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Biodiesel Production from Waste Cooking Oil using Electrostatic Method

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Abstract

Biodiesel (methyl ester) produced from trans esterification of waste cooking oil is a potential material to replace diesel fuel. The biodiesel can be obtained by using electrostatic method equipped with fixed distance electrode 1.5 cm and voltage at 12 volts. Coagulation of particle process i.e. glycerin drops in biodiesel-glycerin mixture was based on electrical field. Reactants used were methanol over KOH catalyst and temperature was set at 60 °C. The residence time was varied as well as methanol to waste cooking oil ratio. Analysis result shows the process was able to obtain yield up to 83.3%. The quality of biodiesel produced was tested and satisfy the requirement according to National Standard of Indonesia (SNI), i.e. density 0.8594 mg/mL (compared to SNI: 0.85-0.90 mg/mL), flash point 191 °C (SNI min 100 °C), water content 0.0342% (SNI max 0.05%) and viscosity at lower limit 2.31 cSt. According to SNI 7182-2015 the above value meets the specified standard.

Keywords: Biodiesel, electrode, electrostatic method, waste cooking oil

Abstrak (Indonesian)

Biodiesel (metil ester) yang dihasilkan dari reaksi transesterifikasi minyak jelantah merupakan bahan yang sangat potensial untuk menggantikan bahan bakar diesel. Biodiesel ini dapat diproduksi dengan metode elektrostatik menggunakan elektroda dengan jarak tetap 1,5 cm dan menggunakan tegangan tetap 12 Volt. Dalam metode ini, proses partikel koagulasi atau tetes gliserin dalam campuran biodiesel-gliserin berdasarkan medan listrik. Pereaksi yang digunakan adalah metanol dan katalis KOH. Proses dilakukan dengan suhu 60 °C. Waktu tinggal dan rasio metanol dengan minyak jelantah divariasikan. Berdasarkan hasil analisis terhadap biodiesel yang dihasilkan, rendemen yang dihasilkan adalah 83,33%, dan kualitas biodiesel pada beberapa parameter masih memenuhi standar mutu biodiesel SNI, yaitu berat jenis 0,8594 mg/ml (SNI-04-7182-2015 sebesar 0,85-0,90 g/ml), titik nyala 191 °C (minimal 100 °C), kadar air 0,0342% (maksimal 0,05%), dan viskositas terkecil 2,31 cSt. Berdasarkan standar biodiesel SNI 7182-2015 dari hasil tersebut untuk nilai berat jenis, titik nyala, kadar air, dan viskositas memenuhi standar.

Kata Kunci: biodiesel, elektroda, metode elektrostatik, minyak jelantah

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INTRODUCTION

Bioenergy such as biodiesel has received great attentions across the globe nowadays. The main advantages of biodiesel are its renewable resources and environmentally friendly compare to fossil fuel. Its utilization can significantly reduce greenhouse gasses emission hence it possesses great potential to solve energy problems in developing country with lack of petroleum resources. Coal utilization as an alternative energy is widely used in such country for encouraging economic growth due to is

availability and cheapness. Coal however caused air heavily polluted and certainly need to be replaced.

Replacing coal with biodiesel in developing country not only maintain the economic growth but also decrease pollution rate by coal power plant which in turn contribute positively to reduce global warming and prevent climate change [1].

Biodiesel also has drawbacks that need to overcome in the future. The decrease of oil price recently to the level USD55.25 per barrel made the selling price of biodiesel less competitive. Directorate general of renewable and conservation energy of The Ministry of Energy and Mineral Resources predicted market index price (MIP) of biodiesel increase to IDR 9000 per liter early 2017. The high price of biodiesel was caused by the increase of raw material and production cost which made market selling price undoubtedly increase [2,3].

