Biodiesel Production from Chicken Fat Using Tetrahydrofuran as Co-Solvent

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ABSTRACT

Biodiesel is produced from transesterification process with vegetable oil or animal fats and methanol as reactans. However insolubility of methanol in oil resulted in long reaction time. To improve the process, co-solvent was used to increase the solubility of methanol in oil. In this study, chicken fat was used as feedstock for biodiesel production through transesterification reaction. The reaction of chicken fat used tetrahydrofuran as co-solvent, NaOH as catalyst, and methanol as reactant at a ratio of methanol to oil 6:1. Variables studied were reaction temperature, reaction time, ratio of co-solvent to methanol, and amount of catalyst. The products of reaction were analyzed by gas chromatography to obtain the composition of biodiesel. The biodiesel properties like methyl-ester content, density, flash point, and viscosity was evaluated and was found to compare well with Indonesian Biodiesel Standard (SNI). The best result was obtained by using 0,5:1 ratio of co-solvent to methanol (v/v), at 50^{o}C, for a reaction time 15 minutes, in the presence 0,8 wt% of catalyst. The results of this work showed that the use of chicken fat is very suitable as low cost feedstock for biodiesel production.

Keyword:biodisel, co-solvent, chicken fat, transesterification

1. INTRODUCTION

Global emissions of CO_2 and other harmful gases such as CO, SOx, NOx and particulates generated by fossil fuel combustion have led to a serious greenhouse effect, acid rain, and the deterioration of human health and the environment. Therefore, the identification of environmentally friendly and renewable sources of alternative energy is becoming an urgent mission for researchers internationally [1]

Biodiesel can be produced by transesterification of biological sources such as edible and non-edible oils and animal fats with methanol [2]. Development of biodiesel production recently usually used vegetable oils (soybean oil, canolla oil, rapseed oil, crude palm oil), animal fats (beef talow, lard, chicken fat, pig fat) and even from waste cooking oil [3].

Broiler chicken is one of the cattle that can be produced in relative short time (35-45 days) and this chicken farms can be found almost at all Indonesia provinces. Chicken fat is waste oil which can be used for biodiesel production. However, this fat is limited but can prevent nature pollution and has low cost [4]. The fat content within chicken fat was relative high about 10,9 wt% [5]. Biodiesel production from chicken fat transesterification does not need the pre-esterification step as the acid value of the melted fat was well below 2% [6]. Amout of FFA contained in fresh chicken fat usually at 0,4% [7].

However, due to low solubility of methanol in oil, the rate of conversion of oil into ester is very slow. An approach to overcome these problems that is now commercialized is the use of co-solvent which is soluble in both methanol and oil. The result is a fast reaction, on the order of 5–10 min, and no catalyst residues exist in either of the ester or the glycerol phase [8]. The cosolvent is preferably completely miscible with both the alcohol and the source of fatty acid triglyceride. The cosolvent preferably has a boiling point of less than about 120°C to facilitate solvent removal after the reaction is complete. More preferably, the cosolvent has a boiling point similar to that of the alcohol. The cosolvent is preferably anhydrous [9].

In this reasearch, tetrahydrofuran (THF) was used as co-solvent to overcome the insolubility of methanol in oil. THF was the best co-solvent due to it's low price, non-hazard, unreactive and has low boiling point (67^oC), and THF may be co-distilled and recycled at the end of the reaction. Furthermore, THF was chosen because of hydrofilic and hydrophobic characteristic that can bind water and alcohol at the hydrofilic side and dissolve organic compounds at hydrophobic side [10].

Many researchers have investigated the cosolvent transesterication of various edible vegetable oils, establishing various optimum operating conditions for those oils. Out of the available researches, none has either critically used chicken fat (which non-edible) for the co-solvent transesterification or establish the process optimum parameters. This work therefore seeks for best conditions for biodiesel production from chicken fat.

2. MATERIAL AND METHODS

Materials

Chicken fats were obtained from slaughter house at Pasar Padang Bulan Medan. Tetrahydrofuran (THF), methanol, sodium hydroxide, ethanol, phenolphalein were purchasec from CV. Multi Kreasi Bersama Medan. All the purchased chemicals were of analytical grades.

Methods

Oil characterization

The oil was characterized for physical and chemical properties such as viscosity, FFA content, and density. Fatty acids content in oil was determined with GC-MS analysis.

Fatty acid methyl ester (FAME) analysis

The compositions of each methyl ester were determined in duplicate using a gas chromatographer equipped a flame ionisation detector and an auto injector.

Other analysis

The density, kinematic viscosity, and flash point of each methyl ester were determined in duplicate according to the procedure of SNI [11].

Oil transesterification

The oil was transesterified in 500 mL three-neck flask that is equipped with hotplate, termometer, magnetic stirrer and reflux condensor. Biodiesel production was made with reacting 100 gr liquid chicken fat and methanol with ratio molar oil : methanol (1 : 6), ratio THF : methanol was varied (0,5 : 1, 1 : 1, 2 : 1, 2,5 : 1, 3 : 1 (v/v)) and amount of sodium hydroxide used (0,8 wt%) at various reaction time (10, 15, 20 minutes) and various reaction temperature (40^oC, 50^oC, 60^oC). Reactant was stirred with magnetic stirrer at 350 rpm to keep the suspension and temperature uniform along the reaction.

