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Effect of DC Voltage on Prototype of Biodiesel Electrostatic Separator with Glycerin from Waste Cooking Oil

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Abstract

The limitations of fossil fuel support on fulfillment of energy need in a sustainable and environment friendly fashion has drove society to efforts of finding and developing fresh and renewably resources. Biodiesel is one the renewable energy resource and shows environment friendly property, consist of alkyl of fatty acids monoester originated from vegetable oil or animal fat. One of important steps in biodiesel production is separation of glycerin from product. Electrostatic method has been proved in accelerating saturation of glycerin. However, several aspects still need a careful assessment to acquire biodiesel production process with standard quality assigned. In this work, we designed an electrostatic separator of biodiesel from glycerin using waste cooking oil feed. The prototype was tested in several different voltages 12 Vdc, 20 Vdc, 30 Vdc and 33.5 Vdc. The result shows the highest voltage obtained is 33.5 Vdc, separation time 2 minutes 10 seconds having viscosity, water content and density i.e. 7.2139 cSt, 0.0321% and 0.85 g/mL respectively whereas flash point increase to 1917 °C. The data confirmed that the product fulfills required standard value for density, water content and flash point.

Keywords: Biodiesel, Glycerin Separation, Electrostatic

Abstrak (Indonesian)

Keterbatasan daya dukung bahan bakar fosil terhadap pemenuhan kebutuhan energi yang berkelanjutan dan ramah lingkungan, telah mengarahkan pada upaya untuk menemukan dan mengembangkan sumber energi alternatif yang bersifat baru dan terbarukan. Salah satu jenis energi tersebut yaitu biodiesel. Biodiesel adalah alkil monoester asam lemak dari minyak nabati dan lemak hewani. Salah satu tahapan dalam memproduksi biodiesel adalah pemisahan gliserin. Metode elektrostatik telah mampu mempercepat kejenuhan gliserin, namun banyak aspek yang perlu diperhitungkan untuk mendapatkan proses yang memenuhi kualitas standar. Pada penelitian ini, telah dibuat suatu alat prototipe separator elektrostatik biodiesel dengan gliserin dari minyak jelantah, kemudian dilakukan pengujian variasi tegangan 12 Vdc, 20 Vdc, 30 Vdc, dan 33,5 Vdc. Hasil menunjukan pada titik tegangan tertinggi yaitu 33,5 Vdc, waktu pemisahan gliserin semakin cepat yaitu 2 menit 10 detik, dengan nilai viskositas, kadar air, dan berat jenis semakin rendah yaitu 7,2139 cSt, 0,0321 %, dan 0,85 gr/ml, sedangkan nilai titik nyala semakin tinggi yaitu 191,7 °C. Hasil tersebut untuk nilai berat jenis, kadar air, dan titik nyala sudah memenuhi standar biodiesel SNI 7182-2015.

Kata Kunci : Biodiesel, Pemisahan Gliserin, Elektrostatik

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INTRODUCTION

Indonesia face a national energy problem in a relatively complicated way. The dominant usage of fossil fuel in day life, higher consumption rate compares to production level, the unstable world oil price and the depleted oil resources are major problems concern with fossil fuel [1].

Several efforts had been made to decrease the energy resource dependent on fossil fuel i.e. policy support on vegetables-based fuel provision and development which is regulated in the presidential instruction no. 1 year 2006 on provision and utilization of vegetables-based fuel as an alternative energy. Another regulation in form of presidential decree no 10/2006 on the formation of national task force in accelerating vegetable-based fuel utilization to reduce poverty and unemployment and regulation assigned by ministry of energy and mineral resources no 25/2013 which is revised by ministry regulation no 20/2014. The policy is about biofuel utilization mandatory in 10% blending mixture (B-10) since 1 September 2013. The government also enforces a national program to utilize local energy resources to create energy independent society among citizen by directing all citizen effort on finding and developing newly and renewable energy resources to fulfil energy need in sustainable way and environment friendly.

Biodiesel is one of known renewable energy with growing interest today. Haryono defined biodiesel as methyl ester which can be produced from vegetables-oil or animal fat and has the standard quality fulfil the requirement for diesel fuel [2]. The dependence on fossil fuel can be reduced by exploit the vegetable-based biodiesel by considering the abundance of its raw material. According to the advisability assessment of several biodiesel raw materials, Ruhyat and Firdaus (2006) concluded that one of most promising vegetable oils for biodiesel production is waste cooking oil [4]. Alternative resources of vegetable oils must be found out due to high cost of producing vegetable oils. Biodiesel production by using waste cooking oil as raw material effectively reduce the biodiesel cost hence can be sold inexpensive. Waste cooking oil is an edible oil which was wasted after being used to fry food and its color turn dark brown. Biodiesel production using waste cooking oil as raw materials hence can also contribute to solve the environmental problem and preserve public health [5].

