IJFAC

Indonesian Journal of Fundamental and Applied Chemistry

Article http://ijfac.unsri.ac.id

Biodiesel Production from Waste Cooking Oil

Endang Sri Rahadianti[1*] , Yerizam [2] and Martha [3]

[1]Applied Master of Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Palembang
[2] Chemical Engineering Department, Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Palembang
[3] Chemical Engineering Department, Renewable Energy Engineering, Politeknik Negeri Sriwijaya, Palembang
*Corresponding Author: erahadianti@gmail.com

Abstract

Increased energy consumption and the depletion of petroleum reserves have pushed up oil prices globally. The diminishing petroleum reserves are a problem inherent in this type of fossil energy. One alternative energy source that has the potential to be developed in Indonesia is biodiesel. Used cooking oil or used cooking oil is a potential raw material for making biodiesel. In this study biodiesel was made from used cooking oil and methanol using the transesterification method with KOH catalyst. The production of biodiesel from used cooking oil begins with mixing raw materials of used cooking oil collected into one. The mixture is then precipitated for 24 hours. The transesterification process was carried out by mixing KOH (1% of oil weight) with methanol (ratio of methanol: oil 6: 1) at a temperature of 65 °C. After the temperature is reached, the methanol and KOH solution is added slowly while pumping (stirring), with a variation of time 30, 45, 60.75 and 90 minutes. Biodiesel purification is done by washing using hot water (temperature 70 °C) twice as much washing. Characteristics of biodiesel based on the best conditions for density 0.886 g / mL, viscosity 5.89 cSt, FFA 0.11% , acid value 0.256 mgKOH/g and flash point 170.52 °C. The biodiesel products based on these parameters meet SNI 7182-2015 standards.

Keywords: energy, biodiesel, waste cooking oil, transesterification, free fatty acid (FFA)

Abstrak (Indonesian)

Peningkatan konsumsi energi dan menipisnya cadangan minyak bumi telah mendorong kenaikan harga minyak secara global. Cadangan minyak bumi yang semakin berkurang merupakan permasalahan yang melekat pada jenis energi fosil ini. Salah satu sumber energi alternatif yang berpotensi untuk dikembangkan di Indonesia adalah biodiesel. Minyak jelantah atau minyak goreng bekas merupakan bahan baku yang potensial untuk biodiesel. Pada penelitian ini biodiesel dibuat dari minyak goreng bekas dan metanol dengan metode transesterifikasi menggunakan katalis KOH. Pembuatan biodiesel bekas dimulai dengan dengan mencampur bahan baku minyak goreng bekas yang dikumpulkan menjadi satu. Campuran kemudian diendapkan selama dua kali 24 jam. Proses transesterifikasi dilakukan dengan mencampurkan KOH (1 % dari bobot minyak) dan metanol (ratio metanol : minyak 6:1) pada temperatur 65 °C. Setelah suhu tercapai, metanol dan KOH ditambahkan secara perlahan sambil dilakukan pemompaan (pengadukan), dengan variasi waktu 30, 45, 60,75 dan 90 menit. Pemurnian dilakukan dengan pencucian menggunakan air panas (suhu 70 °C) sebanyak dua kali pencucian. Karakteristik biodiesel berdasarkan kondisi terbaik untuk density 0,886 g/mL, viscosity 5,89 cSt, FFA 0,11 % , acid value 0,256 mgKOH/g dan flash point 170,52 ^{0}C. Produk biodiesel yang dihasilkan berdasarkan parameter tersebut memenuhi standar SNI 7182-2015.

Kata Kunci: energi, biodiesel,minyak goreng bekas, transesterifikasi, asam lemak bebas (FFA)

Article Info

Received 14 September 2018
Receive in revised 16 September 2018
Accepted 16 September 2018
Available online 10 October 2018

INTRODUCTION

Increased energy consumption and the depletion of petroleum reserves have pushed up oil prices globally. The diminishing petroleum reserve is a problem that is always attached to this type of fossil energy [1]. The main reason for finding alternative diesel engine fuels is because of the high price of oil products [2]. To face the challenges in this energy sector, it is necessary to utilize the potential of new and renewable energy. One alternative energy source that has the potential to be developed in Indonesia is biodiesel.