Biodiesel is an alternative energy which is considered as fuel replacement for petroleum. This energy has advantage due to renewable resources and friendlier to the environment because of its low carbon emission to produced compare to fossil fuel [4,5]. Biodiesel therefore has the potential to solve energy problems in developing country particularly those with lack of petroleum resources. Biodiesel can also act as an energy alternative of coal power plant to stimulate economic growth. Although coal can be provided cheaply but its burning process cause air pollution hence decreasing the utilization of coal also decrease pollution rate from coal later prevent climate change caused by carbon emission [6-8].

Chemically, biodiesel comprise of various fatty acids methyl ester which can be produced from edible oil such as Palm oil, Jathropa oil, Kapuk seed oils and from waste such as cooking oil [9].

Waste cooking oil resulted from cooking oil used for processing food and remains as liquid waste. It has saturated fatty acids higher than fresh cooking oil. Frying process converts unsaturated chain of fatty acids into saturated one and yields new composition by 30% unsaturated and 70% saturated fatty acids [10].

Several studies on the production of biodiesel from vegetable oil such as cotton seed oil through trans esterification over solid base catalysts have been carried out and the results are tested for diesel engine performance [11]. Research on esterification kinetics of castor oil, kapok seed oil, and fatty acids using niobium oxide catalyst have been carried out [12-15]. Here, we use electrostatic method for making biodiesel from used cooking oil with the trans esterification process over KOH catalyst.

Electrostatic or also called coulomb interaction is a branch of physics related to the force released by a static electric field (not changing / moving) against other charged objects. Electrostatic forces can be considered as physical reactions that hold together electromagnetic fields created by subatomic particles, such as electrons and protons. Coulomb's law is a law that describes the relationship between forces that arise between two charge points separated by a certain distance, with the charge value and the separation distance between the two. This law states that the electric force (attraction or repulsion) between two electric charges is proportional to the magnitude of each electric charge and inversely proportional to the square of the distance between the two electric charges [16-17]. Electrostatic method uses electrodes (anodes and cathodes) from various materials, including aluminum, stainless steel, solid wire, etc., where the use of different types of electrodes will produce different yields [18,19]

MATERIALS AND METHODS

Materials

Waste cooking oil was obtained from local food processing business; KOH catalyst as well as methanol (p.a. grade) was purchased from Merck.

Experimental

This research was aimed to design biodiesel reactor using waste cooking oil as feed and equipped with electrostatic separator device. The free fatty acids content was analyzed, and the biodiesel product was identified and classified according to National Standard of Indonesia 7182-2015 [20].

Figure 1 shows the process scheme of biodiesel production from waste cooking oil through electrostatic separator. Prior feeding, the reactant was filtered to remove impurities. Separator tank equipped with electrodes having distance from each other 1.5 cm and voltage 12 V.

The biodiesel product was separated and collected through separator tank and subjected to analysis of density, viscosity, water content and flash point.

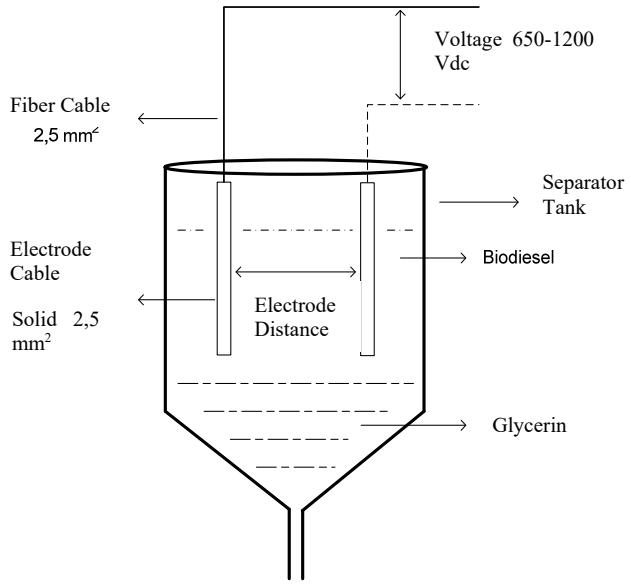

Figure 1. Electrostatic separator of biodiesel and glycerin

RESULTS AND DISCUSSION

The reactor feed i.e. waste cooking oil has the character as displayed in Table 1

