Jurnal Kejuruteraan SI 1(2) 2018: 79-83
http://dx.doi.org/10.17576/jkukm-2018-si1(2)-10

Characterization of Waste Cooking Oil for Biodiesel Production

(Pencirian Sisa Minyak Masak untuk Penghasilan Biodisel)

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ABSTRACT

Waste cooking oil is one of the sources that can contributes to the water pollution. It originates from the preparation of food in the cafeterias and can be harmful to the environment. Therefore, production of biodiesel from waste cooking oil is the best alternative and further studies need to be done on the characterization of waste cooking oil. This study investigates the characteristics of waste cooking oil from cafeterias in Universiti Kebangsaan Malaysia (UKM) Bangi for biodiesel production. Parameters and characteristics of waste cooking oil are very important to determine the quality and suitability of biodiesel that will be produced. Characteristics that need to be observed are kinematic viscosity, saponification, flash point, moisture content and free fatty acid. Observations were done and being compared with the specification of biodiesel stated in the standard ASTM D6751. Methods that have been conducted are ASTM D7042, AOCS Cc 9b-55, AOCS Cd 3-25 and titration. Based on the results, waste cooking oil in UKM have kinematic viscosity of 39.74-56.04 (± 4.904) mm^2/s, saponification value of 198.0-205.5 (± 2.853) mgKOH/g, flash point value of 198-290 (± 44.321) ºC, moisture content of 0.02 to 0.51 (± 0.0712) % and free fatty acid value of 0.52-4.74 (± 0.047) %. From the comparison with ASTM D6751, samples show a very high values for each parameter and transesterification need to be done so that all the values can be reduce and biodiesel can be produced.

Keywords: Waste cooking oil; Biodiesel; Kinematic viscosity; Flash point; Saponification value; Free fatty acid

ABSTRAK

Sisa minyak masak adalah salah satu punca pencemaran air yang datang dari penyediaan makanan di kafeteria. dan perkara ini akan menjejaskan alam sekitar. Oleh itu, penghasilan biodiesel dari sisa minyak masak adalah alternatif yang terbaik dan kajian lanjut perlu dilakukan terhadap pencirian sisa minyak masak. Kajian ini dijalankan untuk mengkaji ciri-ciri sisa minyak masak daripada 10 Kafetaria Universiti Kebangsaan Malaysia (UKM) Bangi untuk penghasilan biodiesel. Parameter dan ciri-ciri sisa minyak masak sangat penting bagi menentukan kualiti dan kesesuaiannya bagi penghasilan biodiesel. Antara ciri-ciri penting yang perlu diperhatikan adalah nilai kelikatan kinematik, nilai penyabunan, takat kilat, kandungan kelembapan dan nilai asid lemak bebas. Pemerhatian dilakukan dan telah dibandingkan dengan nilai spesifikasi biodiesel yang dinyatakan dalam piawaian ASTM D6751. Kaedah yang telah dijalankan adalah ASTM D7042, AOCS Cc 9b-55, AOCS Cd 3-25 dan titrasi. Kajian menunjukkan sisa minyak masak di UKM mempunyai nilai kelikatan sebanyak 39.74-56.04 (± 4.904) mm^2/s, nilai penyabunan sebanyak 198.0-205.5 (± 2.853) mgKOH/g, nilai takat kilat sebanyak 198-290 (± 44.321)ºC, kandungan kelembapan sebanyak 0.02 hingga 0.51 (± 0.0712) % dan nilai asid lemak bebas sebanyak 0.52-4.74 (± 0.047) %. Melalui perbandingan nilai yang diperolehi dengan piawaian ASTM D6751, sampel-sampel menunjukkan nilai yang begitu tinggi and tranesterifikasi perlu dilakukan untuk mengurangkan nilai-nilai tersebut bagi penghasilan biodiesel.

