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Biodiesel Production from Waste Cooking Oil using Induction Heating Technology

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Abstract

Kerupuk and kemplang industries produce at least 65 liters of waste cooking oil per production. One of the applications of new and renewable energy can be done through the conversion of waste oilinto environmental friendly alternative fuel named biodiesel. The biodiesel production process can be conducted by various methods, such as utilizing induction heating technology. This technology has non-contact properties that do not interfere with the reactions that occur because of its application, which produces heat from the workpiece. This study uses waste cooking oil as raw material with variations in the molar ratios 1:3, 1:4, 1:5, 1:6, and 1:7. The analysis showed that the maximum biodiesel production was used of a 1:7 molar ratio with 86.95% yield, 0.86 gr/cm^3 of density, 5.73 cSt of viscosity, 190 ^{o}C of flash point, and 0.44 mg-KOH/gr of acid number. The using this ratio produces maximum yield and following SNI.

Keywords: Biodiesel, induction, heater, waste cooking oil, yield, quality

Abstrak (Indonesian)

Industri kerupuk dan kemplang menghasilkan sedikitnya 65 liter limbah minyak jelantah per produksi. Salah satu bentuk penerapan IPTEK di bidang energi baru dan terbarukan dapat dilakukan dalam mengolah limbah minyak hasil produksi industri ini melalui proses konversi menjadi salah satu bahan bakar alternatif yang ramah lingkungan, biodiesel. Proses produksi biodiesel dapat dilakukan dengan berbagai metode seperti memanfaatkan teknologi pemanasan induksi. Teknologi ini memiliki sifat non-kontak yang tidak mengganggu reaksi yang terjadi karena penerapannya yang menghasilkan panas dari dalam benda kerja. Penelitian ini menggunakan bahan baku minyak jelantah dengan variasi rasio molar 1:3, 1:4, 1:5, 1:6, dan 1:7. Analisa menunjukkan bahwa produksi biodiesel yang paling maksimum adalah penggunaan rasio molar 1:7 dengan perolehan yield 86,95%, densitas 0,86 gr/cm^3, viskositas 5,73 cSt, titik nyala 190 ^{o}C, dan angka asam 0,44 mg-KOH/gr. Penggunaan rasio ini menghasilkan yield yang maksimum serta sesuai dengan SNI.

Kata Kunci: Biodiesel, induksi, pemanas, minyak jelantah, yield, kualitas

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INTRODUCTION

One of Palembang's most popular souvenirs is kerupuk and kemplang. Kerupuk and kemplang industries produce at least 100 kg of various kerupuk and kemplang every production time. This production process produces waste of used cooking oil at least 65 liters per production cycle, and in one month, the production is carried out 8 times. Used cooking oil has potential to be processed into biodiesel that can be used as an alternative fuel diesel engines [1]. Renewable energy is one of the options for the future [2]. One effort to utilize this industrial waste that can be done is by processing it into biodiesel as one form of the application of science and technology in the field of new and renewable energy so that it can be utilized in productive activities in the community.

Various methods in the process of making biodiesel have been carried out. In 2015, Zi-Zheet al developed biodiesel production using recycling crude glycerol esterification catalyzed by alkali catalyst to optimize the formation of biodiesel yields [3].

However, this method is not efficient because it is needed two step long process for yield of the final product 93.1%. Sanjel et al used an supercritical alcohols method in 2015 to produce waste cooking oil-based biodiesel [4]. The temperature needed to process biodiesel is high enough that 210-350 ºC in a 25 mL batch reactor. Subhedar and Gogate [5] have also carried out research on the biodiesel production process using enzymatic inter-esterification method in 2015. This study takes 3 hours to produce biodiesel yield of 96.1%. Another method that has been applied by Zango et al is using heterogeneous catalyst method [6]. The using of this method can produce biodiesel in a shorter time. However, the highest yield of triglyceride conversion is still relatively low, which is 65.5%. In connection with this, the researchers conducted a study in the process of making biodiesel using induction-heating technology.