Table 1. Initial character of waste cooking oil

No	Parameter	Result
1.	Density, gr/ml	0.9054
2.	Viscosity, cST	0.3381
3.	Water content, %	0.1019
4.	Flash point, °C	263
5.	Free fatty acids, %	4.6

The effect of feed ratio and reaction time to the biodiesel product density

The density of biodiesel product obtained in the process conducted is satisfied the standard value by Indonesian National Standard requirement SNI-04-7182-2015. After reaction was carried out for 5 minutes, the density of product has the range 0.8513-0.8594 g/mL.

The correlation between feed ratio (methanol/waste cooking oil) and reaction time with product density is represented in Figure 2.

Figure 2 indicates a decrease in density to the range of 0.8594-0.8513 g/cm^3. SNI Standard for biodiesel suggests the density between 0.85-0.90 g/cm^3 is tolerable.

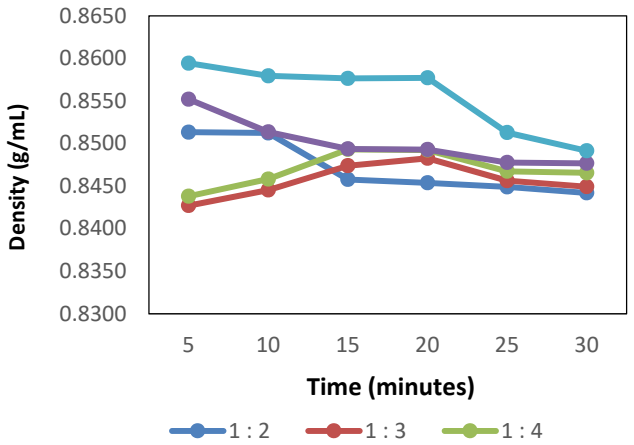

Figure 2. The effect of feed ratio and reaction time to the product density

The lowest density obtained at this process is 0.8512 g/cm^3 attained at mol ratio 1/2 after 10 minutes reaction while the highest density 0.8594 g/cm^3 was obtained from 1/6 mol ratio. The higher ratio of waste cooking oil to methanol ratio, impact to the increasing of the density of biodiesel produced. The increasing of density can caused by the increasing of reaction rate and the shift of reaction equilibrium. The conversion of triglyceride into methyl ester gained in the condition when the biodiesel density decline to lower value of methyl ester compare to triglyceride.

The effect of feed ratio and reaction time to the flash point

Data analysis result for flash point of biodiesel product confirmed to fulfil the required value by SNI standard 7182-2015 i.e. 100 °C. The flash point obtained is decreased from mol ratio 1/6 to mol ratio 1/2. Figure 3 displays the effect of feed mol ratio and reaction time to the flash point of biodiesel product.

Increased of flash point is detected due to the possibility of water content in the mixture or the

remaining glycerol and catalyst used in the biodiesel product. The difference of the flash point between the product result can be also caused by impurities and remaining reactant which enhance the flash point i.e. unreacted waste cooking oil.

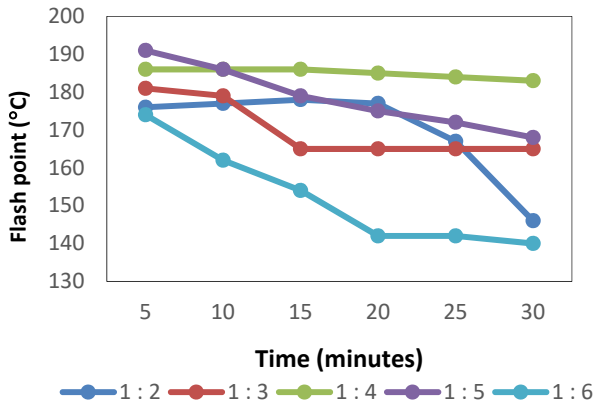

Figure 3. The effect of feed ratio and reaction time to the flash point

The effect of feed ratio and reaction time to the water content of biodiesel product

The water content of the biodiesel product was found did not meet the SNI 7182-2015, i.e. 0.05%. Most of the feed ratio and reaction time variation gave result of biodiesel with water content above the standard allowed.