Biodiesel can be used as a substitute for fossil fuels such as diesel oil. Used cooking oil or used cooking oil is a potential raw material for making biodiesel. Its abundant availability can be estimated from an increase in the rate of growth of oil palm in 2004-2014 at around 11.09% per year [3]. The projected consumption of CPO (crude palm oil) in 2015 for the production of cooking oil and margarine is around 5.9 million tons or 54.63% of the total CPO production [4].

Used cooking oil or Jelantah can be converted to biodiesel because the chemical composition contains free fatty acids (FFA) and when reacted with alcohol and using simple technology will become biodiesel [5]. Biodiesel is derived from fats and oils either by chemical means [6]. There are at least four ways in which oils and fats can be converted into biodiesel, namely, transesterification, blending, micro emulsions and pyrolisis. Among these, transesterification is the most commonly used methods as it reduces the viscosity of oil [7]. Biodiesel production by transesterification reaction can be catalyzed with alkali, acidic or enzymatic catalyst. Alkali and acid transesterification processes require less reaction time with reduced processing costs as compared to the enzyme catalyst process [8,9].

Several studies on biodiesel synthesis from used cooking oil have been carried out. The study [10] has synthesized biodiesel from used cooking oil with the trans-esterification process. Research [11] has synthesized biodiesel using a two-stage catalyst process, namely the esterification process with ferry sulfate catalyst and potassium hydroxide base catalyst. The biodiesel processing process that uses two stages, namely esterification and transesterification requires double consumption of methanol. The addition of catalyst can increase conversion percentage of biodiesel produced [12].

In this study biodiesel was made from used cooking oil and methanol using the transesterification method using KOH catalyst. As for the selection of used cooking oil as a raw material for making biodiesel, in addition to being easy to obtain and the price is low also to utilize used cooking oil which is usually disposed of to be a useful product [13].

MATERIALS AND METHOD

Materials

Waste cooking oil (WCO) used in the research was obtained from street sellers in Palembang City, Indonesia. Samples was taken from Bukit Besar, Palembang, South Sumatera. The chemical and reagent for synthesize include methanol, palmitat acid and KOH were purchase form Merck. The distillated water wa used to make reagents. The characteristic of waste cooking oil is summarized in Table 1. Methanol was used as alcohol for the transesterification reaction. KOH was used as base catalyst.

Synthesis of Methyl Ester

The production of biodiesel from used cooking oil begins with mixing raw materials of used cooking oil collected into one. The mixture is then precipitated for 24 hours. After pretreatment, a preliminary analysis of used cooking oil was carried out, namely FFA level test (max.5%). The trasesterification process was carried out by mixing KOH (1% of oil weight) with methanol (ratio of methanol: oil 6: 1). Used cooking oil is then heated to 65^oC. After the temperature is reached, the methanol and KOH solution is added slowly while pumping (stirring). Heating and stirring are evenly carried out at 65^oC with a variation of 30, 45, 60, 75 and 90 minutes. After the heating process, the mixture is allowed to stand for $\pm$ 1 hour. After the precipitate the separation process is done by taking the bottom first (glycerol), then the upper liquid (biodiesel). Biodiesel purification is done by washing using hot water (temperature 70 ^oC) twice as much washing. Ratio between volume of biodiesel and water for washing are 1: 1. Biodiesel is then heated at 110 ^oC for 10 minutes using a hot plate to remove moisture. The qualitative analysis of biodiesel characteristics refers to SNI 7182-2015.

RESULTS AND DISCUSSION

Analyses of raw material

Used cooking oil before being reacted with methanol is precipitated for 2 times 24 hours, and then an initial analysis of used cooking oil is carried out. The waste cooking oil was illustrated in Figure 1.