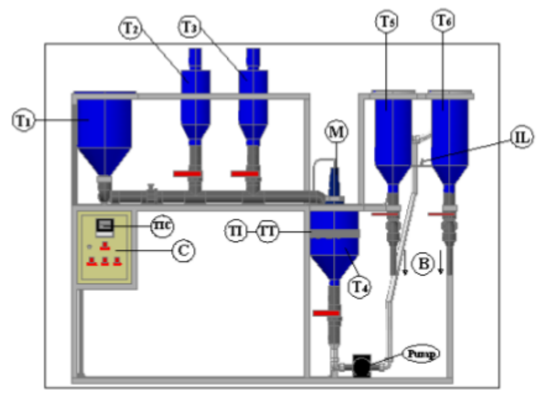
Induction heating is a technology that has been applied in both industries and households. One example of equipment that have used induction as a heater is an induction cooker. Induction heating works as electromagnetic induction principle that directly induces heat into vessel when it switched on [7]. This heat comes from circular eddy currents surrounding the magnetic field. Magnetic induction generates magnetic flux that penetrates the metal so that it produces heat on the metal. Heating by induction is a heating process indirect contact with a heater but using high frequency electricity so it will produce electrically conductive heat. This non-contact nature is another advantage of induction heating because the process does not contaminate the material being heated and very efficient because heat is generated from the workpiece.

Producing biodiesel using induction technology has been carried out and shows the results that the using of this method provides an increase in reaction kinetics and separation processes that occur, thereby reducing costs, but the research needs 1 hour to convert oil being biodiesel [8]. In this study, it used 5 variations of oil/methanol molar ratios to obtain high conversion results and in accordance with biodiesel quality requirements in Indonesia, the Standard Nasional Indonesia (SNI) 7128:2015.

MATERIALS AND METHODS

Materials

The waste cooking oil (WCO) as raw material is obtained from a kemplang and kerupuk factory in the Kenten area, Palembang city. The catalyst used was 1% sodium hydroxide from the weight of the oil. The technology used in the transesterification reaction is in the form of an induction heater with a coil, whichis circular. This coil will induce the mixture inside the reactor so that heat will be generated from the results of the induction. The instrument that is used in this research can be seen in Figure 1.



T1	: Feed tank	B	: Separator valve
T2	: Methanol tank	TI	: Temperature indicator
T3	: Catalyst tank	TT	: Temperature transmitter
T4	: Reactant tank	C	: Controller
T5 & T6	: Separator	IL	: Light indicator
M	: Mixer	TIC	: Temperature indicating controller

Figure 1. Biodiesel production using induction heating technology instrumentation

Methods

The procedure scheme for producing biodiesel from waste cooking oil with induction heating technology is shown in Figure 2.

The initial method carried out was analyzed WCO samples to determine the levels of free fatty acids (FFA) contained in. Then, the analyzed oil samples were transesterified by mixing methanol and catalyst into the oil with an induction heating reactor and carrying out a transesterification reaction at a temperature of 60 ºC for 15 minutes. The methyl ester that has been produced is separated in the separator from by-product (glycerol) and followed by the process of washing methyl esters using warm water (60 ºC) until the wash water is clear. The washed results are heated to remove the remaining water from the washing process. The heated methyl ester analyzed its characteristics to determine its quality and compared it with SNI 7128:2015.

RESULTS AND DISCUSSION

Effect of molar ratio on yield biodiesel

The high yield of biodiesel produced showed that the conversion rate of triglycerides with methanol was high. The molar ratio between oil and methanol is one of the factors that influence the amount of biodiesel yield. The relationship between the molar ratio of oil:methanol and the percentage yield of the resulting methyl ester is shown in Figure 3.

