Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 7, July - 2015

Optimization And Characterization Of Biodiesel Synthesis From Chicken Fat

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***Abstract*—This paper examined the production of biodiesel from chicken fat (CF). The chicken fat 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 the presence of sodium hydroxide (NaOH) as catalyst in a laboratory batch reactor. The effect of temperature (30-65^{0}C), catalyst concentration (0.5-1.50 %w/v) and reaction time (60-120 min), molar ratio of methanol to CF (4:1-8:1) were investigated. Optimum yield of 92.8 % Chicken Fat Methyl Ester (CFME) was obtained at a temperature of 50 ^{0}C, catalyst concentration of 0.75 % w/v, reaction time of 90 min and molar ratio of 7:1. Standard fuel characterization (ASTM fuel tests) was carried out on the CFME. 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

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 [1]. Biodiesel is one known for its biodegradability, environmentally friendliness, higher flash point, reduced exhaust emissions, miscibility in all ratios with petro diesel, compatibility with the existing fuel distribution infrastructure and inherent lubricity [2].
Currently, almost all commercial production of biodiesel process in Europe and America uses edible oils such as rapeseed oil soybean oil as feedstock [3]. 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. 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 [4]. It has been reported that there are very little chance 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 [5].
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 [6]. Waste chicken fat is harmful for human health due to fat contain in the chicken [7].
A number of literatures have been reported on the use of chicken fat for biodiesel production. Mattingly [8] produced biodiesel from chicken fat with 2.3% FFA. The author concluded that it was needed to perform a pretreatment reaction to get high biodiesel yield. Schulte [9] investigated optimum reaction parameters for biodiesel production from chicken fat using supercritical methanol. Alptekin and Canacki [10] reported the optimization of catalyst type on transesterification for methyl ester production from chicken fat obtained from Turkey. The production of Methyl ester from chicken fat with high FFA was also studied [6]. It is important to state that process design and operation parameter varies based on the biodiesel feedstock and quality of the desired end product. It is based on these premises that this study is aimed at studying the optimization and characterization of Chicken Fat Methyl Ester (CFME) using sodium hydroxide as catalyst.

MATERIALS AND METHODS

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

Acid pretreatment step

The Chicken fat was poured in the flask and heated to a temperature of 60 ^{0}C. The mixture of methanol and 1% w/v of H_2SO_4 was separately heated at the same temperature for 5 min and added slowly to the heated oil before turning on the magnetic stirrer at a constant agitation rate, marking the start of the esterification reaction, the process was allowed to run for 1 hour after which the esterification products were poured into a separating funnel where the mixture was allowed to separate and settled in the

two distinct layer overnight .The resultant pre-esterified oil was dried by anhydrous magnesium sulfate before subsequent transesterification . The treated oil was then used as the feedstock for transesterification.

Base catalyzed Transesterification

The esterified fat (<1% FFA) was charged into the reactor and heated at different temperature (30 ^{0} C , 45 ^{0}C and 60 ^{0}C) to optimize the temperature for maximum yield. The mixture of methanol and 1% w/v of KOH was separately heated at the same temperature for 5 min and added slowly to the heated oil before turning on the magnetic stirrer. The reaction mixture was heated and stirred at 300 rpm for 1 h. The samples were withdrawn at the end of the reaction time to determine the % methyl ester formed. The mixture was then poured into a separating funnel overnight to enable it separate into two distinct layers. 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 and dried. The heavier glycerol layer was separated from the lighter Methyl Ester layer by draining from the separating funnel.

Sample Treatment and Analysis

The methyl ester layer separated, was continuously washed with equal volume of hot 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 analyzed by using ASTM standard method and the Purity was determined.

RESULTS AND DISCUSSIONS

Table 1: Physiochemical Properties of Chicken Fat

Parameters	Value
Iodine value (g/100g)	99.61
Density at 15 ^{o}C (g/m^3)	0.872
Kinematic viscosity at 40 ^{o}C (mm^2/s)	5.33
Saponification value (mgKOH/g)	256.65
Acid value (mgKOH/g	3.64
Free fatty acid (%)	1.82
Peroxide value (mol/kg)	8.00

Effect of Process Parameters

Effect of Temperature on biodiesel yield

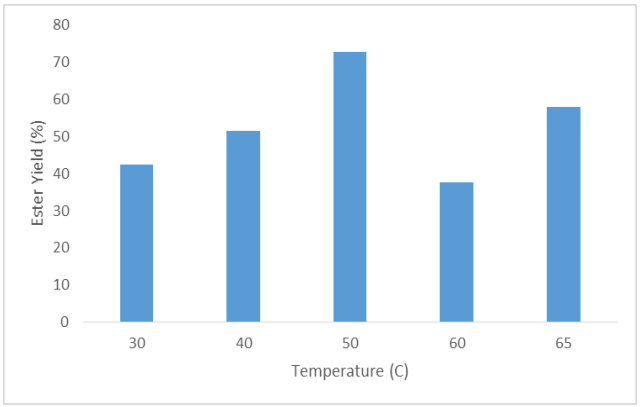

Figure 1: Effect of CFME Yield as a Function of Temperature.

