Production and Characterization of Biodiesel (Methyl Ester) from Chicken Fat

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Abstract
This paper examined the production of biodiesel from chicken fat (CF). The CF was first pretreated with 1% H_2SO_4 to reduce free fatty acid from 3.51 mg/KOH/g to 1.82 mg/KOH/g (< 1%) before tranesterification. The fat was transesterified with methanol in presence of sodium hydroxide (NaOH) as catalyst in a laboratory batch reactor at a temperature of 60 ^{0}C, catalyst concentration of 0.8 % w/v and reaction time of 90 min. Standard fuel characterization (ASTM fuel tests) was carried out on the Chicken fat Methyl ester (CFME). Methyl ester yield of 96.7 % was obtained. Fuel properties of the CFME compare well with the ASTM and EN standards for biodiesel. The result suggests that the fuel can serve as an alternative to petroleum diesel.

Keywords: Chicken fat, Biodiesel, Optimization, Characterization

1.0 Introduction

Biodiesel is a renewable fuel produced from the transesterification of vegetable oils or animal fats with an alcohol in the presence of a catalyst (Knothe, 2006). Biodiesel is one known for its biodegradability, environmental friendliness, higher flash point, reduced exhaust emissions, miscibility in all ratios with petro diesel, compatibility with the existing fuel distribution infrastructure and inherent lubricity (Knothe, 2008).

Most commercial production of biodiesel process in Europe and America uses edible oils such as rapeseed oil and soybean oil as feedstock (Kansedo *et al.,* 2009). A number of these feedstocks such as canola oil, sunflower oil, coconut oil, palm oil and also corn oil have also been used as feedstock in different part of the world (Koh and Mohammed, 2011). In most part of Africa and Asia, edible vegetable oils are always not available in surplus and considerable amount of these oils are been imported to cater for the short fall (Sam *et al.,* 2008). It has been reported that there are very little chances of using edible oil for fuel as they are needed more for food in Nigeria and non edible oil resources strongly proposed as viable option for biodiesel production (Oghenebojoh and Umukoro, 2011).

Chicken fat is a low cost feedstock for biodiesel production compared to high-grade vegetable oils. It is extracted from feather meal which is prepared from chicken wastes such as chicken feathers, blood, offal and trims after rendering process. Feather meal contains significant amount of chicken fat (Alptekin *et al.,* 2011). Waste chicken fat is harmful for human health due to the fat contained in the chicken (Jagadale and Jugulkar, 2012).

A number of literatures have been reported on the use of chicken fat for biodiesel production. Mattingly (2006) produced biodiesel from chicken fat with 2.3% FFA, the author concluded that it needed to carry out pretreatment reaction in order to obtain higher biodiesel yield. Schulte (2007) investigated optimum reaction parameters for biodiesel production from chicken fat using supercritical methanol. Kondamudi *et al.* (2009) reported the study of green process for biodiesel production from chicken fat using potassium hydroxide as a pretreatment agent to remove FFA in the form of soap. After separating the soap, the optimization of transesterification parameters was investigated. Alptekin and Canacki(2011) reported the optimization of transesterification for methyl ester production from chicken fat obtained from Turkey studying the effect of catalyst type. Alptekin *et al.,* (2011) studied the production of Methyl ester from chicken fat with high FFA. It is important to state that process design and operation parameter varies based on the source of biodiesel feedstock and quality of the desired end product. It is based on these premises that this study is aimed at studying the production and characterization of Chicken Fat Methyl Ester (CFME) using sodium hydroxide as catalyst.

2.0 METHODOLOGY

2.1 Materials Method

Waste chicken fat was obtained from a Slaughter House in Jos. It was stored in air tight bag and refrigerated prior to analysis. Sodium Hydroxide, Methanol and phenolphthalein indicator, were all obtained from Chemical Engineering Laboratory and were all of analytical grade, while Distilled Water was obtained from the Chemistry Laboratory of Federal University of Technology, Minna.

2.1.1 Acid pretreatment procedure

Prior to acid treatment, the fat was heated to a temperature of 110 ^{0}C in an open beaker to remove its water content. 10 g of sulfuric acid (H_2SO4) was added to 75.5 g of methanol and the mixture was mixed continuously until a homogenous solution was obtained. The mixture was closed in a tight container to prevent the alcohol from evaporating. The chicken fat was added into the reaction flask equipped with thermometer and magnetic stirrer with hot plate, and it was then heated until the temperature reached 60 ^{0}C, the liquid fat was removed to cool, then the mixture (methanol and sulfuric acid) was poured into the liquid fat and the whole mixture was stirred in the water bath shaker at a speed of 300 rpm for a reaction time of 80 min. The resulting mixture was poured into the separating funnel and was allowed to settle overnight. Two layers were formed after the pretreatment. The upper layer consisting of methanol, sulfuric acid and water while the lower layer consisting of a mixture of chicken fat and esterified FFA.

