The Utilization of Chicken Fat as Alternative Raw Material for Biodiesel Synthesis

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Abstract. A study of biodiesel production of chicken fat through estrification-transesterification reactions has been conducted. The separation of the chicken fat was conducted using heating technique, while the esterification-transesterification was conducted using ethanol reagent with chloride acid and hydroxide kalium catalyses. The identification results were identified chromatographically and spectroscopically and the chemical properties (peroxide number, acid number and saponification number) were determined. The results of the study showed that the ethyl ester resulting from the chicken fat was dominated by ethyl miristic component (1.25%), ethyl palmitic (22.38%), ethyl palmitoleic (3.35%), ethyl stearic (7.56%), ethyl oleic (45.83%), and ethyl linoleic (17.54%). Moreover, the percentage yield of ethyl ester from es-trans reaction of chicken fat was 66-70 %. The ethyl ester had the same characteristic as biodiesel quality standard.

Key Words: chicken fat, esterification, transesterification, biodiesel

Introduction

Recently, fuels become annual issues in both printed and electronic media. It is triggered by the fluctuation of the world raw oil price. Therefore, an effort to supply alternative fuels for the fossil fuels is continuously made. Various studies of energy resources have been conducted, especially in finding natural and renewable resources such as copra oil, oil palm, castor oil and rice and bran oil for biodiesel production (Singh and Singh, 2010; Lee et al., 2007). Biodiesel represents renewable and biodegradable fuel that can be processed through transesterification reaction that changes the ester of glyserol to methanol and ethanol esthers (Janaun and Ellis, 2010; Balat and Balat, 2010).

Biodiesel is not commonly used for transportation and industry due to an existing obstacle that the raw material of the biofuel has low fuel content. According to Jain and Sharma (2010), castor plants produce only 2-4 kg kernels/plant/year, while other raw materials of the biofuels compete its use for foods (oil palm, soy oil and coconut oil). Additionally, the high production cost of the biodiesel is the causal factor of its high selling price.

One of the solutions in supplying the alternative raw materials for biodiesel production is the use of chicken fat. The separation process of the chicken fat is easy and economical (Zheng and Hanna, 2007), since it can be practically processed as the raw material of the biodiesel without any chemical solvent and much work. The results of the study of the separation and the purification of pig fat showed that it only required heating at 60-70 oC to make the fat completely separated form the water content (Gugule and Rampe, 2009).

The selection of the raw material is on the ground that the chicken fat is one of the foods that recently draw good attention because of its negative effect for human health. Various studies on the effect of the chicken fat on health suggest that it can cause increase in blood cholesterol and hypertension. Therefore, making chicken fat as the alternative raw material of biodiesel synthesis is highly profitable.

Based on the results of literature study, chicken fat has not been used as the raw material in biodiesel production although it is abundantly available. It is easy to obtain chicken fat in North Sulawesi. According to Mege et al. (2006) the fat content of each chicken can be 30% of the total meat of the bird. The fat content can be increased by regulating the diet of the bird. In addition, it can be produced as biodiesel through a practical process without any chemical solvent and it is easy to separate. The fat composition of the bird is similar to that of palm oil with its oleic acid content of 39-45% (Jain and Sharma, 2010; Ferari, 2005). According to Zheng and Hanna (2007) and Nelson (2006), the fat composition of the bird consists of 48.5% saturated fat and 51.5% unsaturated fat with the main components of palmitic, stearic and oleic acids.

Thus, the raw material of the biodiesel production in the study could be easily obtained because of its abundant availability at low price, therefore making price of the biodiesel low. Additionally, it is expected that the use of chicken fat as the biodiesel raw material would increase people's income, especially the chicken breeders in North Sulawesi.

Materials and Methods

This experiment was conducted in a laboratory to find out the utilization of chicken fat as alternative raw material of biodiesel synthesis. The procedures involved the processing/the separation/the purification of the raw material, the esterification-transesterification reaction and the physical and chemical characteristic tests conducted in the chemical laboratory of the Faculty of Mathematics and Science of Manado State University. The spectroscopy test of the ethyl ester was conducted in the organic chemical laboratory of the Faculty of Mathematics and Science of Gadjah Mada University, Yogyakarta. The materials were chicken fat and chemicals experimented using a reflux set, a Buchii evaporator set, flasks, pycnometer, electric heater, infrared spectrophotometry, NMR1H spectrometry, gas chromatography-mass spectrometry.

