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Characterization of Mixed Biodiesel and Petrodiesel as Transportation Fuel

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ABSTRACT
The use of biodiesel from palm oil as a substitute for diesel oil is a policy of the Government of Indonesia. In addition to renewable energy, the use of biodiesel as a fuel for transportation and industry is also an effort to reduce imports of diesel oil. Apart from the advantages of renewable biodiesel and almost no sulfur, biodiesel also has several disadvantages when compared to diesel from petroleum. The use of biodiesel as a fuel for transportation must be mixed with petro diesel. In Indonesia today, 30% of diesel fuel sold in the market has been mixed with biodiesel. This paper will present a study related to the percentage of biodiesel blending from various raw materials with petrodiesel to determine the characteristics of the mixed fuel. Biodiesel from palm oil, jatropha and canola is produced in the laboratory. The mixed oil characterization was carried out according to the ASTM test procedure. The viscosity of the mixed oil increases with the increase in the percentage of biodiesel. The flash point value also increases with the increase in the amount of biodiesel in the mixture. The opposite result was obtained for oxidation stability characteristics.

Keywords: *Biodiesel, Petrodiesel, Palm Oil, Characterization, Oil Mixing*

1. INTRODUCTION

Burning fossil fuels can cause environmental pollution, thereby reducing air quality, in addition to exhaust gases in the form of carbon monoxide (CO), sulfur oxides (SOx), and nitrogen oxides (NOx) which cause global warming. The Indonesian government has issued an efficient new and renewable energy development policy to sustain national energy security. In line with the Paris Agreement, the government continues to mitigate Green House Gas (GHG) emissions to meet the commitments stated in the Nationally Determined Contribution (NDC). In terms of mitigation, Indonesia's GHG emission reduction commitment is expressed in percentage reduction of the baseline emission level in 2030. The increasing demand for fuel oil for transportation and industry has prompted government policies to replace diesel oil with biodiesel that is more environmentally friendly. Even the mandatory use of biodiesel is regulated in Permen ESDM 12/2015 with the use of biodiesel (B100) a maximum of 30% by 2025.[1].Since 2009, the Government of Indonesia enacted a mandatory policy on the use of biofuel in the transportation, industrial and power generation sectors, through Minister of Energy and Mineral Resources Regulation No.32 of 2008 concerning Provision, Utilization and Administration of Biofuel as Other Fuels, which has been renewed through ESDM Minister Regulation 2015. The installed capacity of biofuel for biodiesel types has reached 12 million KL per year. Since January 1, 2016, B20 has been implemented on subsidized diesel fuel, while other sectors have been implemented starting September 1, 2018[2]. Biodiesel is chemically a methyl ester made from vegetable / animal oil or fat which is reacted with alcohol (methanol) [3]. The nature of the various fatty esters that make up biodiesel determines the overall nature of biodiesel fuels. The nature of fatty esters is determined by the structure of fatty acids and the alcohol groups [4]. Structural factors that affect the physical properties of the fat ester molecular fuel include chain length, degree of unsaturation and chain branching. The nature of biodiesel fuels that is influenced by the fatty acid profile and structural factors of various fatty esters include ignition quality, combustion heat, cold flow, oxidation stability, exhaust gas emissions, viscosity and lubricity [5]. Biodiesel has similar characteristics to diesel oil, even more environmentally friendly because it does not contain sulfur or aromatics but has a high oxygen content of 10-11% by weight. [6]. This feature of biodiesel is very effective in reducing emissions of hydrocarbons, carbon monoxide and particulates [7-9]. However, on the other hand, there are some disadvantages of biodiesel that inhibit its use, namely kinematic viscosity and higher density, and have a lower heating value than diesel oil.

Biodiesel can be blended perfectly with petroleum diesel and mixing in various compositions to improve fuel quality. But chemical differences in biodiesel and petroleum diesel can cause differences in physical-chemical properties that will affect engine performance and pollutant emissions [10]. At present, up to 20% biodiesel mix with petroleum diesel can be used in all diesel engines without modification [11].