Based on the analyses that have done, the characteristic of raw material can be seen in Table 1. Because of FFA less than 5 %, the feedstock can be transesterified with an alkali catalyst.

Used cooking oil has various characteristics depending on many factors, including the type of oil source commodity, duration of use, fried food ingredients and frying temperature. The main characteristics of used cooking oil are the relatively high levels of free fatty acids, density and viscosity.

Figure 1. Waste Cooking Oil

Table 1. The characteristics of waste cooking oil

Type of Analyses	Value	Unit	Method
Density (40^{0}C)	0,9104	g/mL	Measurement
Viscosity	8,8843	cSt	Measurement
Free Fatty Acid	2,9572	%	Titration
Acid Value	6,1721	mgKOH/g	Titration

In Table 1 the characteristics of used cooking oil used in this study are within the range of characteristics of the results of the study [14] namely acid numbers ranging from 1.78 to 17.85 mg/KOH/g, density 0.9183 - 0.9273 and viscosity 39.81 - 51.44 cSt.

Synthesis of Biodiesel

Biodiesel synthesis is done using heating at a temperature of 65°C which is the optimum temperature for the Trans esterification process that has been done before, where temperature variations are made between the ranges of 45-65°C. The temperature at 65°C was selected based on the pleminary study result. The research was done in oil to metanol volume ratio 6:1, catalyst concentration 1 wt % KOH, and temperature at 65°C. The biodiesel product is shown in Figure 2.

Figure 2. Biodiesel product

The Effect of reaction time to the density

Biodiesel density testing aims to determine the level of fuel feasibility in the engine (in this case diesel engine). The density values were measured at 40 °C and space pressure. The density values were measured at 40 °C and space pressure. From Figure 3 it can be seen that the density at various reaction times has decreased in density. The longer the reaction time, the biodiesel density decreases. The density range obtained from the analysis results is 0.886-0.889 g/mL. The optimum condition at 90 minutes reaction time obtained a density value of 0.886 g/mL. Different results from previous research which obtained biodiesel density from used cooking oil were 0, 852 g/mL [15], 852 kg/m^3 [16] and 0.874 g/mL [17]. This is in line with the statement [18], where the density biodiesel obtained from the transesterification with conventional heat treatment ranges from 0.85 to 0.86 g/mL. The effect of the reaction time on density is shown in Figures 3.

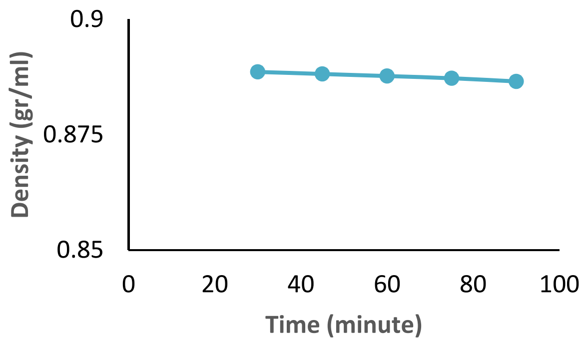

Figure 3. The effect of reaction time to the density of product

Density is the mass of biodiesel per unit volume at a certain temperature. From this statement it can be seen that the lower the density value the better the biodiesel. There are several factors that influence the results of biodiesel density analysis, namely, the first factor is the possibility that there are still a number of used biodiesel washing water, where the water density is 0.99 g/mL which will certainly affect the measurement of biodiesel density. The second factor is that there are still triglyceride molecules that have not been converted into methyl esters (biodiesel).

Based on the results of the analysis, it can be seen that the biodiesel density obtained meets SNI 7182-2015 which is in the range 0.886-0.888 gr / ml. According to [19], the density values within the SNI limit can produce perfect combustion. Biodiesel with a density that exceeds the standard will cause incomplete combustion reactions that can increase engine emissions and wear. This will be happen if the density is low in the ability of high oil fuels [20]. It can be optimized at a temperature of 65oC with a mixing time of 90 minutes with a density of 0.886 g/mL.