Biodiesel was made through chemical process known as transesterification. It involved reaction to obtain ester from another type of ester as reactant. The reaction consists of breaking down triglyceride compound and alkyl group re-arrangement between esters. The final products are methyl ester (biodiesel) and glycerin which is had to be separated further. Separation of biodiesel and glycerin conventionally was conducted through precipitation and centrifugation which is time consuming and high cost. Centrifugal separation was suspected to cause phase transport of biodiesel into glycerin [6,7]. This situation needs to a more appropriate method of separation in both effective and efficient way.

Separation of biodiesel and glycerin has been studied particularly by using electrostatic method [8]. High voltage was used to separate biodiesel and glycerin which reported to increase the glycerin saturation in short time. The result shows FFA content 2%, electrode distance 16.5 cm which placed in a pipe system, voltage 9000 V and produced separation percentage 98% in 25 seconds [9,10]. Further research on glycerin and biodiesel separation using electrostatic coagulation with electrode distance arranged at 3 cm using different electrode and higher electrostatic field intensity effectively reduced glycerin separation time to 19-45 seconds, but no description on voltage parameter and biodiesel percentage acquired [11].

Here, we reported a prototype design of biodiesel electrostatic separator. The biodiesel was produced by using waste cooking oil as raw material and the ester product was separated in a DC voltage and steel electrodes [12-14]. The research was aimed to evaluate biodiesel separation tendency towards voltage variation and compare the final product to the biodiesel standard according to SNI 7182-2015. The standard value evaluated include density, viscosity, water content and flash point [15].

MATERIALS AND METHOD

Experimental Stage

Prior experimental procedure, waste cooking oil (WCO) was prepared and analyzed for preliminary data i.e. FFA, density, water content, viscosity and flash point. Transesterification was conducted in 1:4 WCO to methanol ratio over NaOH (1%) catalyst in a mixing tank heated at 60 °C for 15 minutes. The reaction mixture flowed into electrostatic separation tank by opening the valve. The separator tank is equipped with stainless steel electrodes that are conected to the voltage regulator on the control panel. The separator operates in several voltage to evaluate it effect on the biodiesel quality produced. Analysis of product characteristic was conducted to evaluate its density, viscosity, water content ant flash point at three different voltage used.

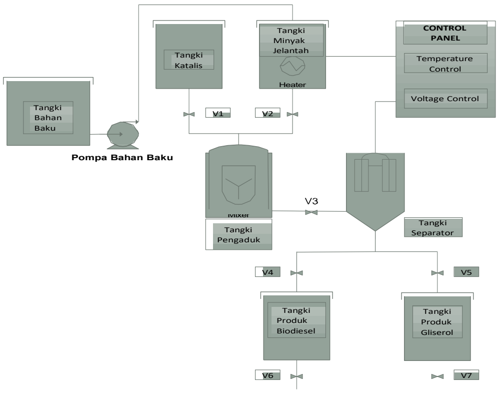

Figure 1. Schematic experiment of biodiesel and glycerin separation

Figure 1 depict flow process of biodiesel separation from glycerin using electrostatic method. Initially, WCO was filtered by using filter cartridge and then placed into raw material tank. Raw material was pumped into WCO tank which is equipped with tubular heater with temperature control to heat up WCO to 60 °C. Catalyst solution (NaOH + methanol) was added into heated WCO and flowed into mixing tank which then reacted to produced biodiesel and glycerin. The final process took place in electrostatic separator tank where the biodiesel was separated from glycerin by means of electrostatics method.

Figure 2. Electrostatic prototype separator for biodiesel and glycerin

Figure 2 how the biodiesel electrostatic separator prototype where (5) indicates electrostatic separator tank made from acrylic with 3-liter capacity equipped. It also equipped with electrode injection made from stainless steel 2.5 mm^2 to distribute electrostatic field from external source through control panel.

Biodiesel product analysis

The product analysis was conducted to evaluate biodiesel produced by means of electrostatic separation according to product standard assigned by SNI 7182-2015 which involved density, viscosity, water content and flash point.

RESULTS AND DISCUSSION

Raw Materials Characteristic

The laboratory result of waste cooking oil (WCO) can be seen in Table 1.

Table 1. Preliminary analysis result of WCO

FFA (%)	Density (gr/mL)	Viscosity (cSt)	Water content (%)	Flash point (°C)
4,6	0,9054	26,437	0,1019	263

Biodiesel Product Characteristic

The separation result after treatment by electrostatic method is displays on Figure 3.

Figure 3. Biodiesel and glycerin separation result

Visual observation on the separation result was conducted based on several electrostatic voltages' setup. The reaction mixture appears to form 2 layers which are glycerin on the bottom and biodiesel on the upper part. Base on the result obtained, we will be able to assess the effect of electrostatic voltage on the biodiesel quality as shown on Table 2.

The effect of voltage variation on the separation

The effect of voltages variation to the separation time and product percentage by using electrostatic method is shown on Table 2.