This paper reports the results obtained from measuring the characteristics of the diesel - biodiesel mixture, as input to guarantee that blended fuel run into Indonesian National Standard. This is done in order to support the government's policy to increase the target of using biodiesel for transportation from 20% to 30%.

2. EXPERIMENTAL

2.1. Materials

The biodiesel used in this study came from palm oil, canola oil and castor oil. Biodiesel from castor oil is obtained commercially, while the other two biodiesels are made in the laboratory. Biodiesel production is carried out through a transesterification process using methanol and potassium hydroxide (KOH) as a catalyst. 6.68 g of KOH is dissolved in 50 g of methanol and then mixed with 400 g of vegetable oil. The mixture is then heated at 50 oC for 2 hours. The glycerol formed is removed through gravity separation, while methanol is removed by a rotary evaporator, which is carried out after the mixture is cool at room temperature. FAME is washed with water until a neutral pH is reached to produce methyl esters. Mixing biodiesel with diesel oil is done with the composition of biodiesel from 0-100% by volume. Table 1 shows a sample list of mixing biodiesel with diesel oil.

Table 1. Samples of Biodiesel and Diesel Oil Mixtures

Biodiesel	Palm Oil (P)	Canola Oil (Ca)	Castor Oil (Cr)
0 %	P- B 0	Ca - B 0	Cr - B 0
10 %	P- B 10	Ca - B 10	Cr - B 10
15 %	P- B 15	Ca - B 15	Cr - B 15
20 %	P- B 20	Ca - B 20	Cr - B 20
25 %	P- B 25	Ca - B 25	Cr - B 25
30 %	P- B 30	Ca - B 30	Cr - B 30
40 %	P- B 40	Ca - B 40	Cr - B 40
100 %	P- B 100	Ca - B 100	Cr - B 100

2.2. Characterization

Characterization of several biodiesel properties including water content, density, kinematic viscosity, oxidation stability and flash point is carried out using the ASTM method according to table 2.

Table 2. Equipment used to measure biodiesel and its mixture properties

No.	Characteristic	Equipment	Testing Method
1	Water content	831 Karl Fisher	ASTM D-6304
2	Density	Anton Paar DMA 4100	ASTM D-941
3	Kinematic Viscosity	VB-X6 Yoshida Kagaku	ASTM D-445
4	Oxidation stability	PetroOXY method	ASTM D 525
5	Flash point	RFP-301	ASTM D93

3. RESULTS AND DISCUSSIONS

It is very important to know the basic characteristics of a mixture of biodiesel and petroleum diesel to ensure that the fuel from the mixture meets the diesel fuel specification standards, especially those applicable in Indonesia. Table 3 presents the characteristics of the initial biodiesel utilized in the experiment.

Table 3. Characteristics of biodiesel and diesel used

Characteristics	Palm	Canola	Castor	Diesel
Water content (ppm)	152.1	165.6	194.9	45
Density (g/cm³)	0.8771	0.8840	0.8847	0.8333
Kinematic Viscosity (cst)	5.30	5.21	5.21	3.07
Oxydation Stability (min)	46	33	14	104
Flash point (°C)	162	176	166	66

3.1. Water Content

Biodiesel has a higher water content and is easier to absorb water than diesel fuel. This is because biodiesel has the polar chemical structure of the carboxylic ester group so that biodiesel is hygroscopic [12]. Moisture content in fuels can cause several problems, including corrosion, water accumulation, and microbial growth in fuel tanks and transportation equipment.