Kata kunci: Sisa minyak masak; Biodiesel; Kelikatan kinematik; Takat kilat; Nilai penyabunan; Asid lemak bebas

INTRODUCTION

Waste cooking oil is the end-product of frying foods using cooking oil which contains plant or animal fats that have been processed. Cooking oil is a glycerol ester consisting of different types of essential fatty acids and is only soluble in organic solvents. The original source of cooking oil is plant-based lipids such as coconut oil, palm oil, olive oil, and canola oil, or lipid-based animals, such as butter and ghee (Jacob et al. 2013). Waste is categorized as fat and grease and in liquid shaped at room temperature. This type of waste is produced by food premises, food industry and household resulting from the preparation of food. However, due to its characteristic of not being soluble in water, it becomes a contaminant to the environment.

The collection and transport systems for collecting waste cooking oil pose a challenge, especially in terms of managing this type of waste. This is because waste cooking oil comes in the form of liquids. If carelessly managed, subsequently it will end up in the sewage system, water and further damaging the environment. It was reported that the amount of waste cooking oil collected in Tango and Kyoto in 2004 was 50 kL (about 132 t), which is equivalent to a 20% reduction in carbon dioxide emissions (Singhabhandhu & Tezuka 2010). The framework of the waste cooking oil was put forth by Yaakob et al. (2013) who sought to optimize the collection of waste cooking oil by creating a system that warns the company if the collection container is full and where the location of the container is by using a mobile application. In the study by Talens Peiró et al. (2010), they considered the life cycle of biodiesel from waste cooking oil involves four stages: the collection, pre-treatment, transmission and transesterification of waste cooking oil. He adopted the Life Cycle Assessment (LCA) which inflow and outflow 'from the cradle to the grave' are being considered. This is from the production, manufacturing, use and recycling until final disposal to produce one ton of biodiesel from waste cooking oil.

Waste cooking oil is harmful to the environment and health of the consumers. Jacob et al. (2013) suggested that the use of waste from the cooking oil is believed to cause cancer due to the toxic contents produced when the oil is oxidized from the fried foods. Most of the by-products resulted from oxidation of the oil are carcinogenic (Hanisah et al. 2013). Meanwhile, the discharged of waste cooking oil will lead to the clogging of sewer pipes and drains (Ashley et al. 2000) causing flooding or sewer overflows. The discharge of waste cooking oil into the water system will change the oxygenation process and destroy aquatic life by covering the surface of water and preventing oxygen from dissolving (Kabir et al. 2014). Waste cooking oil has great potential to be commercialized as it can be used in the production of products such as biodiesel (Kumaran et al. 2011), polyurethane (polyol) and bitumen (Asli et al. 2012) which can reduce the dependency on natural resources.

Waste cooking oil has a potential to be used as an alternative fuel, biodiesel and diesel engine. Any source of fatty acids can be used to produce biodiesel, thus, any animal or plant lipid can be used as substrate for the production of biodiesel. Biodiesel can be made through transesterification process of vegetable oil or animal fat reacts with alcohol and with presence of catalyst such as potassium hydroxide. This initiative is cheaper and environmentally friendly.

Properties of biodiesel can be determined by the structure of the fatty ester component which include quality of ignition, combustion of heat, cold flow, oxidative stability, viscosity and lubrication (Knothe 2005). These properties will allow used of biodiesel as fuel. Biodiesel can bring benefits to the country in few aspects such as economics, environmental management and waste management. Besides that, biodiesel can also be handle like the regular diesel fuel. Biodiesel have a higher flash point (minimum 130ºC) and therefore safer than conventional diesel fuel (minimum 52ºC). Furthermore, biodiesel can also be easily mixed with conventional diesel.

METHODOLOGY

Ten waste cooking oil samples (A, B, C, D, E, F, G, H, I, J) were taken from two different cafeterias (mixed cuisine and fried chicken stall) in UKM, Bangi (Figure 1). Five parameters were used to determine the characteristics of waste cooking oil samples for biodiesel production. These five parameters are kinematic viscosity, saponification, flash point, moisture content and free fatty acids.