Temperature affects transesterification of oil and fat with an alcohol. The temperature for this study was varied between 30- 60 ^{0}C at an increment of 10 ^{0}C. The result of the experiment shows that as the temperature increases from 30-50 ^{0}C, there is a corresponding increase in CFME yield from 42.4-72.8 %. Beyond 50 ^{0}C the CFME shows a decline in yield. This is because at higher temperatures close to the boiling point of the alcohol used, the alcohol seems to evaporate and saponification reaction is favored. This result agrees with the report from [11] that early or initial increase in temperature increases saponification or helps in faster settlement of glycerol.

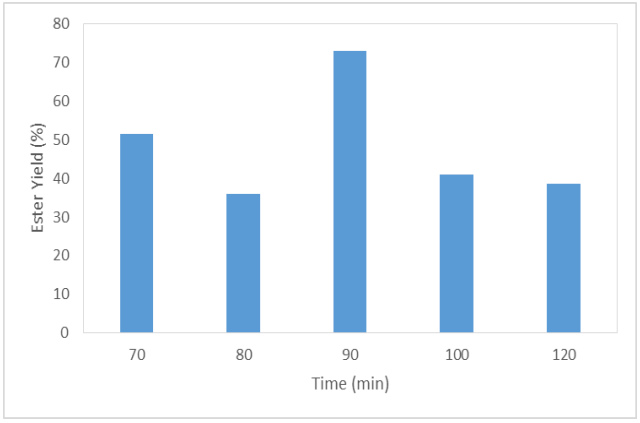

Figure 2: Effect of CFME Yield as a Function of Time of Reaction Time

Reaction time affects transesterification of oil and fat with an alcohol. Several investigations have shown that the conversion rate of biodiesel increases with an increase in reaction time [12]. The reaction time for this study was varied between 60-120 minutes at an increment of 10 minutes. The result of the experiment shows that as the reaction time increases from 60-90 minutes there is a corresponding increase in CFME yield from 58.0-73.0 %, beyond 90 minutes the CFME shows a decline in yield. The production of biodiesel reached the maximum value at 90 minutes.

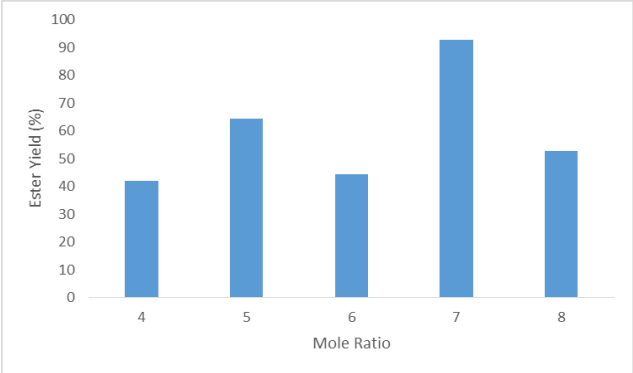

Figure 3: Effect of CFME Yield as a Function of Molar Ratio of Methanol to Chicken Fat

In order to determine the effect of methanol-chicken fat ratio on biodiesel yield, the ratio of methanol was varied from 3:1-8:1 while keeping all other process parameter fixed. For this process, it was observed that the ester yield increases with increase in molar ratio, although the percent yield increased with increase in molar ratio from 3:1 to 7:1 with the corresponding ester yield of 42.0-92.8 %. The molar ratios of 7:1 gave the maximum results for ester yield of 92.8 %, beyond this point (i.e at 8:1) ester yield reduces to 52.8 %. The result shows that there was a significant different between the yields from 7:1-8:1. It has been observed that the increment gain in biodiesel yield decrease with increase on the molar ratio.