The Effect of reaction time to the viscosity

Viscosity is a number that states the amount of resistance of a liquid material to flow or the size of the amount of shear resistance of a liquid material. Wahyuni found that the higher of the viscosity, the thicker and more difficult liquid material to flow [21]. From Figure 4 it can be seen that at 90 minutes reaction time an increase in viscosity occurs, due to incomplete biodiesel manufacturing process because the boiling point of methanol is 64.7^{0}C, then methanol will quickly evaporate before the perfect biodiesel process occurs. The optimum mixing time for viscosity is 75 minutes, with viscosity of 5.89 cSt. This value is greater than the viscosity reported by [15], which is 4.7 cSt. Decreased cooking oil viscosity indicates a certain amount of triglyceride molecules have been successfully converted into shorter or simpler molecules, namely methyl esters. The effect of the viscosity is shown in Figures 4.

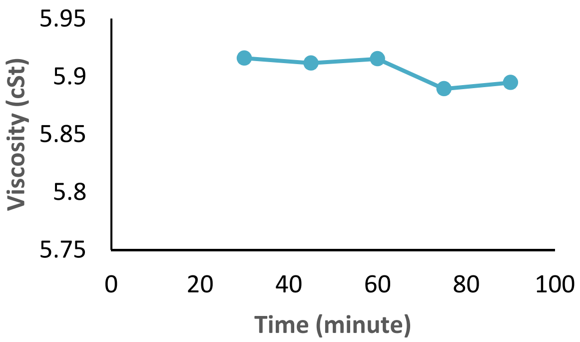

Figure 4. The effect of reaction time to the viscosity of product

Based on the results of the analysis, it can be seen that almost all of the biodiesel viscosity obtained meets SNI 7182-2015 which is in the range of 5.89 - 6.25 cSt. High viscosity can affect the atomization of combustion during injection and other flow losses in the combustion channel. So that it affects the quality of biodiesel [22].

The Effect of reaction time to the acid value

Acid numbers are a measure of the amount of free fatty acids and are calculated based on the molecular weight of fatty acids or a mixture of fatty acids [23]. The number of acids is the number of milligrams of KOH needed to neutralize free acids in one gram of biodiesel [24].

A high acid level indicates the formation of large free fatty acids from oil hydrolysis. The higher the acid number, the lower the oil quality [25]. According to [23] oil or fat will be converted into free fatty acids and glycerol in a hydrolysis reaction. Hydrolysis reactions can occur because of the presence of a number of water in oil or fat that can cause damage to oil or fat. In Figure 5, the acid number shows that for each time the value has met the SNI standard. The decrease in acid numbers indicates that a number of free fatty acids contained in used cooking oil have been converted into biodiesel. The effect of the acid value of the biodiesel product is shown in Figures 5.

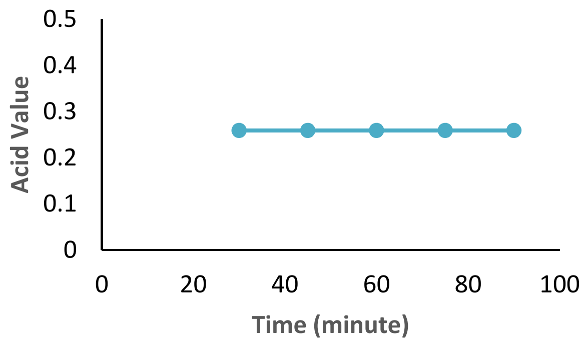

Figure 5. The effect of reaction time to the acid value of product

A high acid value indicates that there is still free fatty acid in biodiesel, where biodiesel will be corrosive to the engine when used. The amount of methanol is intentionally given excess in addition to pushing the reaction towards the product is also intended so that the water formed from the reaction of free fatty acids with methanol can be absorbed by methanol so as not to block the course of the reaction of free fatty acid conversion into methyl esters. This is because the reaction of free fatty acids with methanol which forms methyl esters and water is reversible so that the water formed can react again with methyl esters (biodiesel) under certain operating conditions. Therefore, the lower the acid number, the better the quality of biodiesel [26]. The optimum acid number occurs at a reaction time of 75 minutes with a temperature of 65^{0}C which is 0.2589 mg-KOH/g.

