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Research Paper

The Role of Eucalyptus Oil in Crude Palm Oil As Biodiesel Fuel

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Abstract

Utilization of crude palm oils (CPO) as biodiesel faces difficulty due to their high level of viscosity. Mixing crude eucalyptus oils (CEO) with CPO may reduce the viscosity due to the presence of aromatic compounds in CEO. The single droplet analysis was performed to determine the characteristics of mixing CPO with the CEO. The results showed that the addition of CEO decreased the viscosity due to the presence of intermolecular attractions, thereby leading to more active molecules in the CPO-CEO mixture. Furthermore, the aromatic compound in the CEO helped in decreasing the CPO flash point, while the aromatic compound in the triglyceride molecule weakens the bonds between molecules. The addition of CEO to CPO tends to reduce the ignition delay due to the presence of cineol content in the CEO, which weakens the van der Waals bond in CPO.

Keywords: Eucalyptus oil, Crude palm oil, Biodiesel, Droplet

Abstrak

Minyak sawit (CPO) sebagai bahan bakar biodiesel memiliki viskositas yang tinggi, sehingga perlu penanganan untuk mengurangi viskositasnya. Perpaduan minyak kayu putih (CEO) dengan minyak sawit dapat menurunkan nilai viskositas minyak sawit karena adanya senyawa aromatik di dalam minyak kayu putih. Analisa tetesan (single droplet analysis) telah dilakukan untuk menentukan karakteristik campuran dari minyak sawit dengan minyak kayu putih. Penambahan minyak kayu putih menghasilkan penurunan viskositas karena interaksi antar molekul yang saling tarik-menarik. Interaksi ini menghasilkan pergerakan molekul yang lebih aktif pada campuran minyak sawit -minyak kayu putih. Penambahan minyak kayu putih menurunkan titik nyala bahan bakar. Senyawa aromatik dalam minyak kayu putih menjadi faktor utama yang membantu mengurangi nilai titik nyala pada minyak sawit; senyawa aromatik dalam molekul trigliserida menyebabkan ikatan antar molekul menjadi lemah. Penambahan minyak kayu putih pada minyak sawit menghasilkan pengurangan waktu tunda pengapian karena adanya senyawa Cineol pada minyak kayu putih yang melemahkan ikatan van der Waals dalam minyak sawit.

Kata-kata kunci: *Minyak kayu putih, Minyak sawit, Biodiesel, Droplet*

1. Introduction

Although considered as an alternative renewable fuel, the long-term use of vegetable oil may damage the engine due to its high viscosity. Mixing vegetable oil with other types of fuel is one of many solutions to reduce its viscosity [1].

According to research conducted by Mahmudul et al., mixing castor oil and diesel fuel with volume ratios of 100, 80, 60, 40, 20 and 10% decreases the viscosity of castor oil from 45.75 to 26.58 cSt [2]. Furthermore, adding volatile liquids such as ethanol reduces the flash point and increases the combustibility of the fuel.

Ethanol has strong evaporation characteristic, comprises of hydrogen bonds, and tends to produce low CO and NOx emissions when mixed with fuel [3]. However, ethanol can be considered as non-polar as its high polarity makes it impossible to obtain a homogenous mixture when added to diesel and pure vegetable oils [4]. In a research carried out by Sarin et al., 1-butanol was added to coconut oil-ethanol as an emulsifier and the results showed that higher percentage of ethanol and butanol in the mixture led to reduced viscosity and density [5]. Kivevele et al. mixed crude rapeseed oil with propanol and butanol, which are considered to be non-polar and contain high level of alcohol, to obtain a homogenous mixture. This combination led to a decrease in viscosity and flash point of rapeseed oil due to an increase in the percentage of propanol and butanol.

Alternatively, the viscosity may also be reduced by mixing the vegetable oil with essential oils, which are low in specific gravity and consists of volatile components. It is also dissolvable in diesel oil and contains a large sum of oxygen atoms based on the analysis results of its constituent components [6]. Eucalyptus oil is one of many essential oils classified as aromatic hydrocarbons with good antiknock properties due to the presence of the cyclic compound of six carbon atoms that bind with hydrogen. It is an aromatic compound with the largest cineol content. It is possible to mix eucalyptus oils with vegetable oils due to the aromatic compounds in eucalyptus oils.