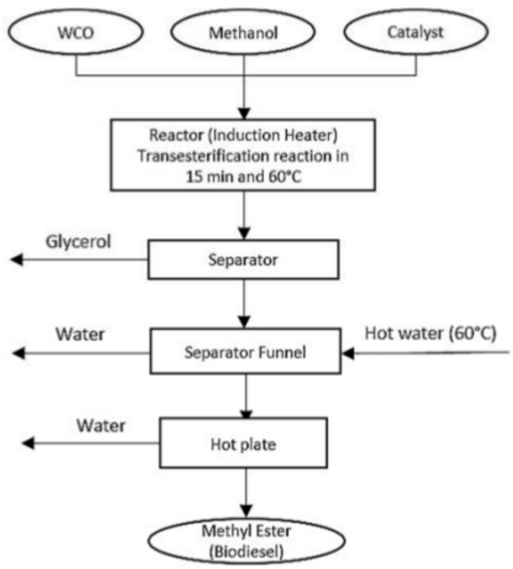


Figure 2. Flowchart for producing biodiesel with induction heating

Based on Figure 3, it is found that the increase in the molar ratio between oil and methanol is directly proportional to the increase in yield of biodiesel obtained. The increase in yield is due to a large amount of methanol used, so the transesterification reaction tends to shift towards the product.

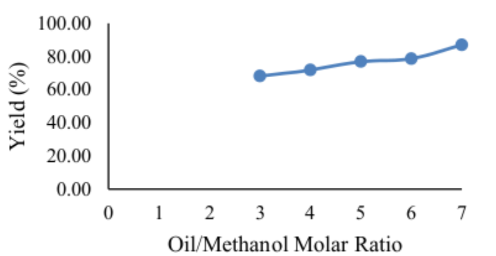


Figure 3. Relation of the molar ratio of oil:methanol to biodiesel yield

The increasing amount of methanol will shift the reaction towards to the right (biodiesel product) so the conversion will increase [9]. Higher molar ratios cause more triglyceride molecules to react [10].

Effect of molar ratio on the density

Density is one of the critical parameters in determining the quality of biodiesel products produced. It has the function of knowing how combustion reactions occur in diesel engine combustion chambers [11]. Fuel density is effective in breaking down fuel spray from injector engines [12]. The relationship between the effect of the molar ratio of oil and methanol to density is shown in Figure 4.

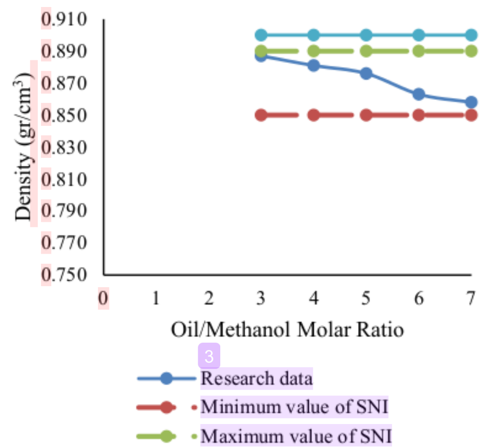


Figure 4. Relation of oil and methanol molar ratio with density

Based on Figure 4, the increase in a molar ratio of oil with methanol will reduce the density of the product produced. The using of a high ratio will decrease the conversion rate of triglycerides to biodiesel. Transesterification slightly reduce the product density [13]. The high conversion rate indicates that the number of triglycerides converted is increasing.

Effect of molar ratio on the viscosity

The product viscosity value is related to the process of injecting biodiesel in the combustion chamber. High viscosity will inhibit the pumping system and make the engine difficult to turn on [14]. The lowest viscosity will facilitate the pumping and atomization of fuel and get better fuel droplets [9]. The relationship between the molar ratio of oil and methanol to viscosity is shown in Figure 5.

Figure 5 shows that the higher molar ratio will reduce the viscosity value of the biodiesel product obtained. Using high ratios of oil with methanol will break triglyceride molecules. The main purpose of transesterification is to lower viscosity [15].

Transesterification breakdowns triglycerides into diglycerides and converts it into monoglycerides. Finally, from monoglycerides forms 3 moles of methyl esters and a mole of glycerol.