Chicken fat separation

The extraction of the chicken fat was conducted by separating the fat from the meat of the bird, then separating the fat from water content which resulted in anhydrate chicken fat (Zheng and Hanna, 2007; Gugule and Rampe, 2009). Subsequently, the physical and chemical properties of the anhydrate fat were tested by determining the acid number, peroxide number and saponification number and water content (AOAC, 1990).

The synthesis of biodiesel from chicken fat

Esterification. There was 100 g of chicken fat and 250 ml ethanol heated at about 60-70 ^{o}C. Three ml sulfuric acid was then added and refluxed for 3 hours. Subsequently, the mixture was maintained in separation funnels for about an hour until two layers appeared. Then the upper layer (A) was used for further transesterification process (Zheng and Hanna, 2007; Gugule and Rampe, 2009).

Transesterification. The transesterification process was conducted using KOH basic catalyst. The reagent was prepared using 2 g KOH dissolved in ethanol. Then, the resulting component of the esteriification process was refluxed with KOH-ethanol solution for 2 hours. Subsequently, the mixture was maintained in separation funnels for 5 hours until different layers was formed. The upper layer was rinsed, which was expected to be ester. Ethyl ester was rinsed with water to reach neutral pH, and then heated to release the water. Finally, the characteristics of the ethyl ester were tested, including physical and chemical properties test and spectroscopic test (Zheng and Hanna, 2007; Gugule and Rampe, 2009).

Ethyl ester characteristic test

The characteristics of the chicken fat and the ethyl ester resulting from the esterification-transesterification (Es-Trans) processes consisted of density determination, ethyl ester profile (gas chromatography) and caloric capacity. Then, the structure was identified spectroscopically, including gas chromatography-mass spectrometry, infrared spectrophotometry, and nuclear magnetic resonance spectrometry (NMR1H).

Results and Discussion

The characteristics of chicken fat

The separation process and the removal of water from the fat were conducted using heating technique on water heater. Earlier, the fat was characterized by determining the acid number, saponification number, and the peroxide number. The data of the chemical properties was presented in Table 1.

The data of the chemical properties was highly required to determine further treatment. The resulting fat represented the most components of chicken meat. The resulting chicken fat was yellow liquid. Belitz et al. (2004) suggested that the yellow colour of the fat was influenced by the presence of linoleic glyceride oxidizing process. The data of the characteristics of the fat was shown by the peroxide number of 9.3. According to Deng et al., 2010, it is necessary to concern that the acid number is no more than one.

The separation of the chicken fat from the water content had been conducted using various treatments to minimize the damage of the fat before further reaction process. The separation was conducted using various solvents such as petroleum ether, chloroform and acetic ethyl. The results of the experiment showed that there was a difficulty in the separation with the solvents. Therefore, the fat-water separation was conducted using heating technique (70^{o}C), an inexpensive good process resulting in acid number as recommended, which can be used for further reaction without any other additional chemicals.

The characteristics of chicken fat biodiesel

Subsequently, the water-free chicken fat was reacted in esterification-transesterification (es-trans) process. The reaction was used because the transesterification reaction was not able to produce ester. It was closely related to the acid number of the fat and hence the esterification was conducted first using acid catalyst. Therefore, the reaction to produce the ethyl ester was the esterification with acid catalyst and continued by the transesterification with base catalyst.

The es-trans reaction was conducted using the pre-reaction HCl-ethanol (esterification) and ethanol (tansesterification) reactions with KOH basic catalyst. The result of the reaction was animal ethyl ester with the density of 0.8142 g/ml with the characteristics of clear yellow colour and liquid at ambient temperature. The data of the characteristics of chicken fat ethyl ester has not been widely studied.

The result of the fat-water separation and the product of the es-trans reaction were presented in Table 2. It was clearly observed from the data in the table that the fat-water separation was easier than the oil extraction process (tryglyceride) of plants. The data indicated that the free fat content was 59%. The water content of the biodiesel raw material had significant impact on the resulting ethyl ester. According to Leung et al. (2010) the water contained in the fat influenced the reaction process; especially it increased the free fat acid value. Furthermore Leung et al., suggested that the water also hydrolyzed the triglyceride into diglyseride and free fatty acid. Therefore, the water was directly removed after the fat component was separated from chicken meat to minimize the acid number of the fat.