With such advantageous properties, it is imperative to further investigate the potential of eucalyptus oils as additives for vegetable oil-based fuel. In this study, crude palm oil (CPO), a vegetable oil, was mixed with crude eucalyptus oil (CEO), an essential oil, to reduce the viscosity of CPO. CPO is a fuel containing high levels of oxygen. Combustion from palm oil reduces emissions such as total hydrocarbons, carbon monoxide, sulfur oxides, and polycyclic aromatic hydrocarbons [7]. On the other hand, CEO contains 44 components, with cineol as the largest at 77.40%, therefore, it is an oxygenated monoterpene.

In order to analyse the efficacy of mixing both oils in reducing the viscosity, single droplet analysis was performed. Hoxie et al. [8] stated that a single droplet analysis is an attractive analysis method used to determine the properties of fuel.

2. Materials and Method

2.1. *Properties measurement*

During property testing, CPO and CEO were obtained from the chemical extraction process using hexane solvent and the distillation of eucalyptus oil in Maluku, Indonesia. Measurement of fuel viscosity using Leybold Didactic brand viscometer with ASTM D445 measurement standards, at UGM integrated research and testing laboratory. Their kinematic viscosity and flash point were measured to determine their quality as those properties are related to the size of the fuel droplet, jet penetration, atomization quality, and spray characteristics [9]. Kinematic viscosity was measured in this study as damages tend to occur in the system when the fuel used is highly viscous and thick, thereby widening the surface area and evaporation time. On the other hand, flash point was measured to obtain the characteristics of a combustible or non-combustible components of the fuel and as a standard in the safety of transportation and storage (ASTM D-92). The flash point is defined as the ignitable air obtained at the lowest temperature from the mixture of steam and air above the surface.

2.2. *Droplet*

Single droplet is an analysis method used to determine the characteristics of the fuel [7], in which the combustion properties measured are greatly influenced by the fuel properties such as volatility, reactivity, and molecular structure. The length and degree of unsaturation of the carbon chain, such as double and triple bonds are common properties of the molecular structure [10]. Single droplet analysis is a convenient research method as the combustion can be easily carried out [11],[12]. Schematic for single droplet analysis is shown in **Figure 1**.

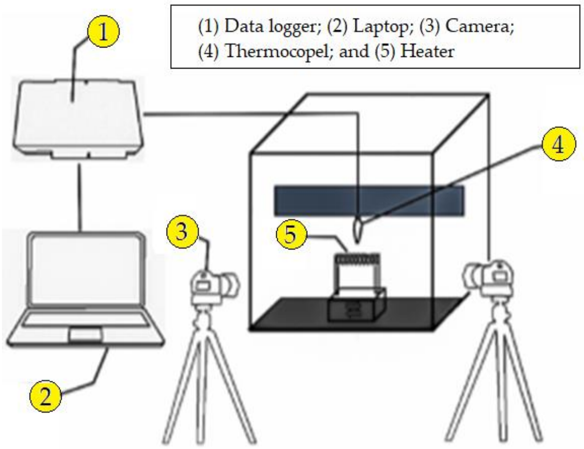

Figure 1. Schematic of the experimental configuration

This study aimed to test the combustion characteristics of a CPO-CEO mixed droplet by adding 5% CEO (hereinafter referred as CEO5). The testing method was performed by suspending a 1 mm droplet at the end of the thermocouple and heated it until it burned using a heater placed 3 mm away from the droplet. The temperature was measured using a thermocouple connected to the data logger which sent the data to the laptop for recording and processing purposes.

The ignition delay time was obtained by measuring the time needed for the flame to start propagating. The flame was induced through using a heater placed under the droplet. The constant burning rate is calculated using the diameter of the droplet and the length of the droplet on. The visualization of the flame was obtained using a Nikon D3300 camera for 60 frames per second.