3. RESULTS AND DISCUSSION

Characterization of the raw chicken fat

Tables 1 and 2 respectively present the compositional analysis and properties of the raw chicken fat. It can be observed from Table 1 that the oil consisted principally of 38,92 %, 19,81 %, and 23, 93 % w/w oleic, linoleic and palmitic acids respectively. The fatty acid composition of the chicken fat used in this work is comparable to those reported by Hermanto et al [5]. This indicates that the oil contained more unsaturated fatty acids (linoleic acid and oleic acid) than the saturated fatty acids (palmitic acid). The oxidative stability of biodiesel is a function of the fatty acid composition of the parent oil. The higher the amount of saturated fatty acid in the parent oil the greater the oxidative stability of the oil and vice versa.

Tabel 1. Fatty acid composition of the raw chicken fat

No.	Component	Composition (Wt%)
1	Palmitic acid (C16:0)	23,93
2	Oleic acid (C18:1)	38,92
3	Linoleic acid (C18:2)	19,81

Tabel 2. Properties of raw chicken fat

Property	Value
Density	894,1 kg/m^3
Viscosity	14,45 cSt
FFA	0,41 %

Properties of the raw chicken oil presented in Table 2 were found to be within the literature values [12]. These include density (894,1 kg/m^3

at 30°C) and viscosity (14,45 cSt at 40°C). However, the free fatty acid content of the raw chicken fat was found to be 0,41% which was within the SNI specified limit of ≤0,5% for biodiesel production. Therefore the raw chicken oil do not need to be neutralized through esterification.

Results of transesterification process

Effect of co-solvent / methanol volume ratio

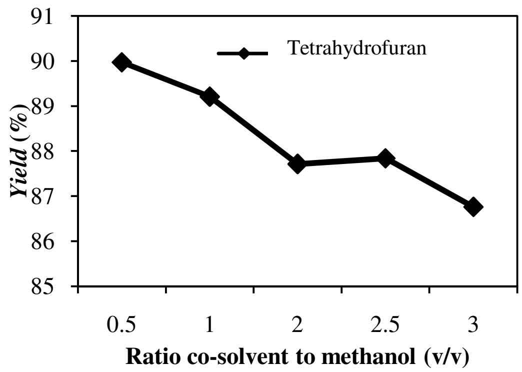

Figure 1. Effect of co-solvent to methanaol volume ratio on the biodiesel yield at NaOH concentration of 0,8 wt%, reaction time of 10 min, and reaction temperature of 50°C

As opposed to conventional transesterification, co-solvent transesterification offers significant reduction in mass transfer resistance [13]. To investigate the effect of co-solvent (THF) to methanol ratio on process, the co-solvent to methanol volume ratio was varied at 0,5:1, 1:1, 2:1, 2,5:1. 3:1 v/v.

Figure 1 presents the influence of THF to methanol ratio in biodiesel yield. The figure indicates that for this investigation, the best co-solvent to methanol volume ratio is 0,5:1 which gives a yield of 93,77%. Further increase in the ratio resulted in the decrease of the biodiesel yield. This could probably be as a result of beyond the optimum level, the co-solvent acts as a barrier between the reactant methanol and the oil molecules and result of dillution effect on the reagens.

Effect of reaction temperature

Temperature is one of the significant factors affecting biodiesel yield. Higher reaction temperature can decrease the viscosity of the oil which results in short reaction time and accelerate the reaction [14]. However, reaction temperature must be lower than the boiling point of the alcohol in order to ensure that the alcohol will not leak out through vaporization [13]. In this work, the reaction temperature was varied at 40, 50, and 60°C, while other variables were kept constant.

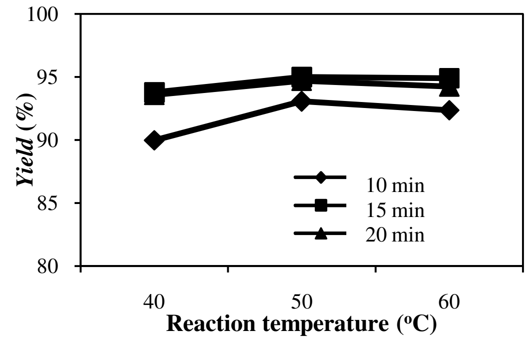

Figure 2. Effect of reaction temperature on the biodiesel yield at NaOH concentration of 0,8 wt% and THF:MeOH 0,5:1

As can be observed in figure 2, the highest yield of 94,98% was obtained at a reaction temperature of 50°C. Beyond this temperature, the biodiesel yield decreased. The decrease in yield at temperature above 50°C could be as result of methanol and co-solvent start vaporization. Therefore, the best temperature is 50°C which is similar to the 40°C reported by Dabo et al [13]. However, they used Jathropa curcas seed oil as feedstock in biodiesel production.