FIGURE 1. Samples of waste cooking oil

i. *Kinematic viscosity (ASTM D7042)*

Spindle Type I and Brookfield DV-II + Pro Viscometer have been used. A total of 300 ml of waste cooking oil were used and value of speed was set at 30.00 rpm. Then, Rheocalc V3.2 Build 46-1 software have been used to measure kinematic viscosity within 30 min. Average value of the kinematic viscosity was displayed as graph and been reported after 30 min. It was then repeated using another 9 samples.

ii. *Saponification*

Test was conducted according to standard method AOCS Cd 3-25.

iii. *Flash point*

Test was conducted according to standard method AOCS Cc 9b-55.

iv. *Moisture content*

150 ml sample waste cooking oil was filtered using Whatsman 41 sized 20-25 micron and sample was weighed using electronic balance. Filtered cooking oil was then heated 70-100ºC for one hour and weighed. Percentage of moisture content of the sample was calculated using following equation, The water content = (weight – final weight of the original sample)/(original weight) x 100.

v. *Free fatty acid*

Test was done using titration method.

RESULTS AND DISCUSSION

The production of biodiesel from waste cooking oils is the best way to be studied more profoundly. One of the studies is the characterization of waste cooking oil. This preliminary study involved five important parameters to determine the suitability of waste cooking oil for biodiesel production.

Figure 2 shows kinematic viscosity values for ten samples that are in the range of 39.74 -56.04 mm^2/s and have been compared with the kinematic viscosity values specified in ASTM standard D6751. These values depend on the free fatty acid that can be found within the waste cooking oil. Sample A shown to have high kinematic value as it has high free fatty acids compared to other samples. All results show the value of kinematic viscosity which are around 40 to 50 times greater than the kinematic viscosity required in the production of biodiesel as compared to ASTM D6751 which is 1.9 – 6.0 mm^2/s (Kumaran et al. 2011). High in kinematic viscosity will cause the combustion that occur in combustion chamber become incomplete and prevent the operation by engine. Besides that, elevated engine oil dilution will also occur because of poor fuel combustion (Abd Rabu et al. 2013). Due to this condition, few techniques need to be done to reduce the kinematic viscosity value.

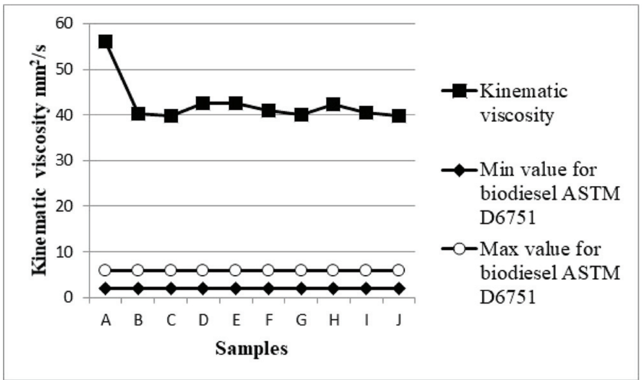

FIGURE 2. Kinematic viscosity values of waste cooking oil samples

Figure 3 shows the value of the saponification for waste cooking oil samples when compared to the value specified in ASTM D6751. All the samples produced values which are between 198.0 to 205.5 mgKOH/g. Saponification occurs because there is presence of free fatty acid in the waste cooking oil samples. High saponification value will affect the production of biodiesel. All the samples A, B, C, D, F, I and J produce saponification values more than 200 mgKOH/g. This condition shown that free fatty acids of all samples are at a high level (Ullah et al. 2014). As for samples E, G and H they produce a value less than 201 mgKOH because frequency they have been used are very low.