3. Resuts and Discussion

The fatty acid content contained in CPO was tested using GC-MS (Gas Chromatography-Mass Spectrometry), as shown in **Table 1**. The properties of the eucalyptus oil used in this study is shown in **Table 2**. CPO has a high viscosity of 48.7 mm^2/sec as it belongs to the monosaturated fatty group which are predominantly made up of palmitic acid ($C_{16}H_{32}O_2$) as much as 40-47% [13],[14]. It also consists of oleic acid ($C_{18}H_{34}O_2$) by 36-44% [1], with a C18 chain length and a carbon double bond that primarily cause the high viscosity of CPO [15].

3.1. *Viscosity*

A comparison of the CPO and CEO5 viscosity is given in **Figure 2**. CEO has a viscosity of 2.197 mm^2/sec, while a typical biodiesel fuel has viscosity value between 2.2 - 5.3 cst. **Figure 2** shows a decrease in viscosity due to the addition of the CEO. The decrease was due to the molecules of CEO and CPO experienced intermolecular attraction forces. These forces caused the molecules of CEO5 to be more dynamic and actively moving as opposed to the molecules of pure CPO. Furthermore, the intermolecular attraction forces also led to a decrease in molecular bonds, and mixture rate. In pure CPO, which has less polar characteristic, intermolecular attractions occurred due to momentary and impacted dipoles. The movement of these molecules is sluggish. However, the addition of a polar CEO led to an increase in the formation time of momentary and impacted dipole to happen more frequently. This led to more active intermolecular forces with eventual decrease in viscosity due to the weakening of the van der Waals bond.

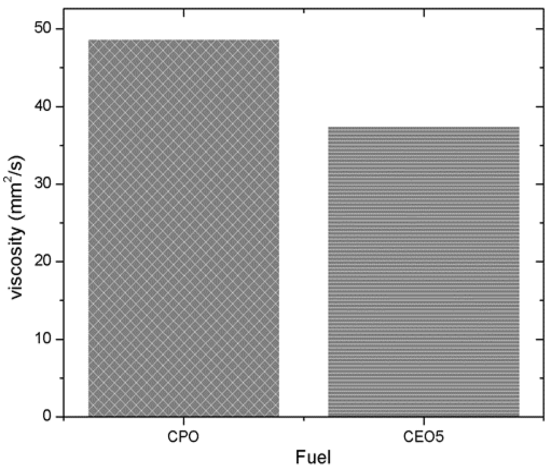

Figure 2. Viscosity comparison of CPO and CEO5

Table 1. The fatty acids content in CPO

Chemical composition	Cn:db	Formula	Structure	Content (%)	Molecular mass (g/mole)
Palmitic	16:0	$C_{16}H_{32}O_2$	$CH_3(CH_2)_{14}COOH$	40-47	256.4241
Palmitoleic	16:1	$C_{16}H_{30}O_2$	$CH_3(CH_2)_5CH\text{-}CH(CH_2)7COOH$	0-0.6	254.4042
Stearic	18:0	$C_{18}H_{36}O_2$	$CH_3(CH_2)_{16}COOH$	3-6	284.4772
Oleic	18:1	$C_{18}H_{34}O_2$	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	36-44	282.4614
Linoleic	18:2	$C_{18}H_{32}O_2$	$CH_3(CH_2)_4CH{=}CH(CH_2)CH(CH_2)_7COOH$	6-12	280.4455
Linolenic	18:3	$C_{18}H_{30}O_2$	$CH_3(CH_2)_(CH{=}(CH_2)3(CH_2)_6COOH$	0-0.5	278.4296

Table 2. Eucalyptus properties

Properties of Crude Eucalyptus Oil (CEO)	
Viscosity at 40° (mm²/sec)	: 2.197
Flash point (°C)	: 49 (120°F) close up
Density at 15°C (gr/cm³)	: 0.900-0.930

3.2. *Flash point*

Vegetable oil has a high flash point due to the molecular weight and carbon chain length in fatty acids [16]. Meanwhile, CPO has a high flash point value due to the increase in the number of free fatty acids (SN) at 0.53 mg KOH/gr, as obtained from the laboratory results of this study. It also has a small SN value due to an increase in molecular oil mass.

