

The Effect of Acetone Amount Ratio as Co-Solvent to Methanol in Transesterification Reaction of Waste Cooking Oil

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Abstract. The production of biodiesel from waste cooking oil by transesterification reaction using acetone as co-solvent has been carried out. This research studied the optimal amount ratio of acetone as co-solvent to methanol in the transesterification process using homogeneous alkaline catalyst KOH 1% (w/w) of waste cooking oil at room temperature for 15 minutes of reaction time. Mole ratio of waste cooking oil to methanol is 1:12. Acetone was added as co-solvent in varied amount ratio to methanol are 1:4, 1:2, and 1:1, respectively. The results of fatty acid methyl esters (FAME) were analysed using GC-MS instrument. The results showed that the optimal ratio is 1:4 with 99.93% of FAME yield.

1. Introduction

Biodiesel is an alternative energy that can be used as fuel like fossil fuel. Biodiesel is obtained from vegetable oil or animal oil so it can be renewed. Since biodiesel is a non-fossil oil it is certainly free from sulfur, which will have a positive impact on the environment. Biodiesel has advantages compared to petroleum diesel fuel derived from petroleum, among others, has a better lubrication properties that can extend engine life, is a safe fuel, easy to handle, and non-toxic, has a relatively low exhaust gas.

Biodiesel is produced by a transesterification reaction between triglycerides and alcohols such as methanol (methanolysis) using a strong base catalyst such as NaOH and KOH. One of the problems in the transesterification reaction of biodiesel is the non-homogeneity of the reactants involved. Methanol is not soluble with triglycerides. Conventionally to increase the solubility of reactants was carried out with temperature 65°C for 2 hours^[1] or with using microwave-assisted reactor^[2]. The use of high energy in reaction for a long time leads to inefficiency in biodiesel production. The use of co-solvent becomes an appropriate alternative to solve the problem of solubility. A one-phase reaction can be formed by adding a solvent that can increase the solubility of the oil, the solvent hereinafter referred to as co-solvent^[3]. Co-solvent is very soluble with alcohol, fatty acids and triglycerides. The used co-solvent should not contain water and the more co-solvent added is better because it will increase the solubility of the oil. The selected co-solvent has a boiling point close to methanol which can facilitate the separation process at the end of the reaction.

Several co-solvents has been used for transesterification reaction including n-hexane, diethyl ether, acetone, 2-propanol, tetrahydrofuran, or ethyl acetate. Acetone was found to be the best co-solvent in transesterification reaction^[4].



Our objective in this research is to understand the effect of acetone amount ratio as co-solvent to methanol in waste cooking oil transesterification reaction.

2. Materials and methods

2.1. Material

Acetone, methanol, and Potassium hydroxide (KOH) is purchased by Merck Millipore (Germany). Waste cooking oil was obtained from several restaurants around campus of Universitas Islam Indonesia Yogyakarta that have already washed with alcoholic washing method ^[5].

2.2. Methods

2.2.1. Transesterification reaction. The transesterification stage is carried out by reacting washed waste cooking oil with methanol containing 1% homogeneous potassium hydroxide (KOH) catalyst into a three-neck flask. Mole ratio methanol/oil is 1:12. Furthermore, acetone is added as co-solvent. The transesterification process is carried out by varying the co-solvent acetone amount ratio to methanol. The mole ratio of acetone to methanol is done by 3 variations: 1: 4, 1: 2 and 1: 1 mol. The entire mixture is stirred using a magnetic stirrer at a constant speed of ± 600 rpm at room temperature (27°C) for 15 minutes.

2.2.2. Separation and identification of Fatty Acid Methyl Esters (FAME). The entire mixture is inserted into the separating funnel and silenced so that the mixture will form two layers (two phases). The lower layer is glycerol which is a by-product of the transesterification reaction process, while the top layer is the methyl esters obtained. The top layer is washed using aquadest and evaporated to separate the excess methanol. The yield of total methyl esters was analysed using GC-MS (Shimadzu QP 2100 SP with RTX-5 column).

3. Results and Discussion

In this research the co-solvent used is acetone. Acetone is an aprotic solvent having intermediate polarity so as to dissolve high-polarity methanol and non-polar use of crude oil triglyceride into a homogeneous reaction system. This phase change increases the rate of transesterification reaction between methanol and triglyceride of cooking oil with the appearance of a homogeneous sodium hydroxide as base catalyst. Another important property of acetone is as aprotic solvent so that acetone has ability to stabilize the methoxide ion formed. This methoxide ion is an active intermediate compound in the transesterification reaction that attacks triglycerides to form methyl esters through the mechanism of S_N2 .

To determine the optimum condition of transesterification reaction by using co-solvent acetone, the mole ratio of acetone to methanol was evaluated.