The data also indicated that the use of chicken fat as biodisel raw material was economical and efficient. Concerning the ethyl ester, the success rate was about 70%. The low ethyl ester rendement was highly influenced by the reaction process including esterification and transesterification. The reaction product was considered low compared to the reaction by Zhang et al. (2010), in which the esterification-transesterification of plant oil using acid and base catalysts was of 96% rendement. However, the esterification-transesterification reaction presented important information about the use of the animal fat that had not been widelystudied. The success of the chicken fat-water separation with heating technique and esterification-transesterification (es-trans) reaction of the chicken fat could be the indicator in using the chicken fat as an alternative raw material in biodiesel production.

The ethyl ester was then analyzed spectroscopically. The first analysis was made using gas chromatography-mass spectrometry. The test was conducted to determine the main component of ethyl ester of the chicken fat. Table 3 summarized the main components of the chicken fat based on literature data (Almeida et al., 2006; Belitz et al., 2004) and the results of the test with gas chromatography-mass spectrometry (GC-MS).

Based on the results of the mass chromatograph-spectrometer test, the ethyl-ester component of the chicken fat was dominated by ethyl miristic (1.25%), ethyl palmitic (22.38%), ethyl palmitoleic (3.35%), ethyl stearic (7.56%), ethyl oleic (45.83%), and ethyl linoleic (17.54%). The fragmentation pattern of the main components of the ethyl ester of the chicken fat was presented to support the data in Table 3.

Since the fragmentation of the ethyl ester component had the same spectrum, only a fragmentation pattern of the ethyl ester was presented, namely ethyl palmitic. The fragmentation pattern of one of the main components of the ethyl ester of the chicken fat is described in Table 4. The data of the gas chromatography-mass spectrometer was very important to support the characteristics of the chicken fat biodiesel because it showed the main ethyl ester components of the chicken fat. Infrared spectrophotometer and nuclear magnetic resonance spectrometer analyses were made to support the data of the gas chromatography-mass spectrometer of the chicken fat ethyl ester. The two instruments were used to identify other possible components of the ethyl ester. The infrared spectrophotometer was used to identify functional groups, especially the presence of hydroxyl group absorption that might be embedded to one of the ethyl ester component. It was also the case of the nucleus magnetic resonance spectrometer that was used to identify hydrogen atom position based on its bound environment with other elements, especially carbon and oxygen atoms. Subsequently, the fragmentation pattern could be described in ion molecular reaction in Fig. 1.

The data of the infrared spectrum and the nucleus magnetic resonance (RM1H) of the chicken fat ethyl ester is presented in the tabulation of Tables 5 and 6.

It was clearly observed from Table 5 that there was a strong ribbon in 1736 cm-1 along with its overtone close to 3464 cm-1 indicating the presence of carbonyl group (C=0). The carbonyl group referred to the functional group of the ester. It was confirmed by the presence of the strong ribbon in the areas of 1234 and 1180 that indicated the C-O group absorption. Moreover, there was an absorption in the area of 3000-2800 cm-1 that indicated the presence of alkyl absorption, which was metilen group (-CH2-) in the area of 1458 cm-1 and methyl group (-CH3) in the area of 1373 cm-1. The presence of the absorption in the areas 3302-

Table 1. The data of the chemical properties of chicken fat

Replay	Acid number	Saponification number	Peroxide number
I	0.8976	55.8756	10.00
II	0.8976	55.8756	10.00
III	0.8976	55.8756	8.00
Average	0.8976	55.8756	9.30

Table 2. The data of the separation of chicken fat and es-trans reaction product

No.	Fat amount			Ethyl ester content		
	Fat wet (g)	Fat anhydrate (g)	Percent	Raw Material fat (ml)	Ethyl ester (ml)	Percent
1	250.0	145.0	58.00	100	70.0	70.0
2	134.2	81.8	60.95	75	53.4	71.2
3	290.0	171.1	59.00	80	55.2	69.0
Average			59.32			70.01