Mixing CEO and CPO reduced the flash point, as shown in **Figure 3**. The aromatic compound, which is triglyceride molecule, weakened the bonds [17]. Furthermore, the difference in polarity led to varying melting and boiling points of the compounds. During the evaporation process, the molecules easily reached the surface of the fuel mixture and evaporated before combustion. The lower the flashpoint temperature, the easier it is for the fuel to evaporate and combust. Therefore, addition of the CEO led to a decrease in the CPO viscosity, due to the activeness of the molecules and thereby making it highly flammable.

3.3. *Ignition delay time*

The influence of CEO addition on ignition delay time of CPO droplets combustion is shown in **Figure 4**. It shows the relationship between adding the CEO to the CPO towards the ignition delay time. The addition of CEO reduced the ignition delay time due to the presence of cineol content in eucalyptus oil. It also weakened the van der Waals bond in palm oil when it mixed with the CEO, thereby infiltrating the carbon chain. Furthermore, the chemical structure of CPO in the form of a straight chain got stretched due to the insertion of cineol and therefore promote the separation of the carbon chains and enhanced their reactivity, thereby lowering the ignition delay time.

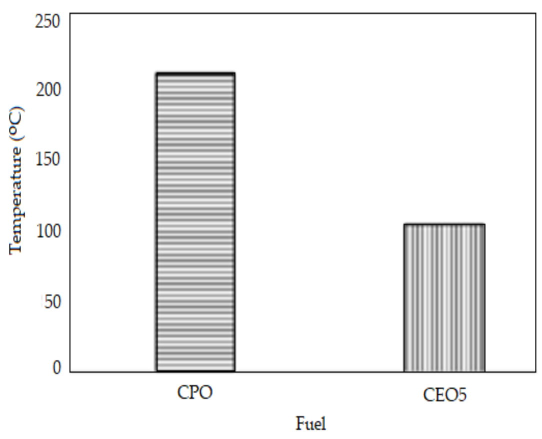

Figure 3. Flash point comparison of CPO and CEO5

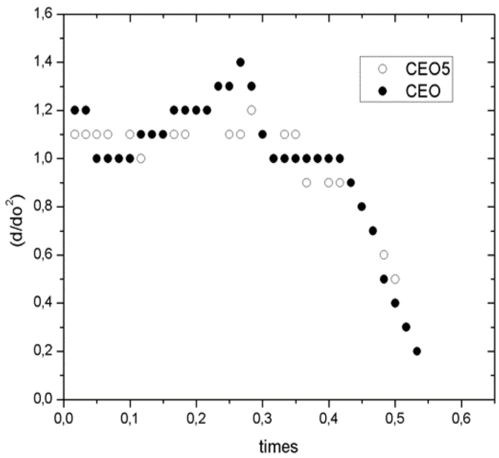

Figure 4. The percentage of crude eucalyptus oil towards ignition delay

3.4. Droplet visualization

The visualizations of droplet testing are shown in **Figure 5**. The presence of internal gasification led to an increase in the growth of bubbles, and this form caused micro-explosion [18],[19]. The addition of CEO promoted the bubble growth and decreased ignition time.

4. Conclusion

Mixing CPO with CEO improves combustion properties and characteristics. Viscosity of CPO decreased due to the intermolecular forces, while flash point decreased due to the weakening of van der Waals forces. Furthermore, this led to a decrease in the ignition rate due to the polarity effects on the intermolecular forces and combustion characteristics of vegetable oil droplets. Therefore, the addition of cineol towards viscosity and flash point tend to change with the geometrical structure of carbon triglyceride chains, thereby weakening the bonding forces of the carbon chain and improving the combustion performance of the fuel in vegetable oils.

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

(a) CPO

(b) CEO5

Figure 5. Transient droplet of (a) CEO and (b) CEO 5 (CPO-CEO mixture) from heating until ignition

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