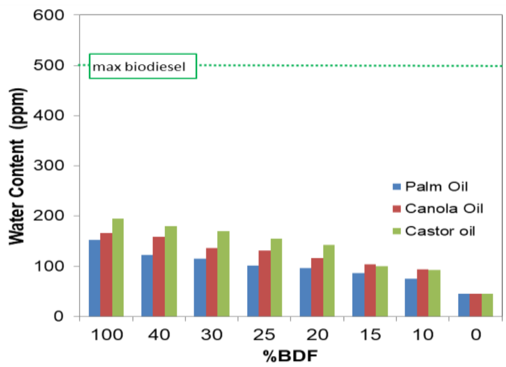

Figure 1 Water content profile in a mixture of biodiesel and petroleum diesel

Figure 1 shows the profile of water content in various biodiesel blends. The highest water content in biodiesel is found in biodiesel derived from castors with more than 4x water content in diesel oil, which is 194.9 ppm. While the water content in biodiesel from palm oil and canola is 152.1 and 165.6 ppm. This moisture content can come from the process of making biodiesel or from water absorbed during storage, especially castor oil that is commercially obtained may have been stored for longer. All biodiesel blends from palm oil, castor oil and canola oil still meet the maximum moisture content requirements of biodiesel, which is 500 ppm. This is due to the high-water content of biodiesel, which is much different from the water content of diesel oil, so that the water content in the biodiesel mixture increases with the increase in biodiesel composition and follows the Arrhenius equation.

3.2. Density

Density is an important property of the fuel that affects the performance of the fuel, such as the quality of atomization and combustion. Biodiesel density is generally higher than diesel oil and is influenced by the composition of fatty acids and their purity. Density can be used as an indicator of contamination because contamination in biodiesel significantly affects density. Density greatly influences cetane number and heating value of fuel [13].

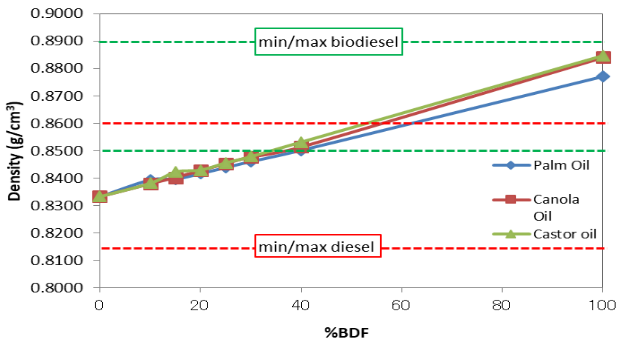

Figure 2 Density profile of a mixture of biodiesel and petroleum diesel

Figure 2. shows that under various conditions the mixing of diesel oil is still in accordance with the Indonesian National Standard for biodiesel (0.850 - 0.890) and diesel (0.815 - 0.860). The greater the composition of the biodiesel, the higher the density of the mixture. This is because the initial biodiesel density, which is greater than the diesel density.

3.3. Kinematic Viscosity

Viscosity affects injection machine operation, especially at low temperatures, where increased viscosity affects fuel fluidity. The viscosity of biodiesel is affected by the length of its constituent fatty acid chain, the longer the fatty acid chain the higher the viscosity. It is also influenced by the position / number of bonds and types of bonds and oxygen groups that exist. The viscosity value can be reduced by reducing the composition of the biodiesel mixing and increasing the temperature.

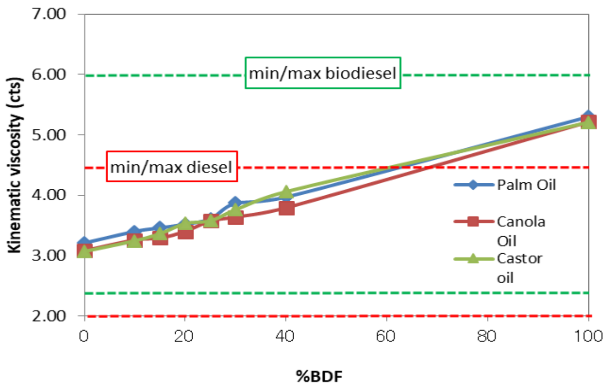

Figure 3 Kinematic viscosity of a mixture of biodiesel and petroleum diesel

The kinematic viscosity of the initial biodiesel and the mixture fall within the range of the standard viscosity of biodiesel, which is between 2.3 - 6 cSt. The initial viscosity values of the three biodiesels were almost the same, namely in the range of 5 cSt. The more biodiesel in the mixture the more viscosity.