Comparison of Product Quality with SNI Standard No. 7182 – 2015

Biodiesel produced from the best conditions based on the criteria of density, viscosity, acid value and FFA content is shown in Table2.

Table 2. Comparison of Product Biodiesel dengan SNI Standard 7182 - 2015

Type of Analyses	Result	Unit	SNI
Density (40^{0}C)	0,886	g/mL	0,856 – 0,890
Viscosity	5,89	cSt	2,3 – 6,0
Free Fatty Acid(FFA)	0,11	%	Max 5
Acid Value	0,256	mgKOH/g	Max. 0,5

Biodiesel FFA levels meet SNI requirements, with a value of 0.11%. This decrease in FFA levels from used cooking oil shows that a number of free fatty acids contained in used cooking oil have been converted to biodiesel. The characteristics of biodiesel from the reaction with 1% KOH catalyst, temperature of 65^{0}C with a variation of reaction time at 30 to 90 with 15 minute intervals, generally have the required quality of SNI 7182-2015.

CONCLUSION

1. Used cooking oil as raw material with a FFA value of 2.9572% can be converted into biodiesel using the transesterification method directly without going through the esterification process.
2. Characteristics of the physical properties of biodiesel in general have met the standards of SNI 7182-2015 based on parameters of quality density, viscosity, acid numbers and FFA.

REFERENCES

[1] BPPT (badan Pengkajian dan Penerapan Teknologi)., Outlook Energy Indonesia., 2014.

[2] A.B. Chhetri, K.W., Islam, M.R., "*Waste Cooking Oil as an Alternate Feedstock for Biodiesel Production*", Energies, 1996-1073, 2008.

[3] Direktorat Jendral Perkebunan., Pertumbuhan Kelapa Sawit., www.ditjenbun.pertanian.go.id, 21 November, 2014.

[4] GAPKI (Gabungan Pengusaha Kelapa Sawit Indonesia)., Konsumsi Sawit Indonesia, www.sawitindonesia.com, 29 April, 2015

[5] S. Suroso., "Efektifitas Pemanfaatan Minyak Goreng Bekas (Minyak Jelantah) Menjadi Biosolar Sebagai Bahan Bakar Alternatif Dikota Surakarta", *J. Autindo*, Vol.1.Nomor 3, 2016

[6] Y. Shimada, Y.Watanabe, A. Sugihara and Y. Tominaga, "Enzymatic Alcoholysis for Biodiesel Fuel Productionand Application of the Reaction to Oil Processing", *J.of Molecular Catalysis B:Enzymatic*, Vol.17, No.3-5, pp.360-364,2002.

[7] F.R. Ma and M.A. Hanna " Biodiesel Production: A Review", *Bioresource Technology*, Vol.70, No.1, pp.1-15, 1999

[8] M.P.Dorado, E.Ballesteros, F.J.Lopez and Mittelbach, " Optimization of Alkali-Catalyzed Transesterification of Brassica Carinate Oil for Biodiesel Production", *Energy Fuels*, Vo.18, No.1, pp.77-83,2004

[9] P.D. Patil., V.G. Gude., H.K.Reddy., T. Muppaneni., S.Deng, " Biodiesel Production from waste Cooking Oil Using Sulfuric Acid and Microwave Irradiation Processes", *J. of Environmental Protection*, Vol.3. pp.107-113,2012

[10] M.D. Solikhah., Paryanto, I., Barus , B.R., "Efek Kualitas Minyak Jelantah terhadap Harga Proses Produksi dan Kualitas Biodiesel", *Prosiding Seminar Nasional Teknik Kimia Indonesia-SNTKI*, Bandung. 2009.