The upper layer was removed, while the lower phase was subjected to heating at 110 ^{0}C for some minutes to remove any residual alcohol and water.

2.1.2 Preparation of Sodium Methoxide

methanol, and the mixture was stirred vigorously until the NaOH dissolved completely to form sodium methoxide

2.1.3 Base catalyzed Transesterification

50 g of the fat-ester was poured into the flask and heated to about 60 ^{o}C, the sodium methoxide was heated gradually introduced into the flask containing the ester, then the mixture inserted into the water bath for agitation and heated to a temperature of 60 ^{o}C for 1 hour with the shaker operating at a revolution of 300 rpm. After 1 hour the solution was poured into the separating funnel to settle for overnight and two phases were formed. The upper layer was Ester Phase (EP) that contained the methyl ester and the bottom layer was Glycerol phase (GP) that contains glycerol (G), water (W) and methanol (M). The EP of the mixture in the samples was separated. The heavier glycerol layer was separated from the lighter methyl ester layer by

draining with the aid of a separating funnel. The methyl ester layer separated was continuously washed with equal volume of warm water at 45 ^{0}C until the wash water was neutral to litmus paper, and then heated on a hot plate to remove any moisture present and dried over anhydrous Na_2SO_4. Finally the methyl ester content of the products was determined.

2.1.4 Characterization of Chicken fat and Chicken fat Biodiesel

The biodiesel produced was tested for its fuel properties; the flash point was determined in a Pensky–Martens closed-cup tester (ISL, Model FP93 5G2) using ASTM D 93. Cloud point and pour point determinations were determined using ASTM D 2500 and ASTM D 97. The kinematic viscosities were determined at 25 °C, using a Viscometer (Model VT-03) following the ASTMD 7042 procedure. While the cloud and pour point was obtained according to ASTM D2500-91 and ASTM D97-96 methods, respectively. The acid value was obtained by titration. The yield of the transesterification process was calculated as:

$$\text{Yield, \%} = \frac{Total\ weight\ of\ methyl\ esters}{Total\ weight\ of\ oil\ sample} \times 100\ \% \qquad (1)$$

The cetane number was obtained empirically (Krisnangkura, 1986).

$$\text{CI} = 46.3 + \frac{5458}{SV} - \frac{0.225}{IV} \qquad (2)$$

SV = Saponification value of ethyl ester; IV = Iodine value of ethyl ester; CN= Cetane number

$$\text{CN} = CI - 1.5 \qquad (3)$$

(Patel, 1999)

The heat of combustion was computed from the correlation given by Demirbas (1998).

$$HC = 10049.43 - 0.015IV - 0.041\ SV \qquad (4)$$

3.0 Results and Discussions

Table 1: Physiochemical Properties of Chicken Fat

Parameters	**Chicken fat**
Iodine value (g/100g)	99.61
Density at 15˚C (g/m^3)	0.892
Kinematic viscosity at 40˚C (mm^2/s)	25.33
Saponification value (mg/KOH.g)	256.65
Acid value (mg.KOH/g)	3.64
Free fatty acid (%)	1.82
Peroxide value (Mmol/kg)	8.00

Flash point is a key property in determining the flammability of a fuel. The flash point of biodiesel is usually higher than that of diesel fuel. The biodiesel produced from CF had a flash point of 170 °C. This result is higher than the minimum specifications of both standards. However, this value is very consistent with other literatures. The high flash point obtained in this study show that the CFME is safe from handling and storage point.

Table 2: Fuel properties against the ASTM standard values with other feedstock

Properties	Unit	ASTM D6751	EN 14214	*JOME	**CFME	***CFME	CF	This study
Ester content	% (mol)	-	96.5 min	95.2	67	88.5		96.7
Kinematic viscosity at 40 ^{0}C	Mm^2/s	19-60	33-50	2.54	5.4	4.94–6.84		5.33
Flash point	^{0}C	130min	120 min	186	174	170-172.8		172
Cloud point	^{0}C	Report	-	-5	14	2- 4		-6
Specific gravity at 15 ^{0}C		-	0.86-0.90	0.886	0.87	0.88–0.89	0.90	0.87
Saponification value	Mg/gKOH	-	-	-	-	-	256.65	226.65
Iodine value	gI/100g	-	-	-	-	-	99.61	85.61
Acid value	mgKOH/g	0.5 max	0.56 max	0.14	0.4	0.28	1.82	0.32
Centane number	-	48-65	51	58	58.4	-		42.55
Calorific value (MJ/Kg)		-	-	38.65	39	40		41.25
Pour point	^{0}C	12max	-	-2	12.4	2-4		-10