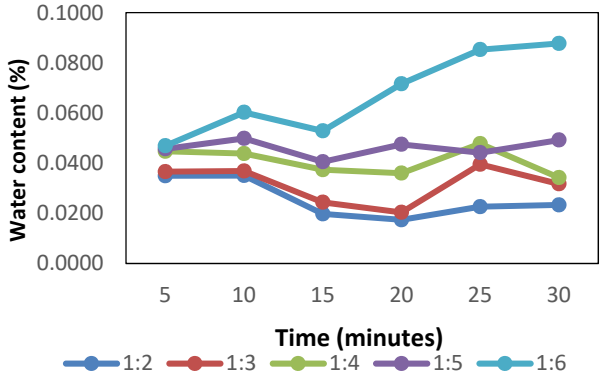

Figure 4. The effect of feed ratio and reaction time to the water content of biodiesel product

The water content is increased as longer reaction time carried out. The increase amount of water was due to water accumulation in the oil before trans esterification process proceeds. High water content can trigger hydrolysis of triglyceride and produced glycerol and free fatty acids. Water contained in fuel can induced crystal formation which in turn blocked fuel flow. Microorganism can also growth in the existence of water and inhibit the flow of fuel.

Figure 4 confirmed that the methanol to waste cooking oil ration which gave the lowest water content was achieved at 1/2 after 20 minutes reaction.

The effect of feed ratio and reaction time to the biodiesel viscosity

Analysis result on viscosity measurement indicate the biodiesel product has fulfill the requirement value by SNI 7182-2015 i.e. 6.0 cSt (centistoke).

The variation of feed ratio and reaction time obviously affects biodiesel viscosity particularly for 1/6 ratio. Figure 5 shows the viscosity value measured for 1/6 ratio was increased as longer reaction time of trans esterification was conducted.

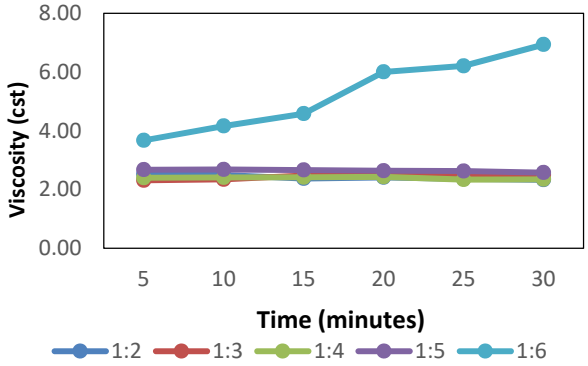

Figure 5. The effect of feed ratio and reaction time to biodiesel viscosity

The increased ratio of methanol to waste cooking oil ratio and longer reaction time accelerate molecular collision in the liquid hence increased its viscosity. The data analysis result proved that larger voltage in the trans esterification process gave result of smaller viscosity of the product. Lowest viscosity obtained in the experiment was 2.31 cSt after 5 minutes reaction time. Linier correlation between voltage used and viscosity measured was found out in the biodiesel product obtained.

CONCLUSION

Based on analysis result, it can be concluded that:

1. Temperature and reaction time gave effect to the biodiesel produced by electrostatic method by varying feed ratio and reaction time at same temperature i.e. 60 °C
2. Yield obtained by the method conducted is 83.33% with biodiesel quality according to SNI fulfil the standard assigned i.e. density 0.8594 mg/mL (0.85-0.90 standard value), flash point 191 °C (min 100 °C), water content 0.0342% (max 0.05%) and lowest viscosity value at 2.31 cSt.

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