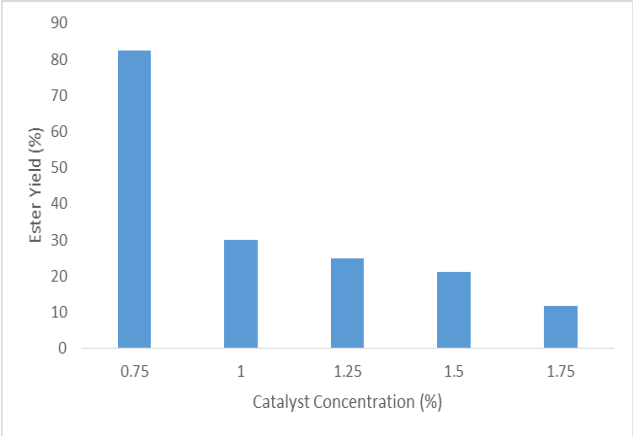

Figure 4: Effect of CFME Yield as a Function of Catalyst Concentration

The effect of sodium hydroxide (NaOH) concentration was studied in the range of 0.5-1.75 % (mass of NaOH/mass of fat), while keeping other process parameter constant. It was observed that the concentration influenced the biodiesel yield in a positive manner only up to a certain concentration of 0.75 % with the highest ester yield of 82.4 %, beyond this concentration the biodiesel yield decreased with increase in NaOH concentration. Higher catalyst concentration favours saponification of vegetable oils.

Table 2: Fuel Properties against the ASTM Standard Values with other Feedstock

Properties	Unit	ASTM D6751	EN 14214	*JOME	**CFME	***CFME	This Study
Ester Content	% (mol)	-	96.5	92.5	67	88.5	96.7
Kinematic Viscosity at 40°C	mm^2/s	19-60	33-50	2.54	5.4	4.94-6.84	5.33
Flash point	°C	130min	120min	186	174	170-172.8	172
Cloud point	°C	Report	-	-5	14	2-4	-6
Specific gravity at 15°C	g/m^3	-	860-900	886	870	883-891	872
Saponific. value	Mg/gKOH	-	-	-	-	-	256.645
Iodine value	gI/100g	-	-	-	-	-	99.61
Acid value	mgKOH/g	0.5 max	0.56 max	0.14	0.4	0.28	1.82
Cetane number	-	-	-	58	58.4	-	42.55
Calorific value	MJ/kg			38.65	39	40	
PourPoint	°C			-2	12.4	2-4	-10

* [13], ** [7], ***[6]

The ester yield of CFME was 96.7% agrees well with the minimum limit of 96.5% specified by EN 14214 standards. 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.

Flash point is a key property in determining the flammability of a fuel. The flash point of biodiesel is higher than diesel fuel, which makes it safer for transportation purpose. The biodiesel produced from CF had a flash point of 170 °C. This result is higher than the minimum specifications of both standards (Table 2). However, this value is very consistent with other literatures. The high flash point obtained in this study shows that the CFME is safe from handling and storage point.

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. The temperature at which crystal agglomeration is large enough to hinder free pouring of fluid is called its pour point (Gerpen *et al,* 2004). The cloud point of CFME was found to be -10°C.

Acid value is a measure of the FFA content in the biodiesel. It is the milligram of potassium hydroxide (KOH) required in neutralizing the FFAs in 1 gram of the sample. The acid value of CFME produced in this 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 is 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.

Kinematic viscosity is a very important property in regard to fuel atomization as well as fuel distribution. Viscosity is also an indication of fuel ageing during storage as it increases due to polymerization caused by oxidative degradation. 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 (ASTMD6751). The kinematic viscosity of the CFME produced in this work was 5.63 mm^2/s as presented in Table 2 . 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 measures how immediately ignition occurs upon injection of fuel into the combustion chamber and smoothness of combustion (Gerpen *et al*., 2004). The cetane number of the biodiesel in this work was 42.55 and as against the ASTM standard of 48-65. This value implies short ignition delay and better ignition properties.

The density at 15 ^{0}C of the CFME was found to be 872, the result was compares favorably with the ASTM D6751 and other reported literatures. Change in the Specific gravity shows that the density of the biodiesel decreased with increasing molar ratio. This was probably due to a decrease in residual triglycerides.

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 1% using H_2SO_4 before the alkaline catalysis. The effects of the variables on the fuel properties such as catalyst concentration, reaction temperature and reaction time were investigated. Optimum yield of 96.7 % CFME was obtained at a temperature of 50 ^{0}C, Molar ratio of 7:1, catalyst concentration of 0.75 % w/v and reaction time of 90 min. Fuel properties of the CFME compare well with the ASTM and EN standards for biodiesel.

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