesel fuel (B30). The characteristics of palm oil biodiesel form the basis of this policy is as far as the fuel specification of biodiesel and biodiesel-diesel blends [10]. Benjumea [11] presented basic properties of palm oil biodiesel-diesel blends into account the particular characteristics of the distillation curve. The distillation temperature variation with distilled percentage for the tested blends is not uniform throughout the boiling interval. Kinematic viscosity of soybean oil biodiesel with grade No. 1 and No. 2 diesel duels showed that viscosity increased with the increasing percentage of biodiesel [11], [12]. This present paper shows the experimental analysis for fuel properties of HSD 48 and HSD 51 due to the addition of palm oil biodiesel. This work evaluates the cetane number, lubricity, water content, acid number, and cold flow properties of HSD 48 and 51. This approach is more likely to predict the change in biodiesel-diesel's fuel properties up to 30%.

2. Methods

2.1. Blend preparation

The commercial biodiesel used in this work was produced from palm oil by the transesterification process. The methyl esters composition of palm oil biodiesel (POB) was determined by gas chromatography (see Table 1). The commercial HSD 48 and HSD 51 were used as the base to make several blends with a wide composition by in-tank blending. Most of the tests were carried out with B10 (10% POB with 90% HSD), B20 (20% POB with 80% HSD), and B30 (30% POB with 70% HSD), due to their widespread use (Table 2). The base fuels are designated as B0 and B100, respectively. All of the fuels were blends on weight at 25 °C. This preparation on weight has the advantage that the weight fraction does not change with temperature.

Table 1. Chemical composition of palm oil biodiesel by gas chromatography

| Fatty Acid Methyl Ester | Mass Percent |
|------------------------|--------------|
| C12:0                  | 0.22 ± 0.01  |
| C14:0                  | 1.22 ± 0.00  |
| C16:0                  | 45.74 ± 0.06 |
| C18:0                  | 5.14 ± 0.01  |
| C18:1                  | 39.65 ± 0.01 |
| C18:2                  | 6.69 ± 0.04  |
Table 2. Biodiesel content of each diesel fuel blends

| Fuel Blends                  | Mass Percent |
|------------------------------|--------------|
| Diesel Fuel Cetane No. 48    |              |
| (HSD 48)                     |              |
| B0                           | 0            |
| B10                          | 10.0 ± 0.07  |
| B20                          | 20.1 ± 0.07  |
| B30                          | 30.3 ± 0.14  |
| Diesel Fuel Cetane No. 51    |              |
| (HSD 51)                     |              |
| B0                           | 0            |
| B10                          | 10.1 ± 0.00  |
| B20                          | 19.4 ± 0.07  |
| B30                          | 29.9 ± 0.21  |

2.2. Experimental

Cetane number was measured according to ASTM D 613. Density was determined following ASTM D 4052. Kinematic viscosity was determined according to ASTM D 445 using a capillary tube viscometer with a calibration constant of the viscometer at 40 °C. All the test fuels were distilled following the procedure established by ASTM D 86. The temperature values measured were normalized to standard atmospheric pressure recommended by ASTM D 86 through the Sidney-Young correlation. Lubricity was measured according to ASTM D 613. Acidity and water content were determined following ASTM D 664 and ASTM D 6304. The cold flow properties, evaluated by cloud point, pour point, and cold filter plugging point according to ASTM D 2500, ASTM D 95, and ASTM D 6371.

3. Results and discussion

3.1. Basic properties of diesel fuel and biodiesel

The basic properties of HSD 48, HSD 51, and palm oil biodiesel are presented in Table 3. Palm Oil Biodiesel is denser, more viscous, and has a narrower boiling interval than diesel fuel. These were indicating the composition of fatty acid methyl ester in biodiesel has similar boiling points. The most critical property of palm oil biodiesel is its cold flow properties due to its high cloud point, cold filter plugging point, and pour point. At 16°C, palm oil biodiesel starts to form crystals around 15°C. These crystals may plug filters and fuel lines. The other critical properties were that biodiesel has high water content and acid value than diesel fuel. On the other hand, the methyl ester group in biodiesel cause increasing fuel lubricity.
Table 3. Basic properties of HSD 48, HSD 51, and palm oil biodiesel