Flash point is defined as the minimum temperature at which vapor of the samples will flash momentarily on application of a standard flame under specified test conditions. It can be used to predict a possible fire hazard during transport,

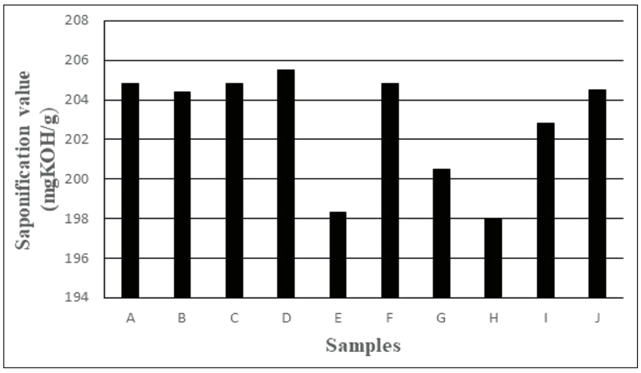

FIGURE 3. Saponification value of waste cooking oil samples

storage and handling. Figure 4 shows the values of the flash point of the sample that are between 198 -290ºC. High flash point value will affect the production of biodiesel. Waste cooking oil samples have high value of flash point because they have been exposed to the high heat that have been used during the cooking process. Based on the specifications of biodiesel (B100) in the standard ASTM D6751, the minimum value of the flash point for safety is 130ºC).

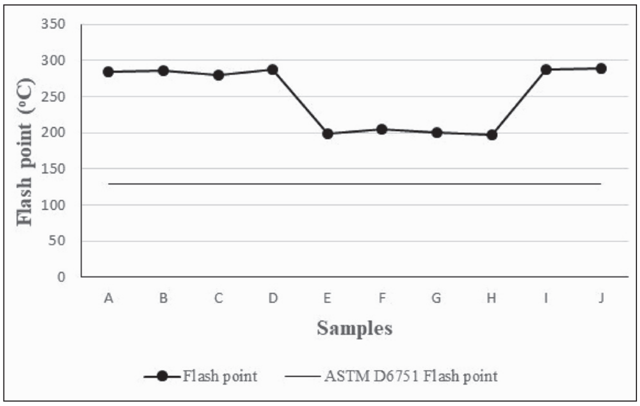

FIGURE 4. Flash point value for waste cooking oil samples

Figure 5 shows graph of moisture content of all waste cooking oil samples as compared to the moisture value that have been specified in ASTM D6751. All the samples shown to have moisture content that are less than one percent. Maximum percentage of moisture content to produce biodiesel when compared to the ASTM D6751 standard is 0.050% (Glycerintraders 2007). Most of the samples showed greater value when being compared to the value specified in ASTM D6751. Moisture content of waste cooking oil for samples A, B, E, and I have values more than 0.05% in which each of them are 0.07, 0.09, 0.15, 0.07, and 0.15 percent respectively. Presence of water in oil sample had a negative effect because it will lead to hydrolysis and resulted in low biodiesel production and catalyst consumption (Yaakob et al. 2013). Besides that, it will also generate soap and lather resulting in increased viscosity. In addition, formation of gel and foam also prevent separation of the glycerol and biodiesel.