Table 3. The main components of ethyl ester from chicken fat

Fatty acid	Systematic name	General name	Chicken fat (%)	
			Literature*	Analysis Data **
C14	Tetradeca-noic	Ethyl myristic	0.58	1.25 (2)
C16	Hexadeca-noic	Ethyl palmitic	22.21	22.38 (5)
C16:1 (9)		Ethyl palmitoleic	7.09	3.35 (4)
C18	Oktadeca-noic	Ethyl stearic	5.99	7.56 (10)
C18:1(9)		Ethyl oleic	43.04	45.83 (8)
C18:2 (9,12)		Ethyl linoleic	18.97	17.54 (7)

*Surce: Almeida et al., 2006; Belitz et al., 2004; **Analysis results

Table 4. The fragmentation pattern of ethyl palmitic

m/z		Abundance		Fragmentation
Peak	Ethyl Palmitic	Peak	Ethyl Palmitic	
284	284	8	7	M+, C18H36
255	255	4	3	M-29, M-C2H5
241	241	11	8	M-43, -C3H7
227	227	6	3	M-57, M-C4H9
213	213	8	4	M-71, M-C5H11
199	199	8	5	M-85, M-C6H13
185	185	8	5	M-99, M-C7H15
171	171	6	4	M-113, M-C8H17
157	157	17	18	M-127, M-C9H19
143	143	10	8	M-141, M-C10H21
129	129	4	4	M-155, M-C11H23
115	115	9	9	M-164, M-C12H25
101	101	59	60	M-183, M-C13H27
88	88	Base Peak	Base Peak	M-196, M-C14H28
70	70	21	21	M-214, M-C15H32
57	57	26	18	M-227, C4H9
41	41	30	30	M-214, M-C3H5

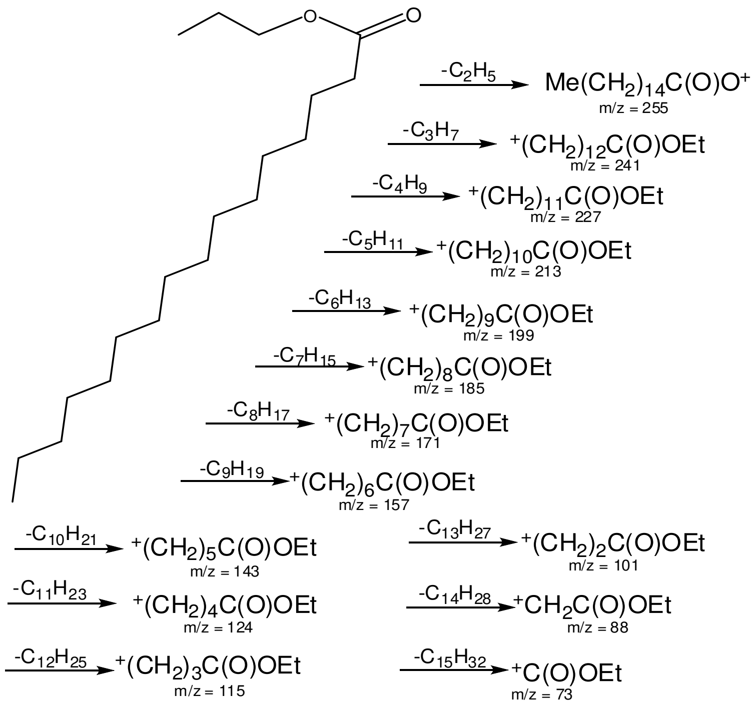

Figure 1. The fermentation pattern of ethyl palmitic

Table 5. The infrared absorption data of ethyl ester from chicken fat

υ (cm-1)	Absorption
1736, 3464	Carbonyl group (C=O)
1180, 1234	C-O
3000-2800 (strect.), 1458	Alkyl (- CH2 -)
3000-2800 (strect.), 1373	Alkyl (- CH3)
3302-3232 (strect.), 1659, 1000-650	C – C alkene

Table 6. The data of the RHI1H spectrum of ethyl ester

Data RMI 1H		
δ (ppm)	Multiplicity	Atomic Position H
0.9 – 1.3	t	-CH3 (d)
2 – 2.2	m	-CH2- (c)
4-4.2	m	=CH- (b)
5.3	m	=CH- (a)

3232 cm-1 indicated alkena group (=CH) confirmed by the presence of the absorption in the areas of 1659 cm-1 and 1000-650 cm-1. Thus, Table 5 indicated that the identified compound had hydrogen atom bound to the methyl group (-CH3), -CH2- and =CH- and carbonyl group. The infrared spectrum data was confirmed by the data of the RMI1H (Table 6).