[11] Y.Wang., Qou., S.,Liu., P., Zhang, Z.,"Preparation of Biodiesel from Waste Cooking Oil via Two-Step Catalyzed Process, *Energy Conversion & Management*, Vol.48, Issue 1, pp. 184-188, 2007

[12] Hasanudin, Rachmat, A.," Production of Biodiesel from Esterification of Oil Recovered from Palm Oil Mill Effluent (POME) Sludge using Tungstated-Zirconia Composite Catalyst". *Indonesian Journal of Fundamental and Applied Chemistry*, Vol. I, No.2, pp. 42-46, 2016

[13] Encinar, Jose. M., " Preparation and Properties of Biodiesel from Cynara Carduncus L.Oil", *Industrial and Engineering Chemistry Research*, Vol. 38.,No.8, pp 2927–2931, 1999

[14] Sanli, H., Canakei, M., Alptekin, E, "Characterization of Waste Frying Oils Obtained from Different Fasilities". *In Word Renewable Energy Congress*, Linkoping,Sweden, 2011

[15] Haryono., C.L.,Natanel, I.,Rahayu, A.N., Wicaksono," Esterifikasi dan Transesterifikasi Serempak Minyak Jelantah menjadi Biodiesel dengan Katalis Resin Penukar Kation", *Prosiding Seminar Nasional MIPA*, 2016.

[16] E. Setiawati., F. Edwar.," Teknologi Pengolahan Biodiesel dari Minyak Goreng Bekas dengan Teknik Mikrofiltrasi dan Transesterifikasi sebagai Alternatif Bahan Bakar Mesin Diesel", *Jurnal Riset Industri* , Vol.6, No. 2, hal. 117-127,2012.

[17] E.S. Yusmartini., Rusdianasari, "Separation Process Biodiesel from Waste Cooking Oil Using Ultrafiltration Membranes",*Proceeding First*, 2016
[18] S.V., Sinaga.,A. Haryanto.,S. Triyono,"Pengaruh Suhu dan Waktu Reaksi pada Proses Pembuatan Biodiesel dari Minyak Jelantah", *Jurnal Teknik Pertania*n, Vol 3, No 1.pp 27-34, 2014
[19] Budiman., R.D., Kusumaningtyas, Y.S., Pradana, N.A., Lestari, "*Biodiesel: Bahan Baku, Proses dan Teknologi*", cetakan pertama, Gajah Mada, 2014.
[20] Machmud, S., "Pengaruh Perbandingan Solar – Biodiesel (minyak jelantah) terhadap Emisi Gas Buang pada Motor Diesel", *Jurnal Janateknika*, Vol.11 No.2, 2009.
[21] S. Wahyuni, Ramli, Mahrizal, "Pengaruh Suhu Proses dan Lama Pengendapan terhadap Kualitas Biodiesel dari Minyak Jelantah", *Pillar of Physics*, Vol.6, hal.33-40, 2015
[22] R.Prihandana., Hendroko, R. dan M.,Nuramin, M. 2006. *Menghasilkan Biodiesel Murah, Mengatasi Polusi dan Kelangkaan BBM*. Agromedia Pustaka, Jakarta, 2006
[23] S. Ketaren, "*Pengantar Teknologi Minyak dan Lemak Pangan"*. Universitas Indonesia. Jakarta 2005.
[24] E. Hambali, "*Teknologi Bioenergi*", Jakarta:Agro Media Pustaka, 2007
[25] S. Sudarmadji., B. Haryono and Suhardi, "*Analisa Bahan Makanan dan Pertanian*", Edisi Kedua, Liberty, Yogyakarta, pp.93-104,2003
[26] Fitriani, "*Produksi Biodiesel dari Minyak Jelantah melalui Transesterifikasi dengan Bantuan Gelombang Ultrasonik"*, Bandar Lampung:Lampung, 2016.