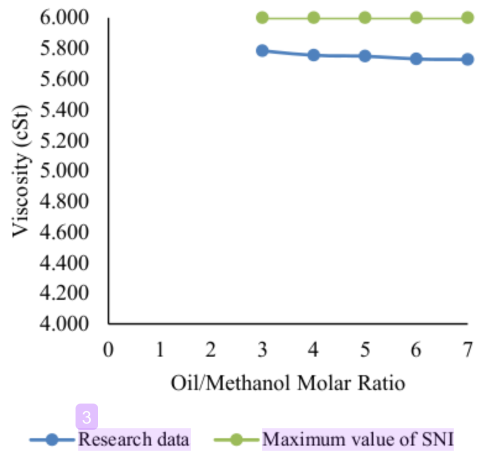


Figure 5. Relationship between oil and methanol molar ratio with the viscosity

Effect of molar ratio on the flash point

Flash point is the temperature of heated oil that easily burns when exposed to a flame [16]. This parameter is important to know because it is related to the process of storing and transporting fuel. The effect of variations in the molar ratio between oil and methanol to the flash point of the biodiesel product is shown in Figure 6.

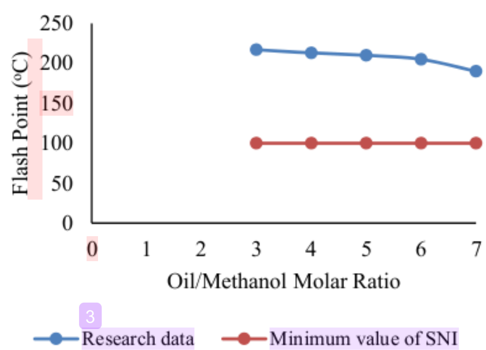


Figure 6. Relationship between oil and methanol molar ratio with a flash point

Based on the graph obtained, the product flash point is influenced by the large molar ratio between oil and methanol. Increasing the flash point value can be caused by less optimal washing processes or glycerol and unreacted catalysts that are still left in the product [17]. The flash point of the product produced is still above the minimum allowed by SNI. This shows that the amount of methanol used affects the magnitude of the flash point of the product produced.

Effect of molar ratio on the acid number

The acid number in biodiesel shows the amount of free fatty acids contained. The number of acids that are increasingly contained in biodiesel products can increase the formation of ash in the fuel combustion process, fuel deposits, and reduce the use of pumps and fuel filters.

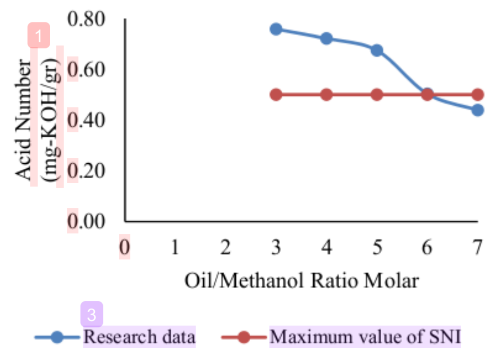


Figure 7. The relationship of the molar ratio of oil and methanol to acidic numbers

Based on Figure 7, it is found that the using of oil and methanol molar ratio affects the acid number of the product produced. A large amount of methanol that is used reduces the acid value of the biodiesel product produced that can be caused by the large amount of methanol that makes more of the conversion of triglycerides into biodiesel so the free fatty acids contained in the oil are reduced. High fatty acids can be overcome by increasing conversion, one of them by increasing the number of reactants [17]. Some biodiesel products are still above the range allowed by SNI. High acid numbers can be caused by the presence of impurities contained in oil [6].

CONCLUSION

Induction heating is a potential technology to be applied in the process of utilizing kerupuk and kemplang factory waste oil. The using of induction heating gives advantages of its non-contact properties so it does not pollute the material being heated and very efficient because of the heat produced from the material. Induction heating utilizes the heat generated in the metal regarding induction from the magnetic field. The using of induction heating technology with a variation of the molar ratio of oil to methanol gives the maximum value at a ratio of 1:7 with 86.95% yield, 0.86 gr/cm^3 of density, 5.73 cSt of viscosity, 190 °C of flash point, and 0.44 mg-KOH/gr of acid number. This parameter value is following the SNI 7128:2015.

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