Effect of reaction time

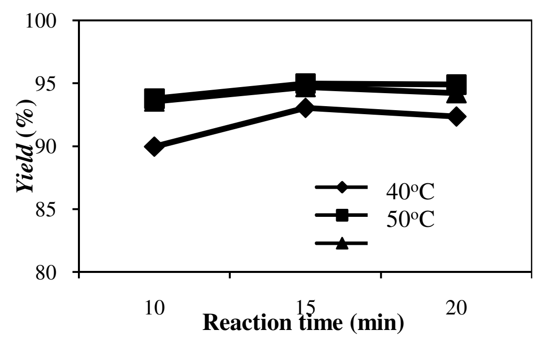

Figure 3. Effect of reaction time on the biodiesel yield at NaOH concentration of 0,8 wt% and THF:MeOH 0,5:1

Duration of reaction has been established as one of the critical parameters for biodiesel production. As reported by several authors, conventional transesterfication with base or acid catalyst was completed in 60-360 minutes.

However, it has been found out that incorporation of a co-solvent to the transesterification leads to the reduction of the reaction time. At this work, reaction time was varied at 10, 15, 20 minutes, while other reaction variables were kept constant.

At these conditions, figure 3 shows the highest yield of 94,98% was obtained at the 15 minutes reaction time. However, increasing reaction time beyond its optimum, will not much longer affect the biodiesel yield [15]. Therefor, 15 minutes reaction time was chosen as the best reaction time for this work.

Effect of catalyst concentration

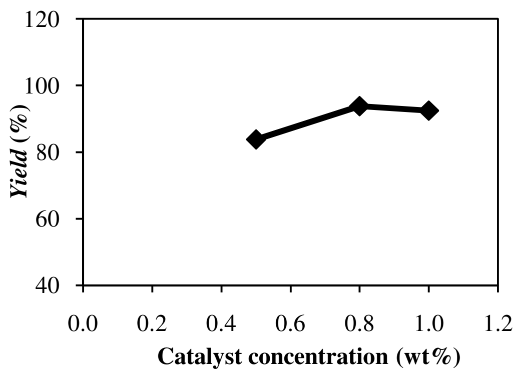

Figure 4. Effect of catalyst concentration on the biodiesel yield at THF:MeOH 0,5:1, reaction time of 10 min and reaction temperature of 50^{o}C

Investigating the effect of catalyst concentration (NaOH) on the yield of biodiesel was carried out by varying the concentration of NaOH at 0,5, 0,8, and 1,0 wt% of oil and keeping the other variables stated above constant. The result shown in Figure 4 indicates that the best catalyst concentration was 0,8 wt%. Further increase in concentration of catalyst beyond this facilitated saponification reaction and caused difficulty in the biodiesel separation from glycerol [16]. This resulted in a lower yield of biodiesel at higher catalyst concentration. This finding similar with the findings of Dabo et al [13] that the introduction of a cosolvent to the transesterification alcohol reduces the amount of catalyst required compared to conventional transesterification as reported by Encinar et al [17] used 1,0 wt% of catalyst.

Characterization of the produced biodiesel

Sample of the biodiesel produced at the best conditions established previously was characterized to ascertain its composition and relevant properties. Analysis by gas chromatography showed that the methyl ester content in the sample was 98,23%. This result has already fulfilled the Indonesian biodiesel standard (SNI).

Tabel 3. Properties of biodiesel produced

Property	Unit	SNI	FAME
Density	Kg/m^3	860-890	894,1
Viscosity	cSt	2,3-6	14,45
Methyl ester content	%	≥96,5	98,23
Flash point	^{o}C	Min. 100	164

The produced biodiesel at the best conditions was analysed to ascertain its quality with respect to the standard biodiesel properties. Table 3 shows the comparative properties of the produced chicken fat biodiesel with respect to the SNI biodiesel. It can be observed from the table that the produced biodiesel (FAME) virtually conforms to the properties specified by the Indonesian biodiesel standard (SNI).

4. CONCLUSION

The following conclusions were drawn from this work :

1. Effect of co-solvent to methanol on biodiesel yield shows that biodiesel yield decrease as amount of co-solvent increase.
2. Yield of biodeisel increase with reaction temperature increase.
3. Biodiesel yield increase as reaction time increase. However, if the optimum reaction time reached, reaction time do not affect more of biodiesel yield.
4. Properties of biodiesel produced from chicken fat such as density, viscosity, and flash point show that the values are within the Indonesia biodiesel standart (SNI) for biodiesel and can be used in diesel engine.
5. Tetrahydrofuran as cosolvent is suitable in transesterification reaction for producing biodiesel from chicken fat.
6. The best conditions of transesterification were found to be 50^{o}C, 15 min, 0,8 wt% of catalyst concentration, and 0,5:1 of co-solvent to methanol volume ratio.
7. The result of this work showed that the use of chicken fat is very suitable as low cost feedstock for biodiesel production.

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