Table 2. Effect of voltage different on the separation at electrode distance 1.5 cm

Voltages (V_{DC})	Current (A)	Separation time	Separation percentage
12	0.54	3 min 2 sec	10%
20	0.76	2 min 58 sec	precipitation
30	1.01	2 min 48 sec	based on
33.5	1.1	2 min 10 sec	total volume

The data from Table 3 confirm that voltage of the electrostatic equipment affects the separation of biodiesel and glycerin. The higher the voltage used in the process, the faster separation achieved product percentage required. This result is similar to what have been reported by Greg Austic and Scott Shore (2009) and Abbaszadeh et al, (2013). This two previous research was used a relatively higher voltage as well as distance and different arrangement of electrode. Figure 4 provide a distinct pattern on how increasing voltage can separate glycerin in a shorter time.

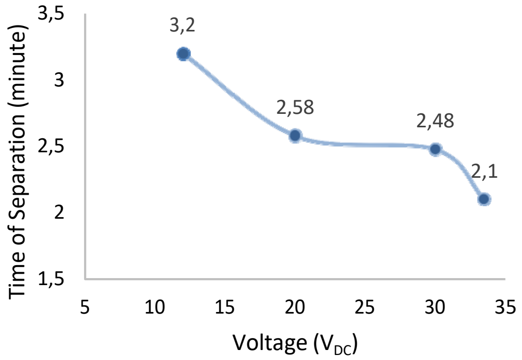

Figure 4. The effect of voltage on separation time

The Biodiesel Products

The analysis result of biodiesel product to determine its density, viscosity, water content and flash point has been obtained. According to National Standard assigned in SNI 7182-2015, kinematic viscosity shows dissatisfactory result since it does not fulfil the required value 2.3-6.0 cSt. Kinematic viscosity above standard value i.e. 7.21 cSt was obtained by using voltage 33.5 VDC. This can be explained by the lack of voltage used in the electrostatic separator.

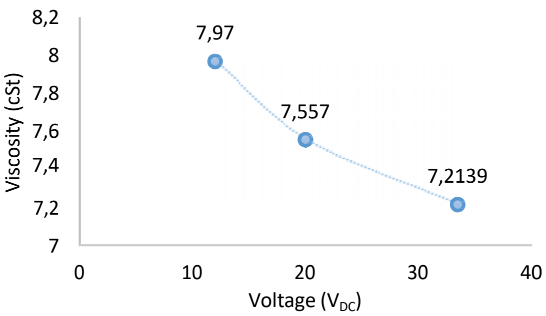

Figure 5. The effect of electrostatic voltage on biodiesel viscosity

It can be discerned from Figure 5 that the increasing of the separator voltage cause decreasing in the product viscosity. Viscosity is an important parameter because high viscosity number of it will hamper vehicle pump system and make engine hard to turn on.

Analysis result for water content and flash point suggest that the biodiesel produced has fulfil the required standard value for all separator voltages variation conducted. The national standard required that water content of biodiesel has not value more than 0.05%. Our biodiesel result shows the highest water content was obtained by using electrostatic voltage 12 V_{DC} at 0.0374%.

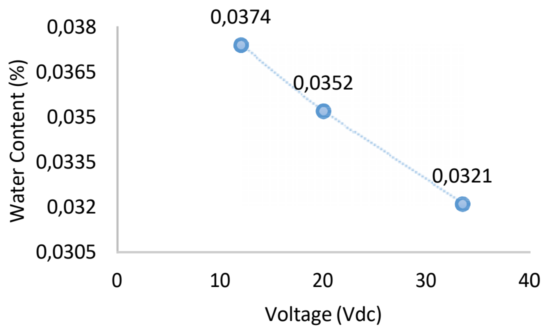

Figure 6. The effect of separator voltage on water content

Figure 6 shows the inverse correlation between separator voltage with water content of biodiesel. As the voltage getting higher, the content of water is getting lower. In contrary, low flash point of biodiesel (184 °C) obtained by using low voltage (12 V_{DC}) as can be seen on Figure 7 whereas national standard required minimum flash point at 100 °C.

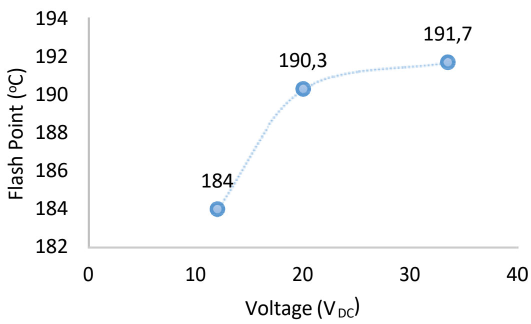

Figure 7. The effect of separator voltage on biodiesel flash point

The correlation between separator voltage and flash point according to Figure 7 is linier i.e. high separator voltage produced biodiesel with high flash point.

CONCLUSION

The effect of voltage variation on electrostatic separation of biodiesel from glycerin has been evaluated. The voltage has linier correlation with shorter separation time i.e. 33.5 VDC separates biodiesel from glycerin within 2 minutes and 10 second with result 10% biodiesel based on total volume. The biodiesel quality was compared to national standard SNI 7182-2015 and confirmed to fulfil the requirement for density, water content and flash point, whereas for viscosity still had value above the standard. Electrostatic effectively induced glycerin coalescence to form a bigger aggregate which in turn precipitate due to gravitational force. The electrostatic separation method hence is a promising technique to increase biodiesel production in a larger scale.

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