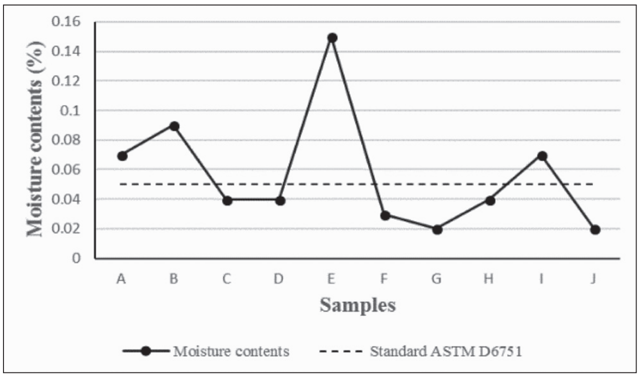

FIGURE 5. Moisture content values in waste cooking oil samples

Free fatty acid is a chemical molecule that is formed in waste cooking oil. Presence of free fatty acids can be identified in the event of a change of colour in the titration experiments for waste cooking oil and fat samples. Figure 6 shows that acid values of all samples exceed the maximum value that is required in biodiesel which is 0.05 mgKOH. High in free fatty acids will lead to saponification and causes low biodiesel yield (Yaakob et al. 2013). Furthermore, high in free fatty acids will also cause an increase in viscosity. Transesterification of alkali or acid catalyst is a process used in the production of biodiesel. This process aims to reduce the viscosity or concentration of oil so that the viscosity is close to diesel. High viscosity will cause difficulties to inject fuel from the fuel tank to the engine and causes atomization to occur. Early treatment should be done before the transesterification process is carried out to reduce free fatty acids. High free fatty acid will interfere with the production of biodiesel. The initial free fatty acid content has great influence in the process of transesterification of catalysts because when the concentration is high, the production of biodiesel expressed by the mass conversion is reduced and causes the formation of soap.

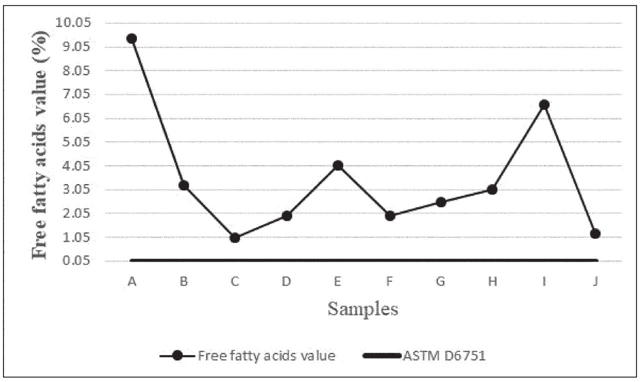

FIGURE 6. Free fatty acids value in waste cooking oil samples

Based on the analysis of data and observations in this study, it shows that the value of kinematic viscosity, saponification, flash point, moisture content and free fatty acids in waste cooking oil samples are very high compared to the biodiesel specification in standard ASTM D6571. To reduce these values, transesterification need to be done so that samples can be converted into biodiesel (Abd Rabu et al. 2013). Transesterification for biodiesel production can be catalysed using homogenous or heterogenous catalyst. This process can help to esterify the high amount of free fatty acid to form free fatty acid ester (Gnanaprakasam et al. 2013). Furthermore, this transesterification also involves simple process that can produce diesel with physical characteristics that is almost identical to the fossil diesel fuel (Yaakob et al. 2013). Collecting waste cooking oil for recycling purposes are very beneficial for the society and environment. UKM has successfully implemented the collection of waste cooking oil in all cafeteria to produce biodiesel. Rahman et al. (2017) reports that there was an increment of waste cooking oil collection in UKM as well as the active participation of the six cafeterias with a total accumulation of 1350 kg/year was successfully collected. This initiative can reduce toxic gas emission, reduce cost and reduce global warming. In addition, waste cooking oil is also expected to be very important in the future because of its low cost and wide availability (Yaakob et al. 2013).

CONCLUSION

Waste cooking oil have different characteristics based on the source of waste generation. This can affect the quality of product such as biodiesel production. From this preliminary study, it shows that values of kinematic viscosity, saponification, flash point, moisture content and free fatty acid of waste cooking oil from UKM cafeteria were high compared to the standards and process of transesterification is needed. However, further investigation need to be done on more parameters to observe the suitability of waste cooking oil for biodiesel production.

ACKNOWLEDGEMENT

This project was supported by Universiti Kebangsaan Malaysia (Project TD-2016-013 & AP-2014-019).

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Received date: 1st June 2018
Accepted date: 15th August 2018
Online First date: 1st October 2018
Published date: 30th November 2018