* Xin *et al*(2011) ** Jagadale and Jugulkar (2012) ***Alptekin, Mustafa Canakci(2011)

Cloud point is the temperature at which wax first becomes visible to the naked eye when the fuel is cooled. The cloud point of CFME was found to be -6°C. According to ASTM D6751 and EN 14214 standards, no limit is specified for cloud point. This may probably be due to the fact that the climate conditions world over vary to a great extent, thus affecting the needs of biodiesel consumers in each particular region. According to Demirbas (2009) cloud point of biodiesel depends on the feedstock used for its production.

The pour point is the lowest temperature at which a fuel sample will continue to flow (Van Gerpen *et al*., 2007). The pour point also has implications for the handling of fuels during cold temperatures. The pour point for CFME was found to be -10°C. The pour point from this work is quite impressive when compared with the ASTM maximum of 12 °C (Demirbas, 2009)
The acid value of CFME produced in these work was 0.364 mg of KOH/g. Both standards specified a maximum limit of 0.5 mg of KOH/g for biodiesel. The low acid value of CFME obtained an indication of good biodiesel quality. The acid value of biodiesel fuel depends on the type of feedstock and how well the fuel is processed. A high acid value makes the fuel prone to polymerization and also acts as catalyst for hydrolysis.

The ester yield of CFME was 96.7% agrees well with the minimum limit of 96.5% specified by EN 14214 standards (Musa, 2012). This result shows the purity of CFME and the completeness of the alkaline transesterification reaction. The ester content of chicken fat biodiesel is very promising when compared with other reported work (Xin *et al.,* 2009).
Viscosity is also an indication of fuel aging during storage as it increases due to polymerization caused by oxidative degradation (Karme and Chida, 2005). For biodiesel to be used in diesel engine, the kinematic viscosity must be between 1.9 and 6.0 mm^2/ s at 40 ^{0}C (Demirbas, 2009)

The kinematic viscosity of the CFME produced in this work was 5.63 mm^2 / s as presented in Table 1. High viscosity leads to a higher drag in the injection pump and thus results into higher pressures and injection volumes more especially at low engine operating temperature.

The cetane number relates to the readiness of the fuel to self-ignite when exposed to the high temperatures and pressure in the diesel engine combustion chamber. It is not directly related to the energy content of the fuel (Van Gerpen *et al*., 2007). The cetane number of the biodiesel in this work was 42.55 and as against the ASTM standard of 48-65. This is an indication that CFME has good ignition quality and would perform optimally when used in diesel engine. The value obtained was also greater than the cetane number of petrodiesel whose minimum is 40. It is important to state that the result of this study agrees well with the report of Alptekin,and Canakci, (2011).

Specific Gravity is an important property in diesel engine performance, since fuel injection operates on a volume metering system (Dermirbas, 2009). The Specific gravity (SG) at of the CFME was found to be 0.872. The result compares favorably with the ASTM D6751 and other reported literatures. Change in tSpecific gravity is an indication that the density of the biodiesel decreased with increasing molar ratio. This was probably due to a decrease in residual triglycerides.

The heating value is a typical measure of the energy content in a fuel. The heating value of biodiesels is between 39 – 41 MJ/kg (Bapjai and Tyagi, 2006). This value along with other thermodynamic criteria that sets the maximum possible power output for diesel engine (Anton *et al.,* 2006). The result of this study revealed a value of 41.20 MJ/Kg which is very consistent with the heating value of biodiesel and shows that the biodiesel produced has about 91 % the heating value of petroleum diesel as shown in Table 2. From operational point of view, biodiesel has got about 90 % of energy content of petroleum diesel measured on volumetric basis, improved combustion efficiency because of its oxygen content and improved lubricity which partly compensate the impact of the lower energy content (Anton *et al.,* 2006).