3.4 The Stability of Oxidation

The stability of biodiesel oxidation is lower than petroleum diesel because lipids can undergo an auto-oxidation process that occurs both biologically and chemically. Biodiesel oxidation causes changes in properties such as an increase in acid numbers, peroxide numbers and viscosity. Evaluation of oxidation stability is needed specially to determine the storage method. Based on the raw material, the higher the level of unsaturation, the greater the tendency to experience oxidation. According to Pinzi, the oxidation level of biodiesel is more influenced by the composition of the alkyl ester than the environment.

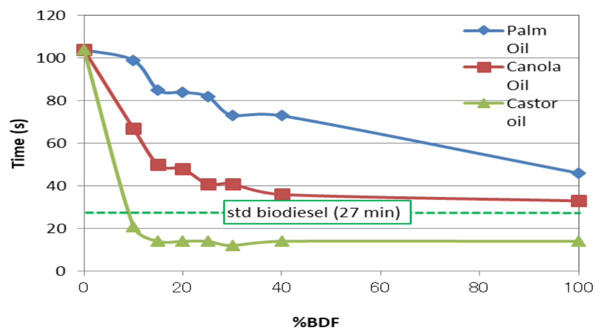

Figure 4 Oxidation stability of a mixture of biodiesel and petroleum diesel

The oxidation stability of the biodiesel mixture, whether from palm oil, castors, or canola, is getting lower with increasing biodiesel percentage. Castor oil biodiesel has the lowest stability of 14 minutes, and the mixture also does not meet biodiesel specifications (27 minutes). This is caused by the high content of unsaturated acids, namely linoleic acid and linolenic acid in castor oil [14]. The content of saturated fatty acids in castor oil is only about 21% [15].

3.5. Flash Point

The flash point is the temperature at which the ignition occurs when exposed to a spark. In general, biodiesel has a higher flash point than petroleum diesel. The high flashpoint of biodiesel is caused by the presence of C18: 1 and C18: 2 unsaturated acid chains in vegetable oil raw materials. The flash point is very influential on fuel handling, where fuel safety is guaranteed with a higher flash point value. [16].

The starting point of biodiesel from both palm oil, castor, and canola is more than the minimum standard of biodiesel which is 100 oC. The minimum standard flashpoint for petroleum diesel is 52oC. Increasing the biodiesel content in the oil mixture will have an effect on increasing the flash point. All biodiesel and petroleum diesel mixes have flash points that exceed the minimum standard of diesel flashpoint.

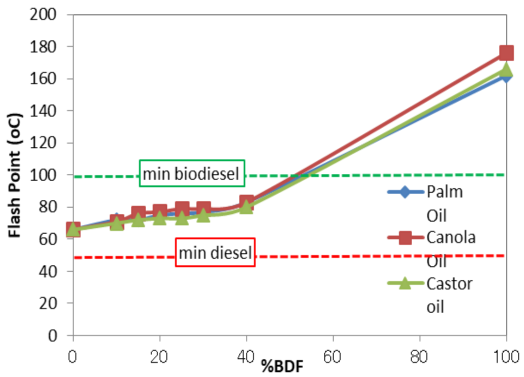

Figure 5 Flash point of a mixture of biodiesel and petroleum diesel

4. CONCLUSION

The characteristic of a mixture fuel is the additive between the properties of biodiesel and diesel, depending on the volume fraction of the mixture used. In general, the mixture of diesel and biodiesel from palm oil and canola oil in various compositions meets the specifications of biodiesel and diesel fuel specifications in Indonesia, so that it can be an alternative fuel to replace pure diesel. However, for castor oil it does not meet the requirements for oxidative stability. Oxidation stability can be improved by adding antioxidants to the mixture. To predict the characteristics of biodiesel blends it is necessary to do a detailed analysis of the constituent raw materials.

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