The results of the analysis showed that the ethyl ester of the chicken fat did not contain any glycerol and methanol. Considering biodiesel quality standard, the maximum methanol content was 0.2%, maximum free glycerol content 0.02% and total glycerol 0.240% (ASTM D6751-09, 2008).

Based on the spectroscopy data it was observed that the identified compound consisted of some chicken fat ester ethyl components. The data of the gas chromatography-mass spectrometer showed that the chicken fat ethyl ester was dominated by ethyl oleic (45.83%). The component highly supported the effort to use the chicken fat as alternative raw material in producing biodiesel because its content was similar to that of oil palm (oleic acid 39-45%) (Belitz et al., 2004).

Conclusions

Conclusions

Based on the results and the discussion of the study it could be concluded that chicken fat could be used as alternative raw material in producing biodiesel. The separation of the fat could be conducted using heating technique and transesterification. The characteristics of the resulting ethyl ester of the chicken fat were similar to those of the standard biodiesel.

Recommendation

It was necessary to conduct further study, especially to test the applicability of the biodiesel resulting from the chicken fat as the fuels of motorized vehicles.

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References

Almeida JC, MS Parassolo, JL Camargo, N Bragagnolo and JL Gross. 2006. Fatty acid composition and cholesterol content of beef and chicken meat in Southern Brazil. Braz. J. Pharm. Sci. 42(1):109-117.

AOAC. 1990. Official Methods of Analysis. Assoc. Offic. Anal. Chem. Washington DC.

Balat M and H Balat. 2010. Progress in biodiesel processing. App. Energy. 87(6):1815-1835.

Belitz HD, W Grosch and P Schieberle. 2004. Food Chemistry. 3rd Revised Edition. Springer. Pp.646.

Deng X, Z Fang, Y Liu and C Yu. 2011. Production of biodiesel from jatropha oil catalyzed by nanosized solid basic catalyst. Energy. 36(2):777-784.

Ferrari. 2005. Oxidative stability of biodiesel from soybean oil fatty acid ethyl ester. Scienta Agricola. 62(3):291-295.

Gugule S. 2006. Isolasi dan identifikasi trimiristin dari buah pala (Myristica fragrans, H). Buletin Kimia Indonesia. 1(1):24-31.

Gugule S and M Rampe. 2009. Pembuatan biodisel via reaksi transesterifikasi terkatalisis basa lemak babi dan alkohol cap tikus. Laporan Penelitian Stragnas – Lemlit UNIMA Manado.

Jain S and MP Sharma. 2010. Prospects biodiesel from jatropha in India: a review, renewable and sustainable energy review. 14(2): 763-771.

Janaun J and N Ellis. 2010. Perspective on biodiesel as a sustainable fuel, renewable and sustainable energy review. 14(4): 1312-1320.

Lee KW, XY Jin, HM Jin, Y Li, YW Kim and KW Chung. 2007. A kinetic study on the transesterfication of glyceryl monooleate and soybean used frying oil to biodiesel. J. Ind. Eng. Chem. 13:799-807.

Leung DYC, X Wu and MKH Leung. 2010. A review on biodiesel production using catalyzed transesterification. App. Energy. 87(4):1083-1095.

Mege RA, W Manalu, N Kusumorini and SH Nasution. 2006. Pengaruh superovulasi terhadap produksi anak babi. J. Anim. Prod. 8:14-18.

Nelson RG. 2006. Energetic and economic feasibility associated with the production, processing, and conversion of beef tallow to a substitute diesel fuel. Biomass and Bioenergy. 30(6): 584-591

Ramos MJ, CM Fernandes, A Casas, L Rodriguez and A Perez. 2009. Influence of fatty acid composition of raw materials on biodiesel properties. Bioresource Technolog. 100(1):261-268.

Singh SP and D Singh. 2010. Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: a review. Renewable and Sustainable Energy Reviews. 14(1):200-216.

Zhang J, C Shangxing, Y Rui and Y Yuanyuan. 2010. Biodiesel production from vegetable oil using heterogenous acid and alkali catalyst. Fuel. 89(10):2939-2944.

Zheng D and MA Hanna. 2007. Preparation and properties of methyl esters of beef tallow. University of Nebraska Agric. Res. Div.