3.1.1. Effect of amount of acetone to methanol to yield of transesterification product

Molar ratio of acetone to methanol is one of the important aspects affects yield of transesterification product. This study aims to obtain the optimum amount ratio required to obtain a homogeneous reaction conditions resulting in the most transesterification product. Amount ratio of acetone to methanol was varied over 1:4, 1:2, and 1:1.

Table 1. Yield of transesterification product of waste cooking oil with varied amount ratio of acetone to methanol

No	Weight of WCO (g)	Amount ratio of acetone to methanol	Weight of transesterification products (g)	Yield of transesterification products (%)	Density (g/mL)
1	10	1:4	6.183	61.83	0.87
2	10	1:2	7.270	72.70	0.87
3	10	1:1	4.823	48.23	0.88

Table 1 shows that the addition of acetone as a co-solvent in the transesterification reaction causes a decrease in the yield of transesterification products. Most of products is obtained at a ratio of 1:2 (acetone: methanol). The addition of acetone with a ratio above 1: 2 causes a decrease in the yield of transesterification products.

3.1.2. Effect of acetone amount ratio to methanol to FAME yield

The yield of FAME was determined via GC-MS analysis. The GC-MS obtained data of FAME composition in biodiesel.

Table 2. Biodiesel composition and FAME yield in varied acetone amount ratio to methanol via GC-MS analysis

No.	Retention time (minutes)	Chemical Constituents	Area Percentages (%)		
			1:4	1:2	1:1
1	11.40	Methyl Laurate	0.06	0.05	0.05
2	13.86	Methyl Miristate	0.76	0.80	0.85
3	15.91	Methyl Palmitoleate	0.31	0.33	0.35
4	16.15	Methyl Palmitate	38.30	38.21	38.32
5	17.14	Methyl Heptadecanoate	0.07	0.08	0.08
6	17.97	Methyl Oleate	54.92	54.6	54.47
7	18.14	Methyl Stearate	4.64	4.79	4.83
8	19.62	Methyl Hexadecadienoate	0.08	0.08	0.09
9	19.79	Methyl-9,10-Methylene Hexadecanoate	0.31	0.31	0.30
10	19.99	Methyl Aracate	0.38	0.41	0.40
11	21.69	Methyl Docosanoate	0.05	0.06	0.07
12	23.38	Methyl Lignoserate	0.05	0.05	0.06
FAME Yield			99.93	99.77	99.87

Table 2 shows that the lowest ratio (1: 4) gives FAME with highest yield of 99.93% followed by the ratio of 1: 2 of 99.77% and the ratio of 1: 1 of 99.87%. This suggests that the addition of small amount of acetone as co-solvent can increase the amount of methyl esters so that the transesterification reaction process is more efficient. Based on the composition of the transesterification result, the highest peak value of chromatogram is methyl palmitate, methyl oleate and methyl stearate compounds.

The greater amount of acetone in the mixture does not give a significant percentage difference in yield of methyl esters, but causes a decrease in the yield of methyl ester on the weight of the waste cooking oil. Increasing the amount of acetone causes the separation of methyl ester products to glycerol and the residual triglycerides becomes more difficult to be marked by the length of time required for the emergence of two layers of organic layer containing methyl esters and glycerol layer.

4. Conclusion

The amount of acetone ratio as a co-solvent to methanol in the transesterification reaction gives effect to the yield of biodiesel and FAME yield. The highest FAME yield was produced at room temperature conditions for 15 minutes with a ratio of 1: 4

References

- [1] Wang Y, Ou S, Liu P, Xue F, Tang S. Comparison of two different processes to synthesize biodiesel by waste cooking oil. *J Mol Catal A: Chem* 252 (2006):107–12.
- [2] Zhang S, Zu Y-G, Fu Y-J, Luo M, Zhang D-Y, Efferth T. Rapid microwave-assisted transesterification of yellow horn oil to biodiesel using a heterogeneous solid catalyst. *Bioresour Technol* 101 (2010) 931–6.
- [3] Mahajan, S., Konar, S.Kdan Boocock, D.G.B., 2006, Standard Biodiesel from Soybean Oil by a Single Chemical Reaction, *J. Am. Oil Chem. Soc.* 83:641– 645.
- [4] Thanh, L.T., Okitsu, K., Sadanaga, Y., Takenaka, N., Maeda, Y., and Bandow, H., A New Co-Solvent Method for The Green Production of Biodiesel Fuel –Optimization And Practical Application, *Fuel* 103 (2013) 742–748
- [5] Julianto, T.S. and Suratmi, The Effect Of Concentrations And Volumes of Methanol in Reducing Free Fatty Acid Content of Used Cooking Oil as Biodiesel Feedstock, *International Conference on Chemistry, Chemical Process and Engineering (IC3PE) 2017*, AIP Conf. Proc. 1823, 020130-1–020130-5