4.0 Conclusion

In this study, biodiesel was produced from low-cost chicken fat with high FFA. The FFA level of the feedstock was reduced to less than using 1% H_2SO_4 before the alkaline catalysis. Biodiesel yield of 96.7 % of CFME was obtained when the fat was transesterified with methanol in presence sodium hydroxide (NaOH) at a temperature of 60 ^{0}C, catalyst concentration of 0.8 % w/v and reaction time of 90 min. The fuel properties of the CFME met both the ASTM D6751 and EN 14214 biodiesel standards

References

Anton A. kiss., Alexandre C. Dimian, Gadi Rothenberg (2006)., "Solid Acid Catayst for Biodiesel production – toward sustainable Energy" "*Advance Synthesis Catalysis"*, 348 75 -81.

Bapjai, D., and Tyagi, V.K (2006).Biodiesel: Source, Production, Composition, Properties and its Benefits. Journal of Oleo Science, Vol. 55.

Demirbas, A., (2009) Characterization of Biodiesel Fuels. *Energy Source* Part A 31 889 – 896.

Demirbas A.,(1998).Fuel properties and calculation of higher heating values of vegetable oils. *Fuel*, 77, (9/10),1117-1120.

Alptekin E. and Canakci .M (2011). Optimization of transesterification for methyl ester production from chicken fat, *Fuel*, 90 (2011) 2630–2638.

Alptekin, E., Canakci M. , Huseyin S. (2011) Methyl ester production from chicken fat with high FFA :In Proceeding of World Renewable Energy Congress, 8-13 May,2011, Linkoping, Sweden.

Van Gerpen J., B.Shanks, and R. Pruszko, D. Clements, G. Knothe (2007). Biodiesel Analytical Methods, National Renewable Energy Laboratory 1617 Cole Boulevard, Golden, Colorado,USA, pp16, Available at http://www.osti.gov/bridge

Jagadale S.S., Jugulkar L.M.(2012)Production and Analysis of Chemical Properties of Chicken Fat Based Biodiesel and its various Blends, *International Journal of Engineering Research and Development*, Volume 1, Issue 7, pp.34-37.

Kondamudi N, Strull J, Misra M, Mohapatra S.K. (2009). A green process for producing biodiesel from feather meal. *J. Agric. Food Chem*.57:6163-66.

Kansedo, J., Keat, T. L, Subhash, B (2009) *Cerbera odallam* (Sea mango oil) as a promising non-edible feedstock for biodiesel production. *Fuel,* 88, 1148-1150.

Karmee, S. K., & Chadha, A. (2005). Preparation of biodiesel from crude oil of Pongamia pinnata. Bioresourec Tech*., 96(13), 1325-1429.* http://dx.doi.org/10.1016/j.biortech.2004.12.011.

Knothe, G. (2006) Analyzing biodiesel: Standards and other methods. *Journal of American oil chemist society*, 83, 823 – 833.

Knothe, G. (2008) Designer Biodiesel: Optimizing Fatty Ester Composition to improve Fuel properties. *Energy &Fuel* (22) 1358 – 64.

Koh, M.Y., and Mohammed, T.I.G.,(2011) A review of biodiesel production from *Jatropha curcas* L.oil. Renewable and Sustainable Energy Reviews, 15, 2240-2251.

Krisnangkura .K.,(1986). Asimple methodfor estimation of cetane index of vegetable oil methyl esters. J. Am. Oil Chem. Soc., 63(4), 552-553.

Mattingly B.G. Production of biodiesel from chicken fat containing free fatty acids. Master of Science Thesis, University of Arkansas (2006).

Oghenejoboh, K. M. and Umukoro, P. O. (2011) .Comparative Analysis of Fuel Characteristics of Bio-Diesel Produced from Selected Oil-Bearing Seeds in Nigeria. *European Journal of Scientific Research*. vol.58, No.2 ,(2011), pp.238-246.

Patel V., (1999). Cetane Number of New Zealand Diesel. Report. Office of Chief Gas Engineer, Energy Inspection Group, Ministry of Commerce Press, Wellington, New Zealand.

Sam, S.M., Akonye, I.A., Mensah, S.I., & Esenowo, G.J.,(2008) Extraction and Classification of Lipids from Seeds of *Persea Americana* (MILLER) and *Chrysophyllum albidum* (G.DON). *Scientia Africana,* Vol.7 (No.2), pp 35-38.

Schulte W.B.(2007). Biodiesel production from tall oil and chicken fat via supercritical methanol treatment. Master of Science Thesis, University of Arkansas (2007).

Xin Deng, Zhen Fang, Yun-hu Liu, Chang-Liu Yu (2011). Production of biodiesel from Jatropha oil catalyzed by nanosized solid basic catalyst, *Energy,* 36,777- 784