| Properties          | Unit        | ASTM Method | HSD 48       | HSD 51       | Palm Oil Biodiesel |
|---------------------|-------------|-------------|--------------|--------------|--------------------|
| Cetane Number       | D 613       | 48.3 ± 0.1  | 51.5 ± 0.1   | 54.7 ± 0.1   |                    |
| Density at 15 °C    | kg/m³       | D 4052      | 838.7 ± 0.4  | 836.0 ± 0.6  | 874.9 ± 0.3        |
| Viscosity at 40 °C  | cSt         | D 445       | 2.70 ± 0.01  | 2.99 ± 0.07  | 4.51 ± 0.04        |
| Distillation T₉₀    | °C          | D 86        | 350.4 ± 0.0  | 335.4 ± 0.4  | 351.2 ± 0.0        |
| Lubricity           | micron      | D 6079      | 333.8 ± 1.8  | 321.0 ± 0.4  | 234.3 ± 1.8        |
| Water Content       | mg/kg       | D 6304      | 70.5 ± 3.5   | 69.5 ± 1.0   | 348.7 ± 0.2        |
| Acid Value          | mg KOH/g    | D 664       | 0.11 ± 0.01  | 0.06 ± 0.01  | 0.37 ± 0.01        |
| Sulphur Content     | %m/m        | D 4294      | 0.06 ± 0.0   | 0.02 ± 0.0   | Nil                |
| Cloud Point         | °C          | D 2500      | 9.3 ± 0.1    | -7.3 ± 0.2   | 16.0 ± 0.3         |
| Cold Filter Plugging| °C         | D 6371      | 10 ± 0       | -8 ± 0.8     | 15 ± 0             |
| Pour Point          | °C          | D 97        | 6 ± 0        | -9 ± 0       | 15 ± 0             |

3.2. Effect of biodiesel content

3.2.1. Cetane number
The cetane number is a basic property of diesel fuels that are indicating the ignition characteristics. The effect of biodiesel content on the cetane number (CN) of pure fuels and a wide spectrum blends to 30% is shown in Fig. 1. This parameter can be measured in a specially designed test engine (ASTM D 613), CFR F5 Cetane Rating Unit. As was expected, the cetane number is directly proportional to biodiesel content [13]. The addition of each 10% of biodiesel, contributes to increasing cetane numbers of HSD 48 by 2 point and increasing cetane numbers of HSD 51 by 1 point. Overall, biodiesel's addition up to 30%, causing an increase in the cetane number of HSD 48 by 4.8 points and HSD 51 by 4.1 points.

![Figure 1. Variation of cetane number with biodiesel content](image)

3.2.2. Lubricity
Fig. 2 shows the effect of biodiesel content on the lubricity for pure fuels HSD 48 and 51 and B10, B20, and B30 blends. As shown in this figure, all curves tend to different intercepts, which defines
two zones with different behavior. Biodiesel can improve fuel lubricity by decreasing wear scar diameter [5], [14]. The effect is seen in HSD 48 and HSD 51 blends with biodiesel up to 30%, that the fuel lubricity was increased by 10-18%.

![Variation of lubricity with biodiesel content](image2)

**Figure 2.** Variation of lubricity with biodiesel content

### 3.2.3. Acidity

Fig. 3 shows the effect of biodiesel content on the acid number of HSD 48 and HSD 51 with biodiesel content. As can be seen in this figure, acidity slightly increases with biodiesel content [15]. The increases in acid numbers have more impact compared to HSD 51. HSD 48 blends with biodiesel up to 30% increase the acid value by 0.25 mg KOH/g. HSD 51 blends with biodiesel only increase the acid value by 0.07 mg KOH/g.

![Variation of acid value with biodiesel content](image3)

**Figure 3.** Variation of acid value with biodiesel content

### 3.2.4. Water Content

Fig. 4 shows the effect of biodiesel content on the water content corresponding to three representatives, pure fuels, B10, B20, and B30. The presence of more polar functional groups on biodiesel structure makes it easier to bind water. The higher biodiesel content causes an increase in water content [16].
The B30 of HSD 48 shows an increased water content by 160 ppm. The B30 of HSD 51 shows an increased water content by 60 ppm. The addition of each 10% of biodiesel, contributes to the increasing water content of HSD 48 by 50 ppm, which is on HSD 51 only 20 ppm.

![Figure 4](image)

**Figure 4.** Variation of water content with biodiesel content

3.2.5. Cold flow properties
The cold flow properties are the most critical properties due to its utilization as a neat fuel or in rich biodiesel blends, especially in cold climates or in the winter season [17], [18]. The cold flow properties are evaluated by three-parameter, cloud point, pour point, and cold filter plugging point. Palm oil biodiesel blends up to 30% induces the cold flow properties of HSD 48, that increase by 4°C. Meanwhile, the effect on cold flow properties of HSD 51 increase by 6°C.

![Figure 5](image)

**Figure 5.** Variation of cold flow properties with biodiesel content
4. Conclusions

The fuel properties of palm oil biodiesel and its blends with HSD 48 and HSD 51 were measured according to ASTM standards. Experimental data showing cetane number and lubricity increased. Tightening up the quality of biodiesel properties is important in improving the negative effect of biodiesel blends. The negative effect is increasing acid value and water content, also decreasing heating value and cold-flow performance, such as cloud point, pour point, and cold filter plugging point. The addition of palm oil biodiesel up to 30% (B30) can promote renewable fuels with tolerable characteristics with HSD fuel specification by improving the quality and specification of biodiesel and blends.

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