Production and Characterization of Biodiesel from Chicken Fat

Nuhu, S.K. and Kovo, A.S.

1Department of Mineral and Petroleum Resources Engineering, School of Engineering
Plateau State Polytechnic, B/Ladi P.M.B. 02023, Bukuru Plateau State, Nigeria
2Department of Chemical Engineering, School of Engineering and Engineering Technology,
Federal University of Technology, Minna, P. M. B. 65, Minna, Niger State, Nigeria

Accepted 26 December, 2014

Chicken fat feedstock was used for the production of biodiesel in a two-step transesterification process due to its high free fatty acid (FFA) of 4.16%. The first step in the process called esterification is the pre-treatment, and this was done using 20wt % of hydrogen tetraoxosulphate (VI) acid and methanol-chicken fat molar ratio of 40:1 at 60°C reaction temperature and 80 minutes of reaction time. This was able to reduce the FFA to 0.43%. The transesterification reaction is the second step and was carried out using potassium hydroxide as catalyst with methanol. The effect of various process parameters such as reaction temperature and time, molar ratio of alcohol to fat and catalyst concentration on biodiesel production were investigated. The highest Chicken Fat Methyl Ester (CFME) yield of 93.4% was obtained from 50g of chicken fat at 60°C reaction temperature and a reaction time of 120 minutes corresponding to 6:1 molar ratio of oil-to-methanol and 1wt% catalyst concentration. The CFME properties like density, specific gravity, kinematic viscosity, cloud point, pour point, flash point, cetane number, iodine value and saponification value were determined and found to be 0.877kg/m³, 0.866, 4.4m²/s, 267K, 265K, 428K, 50.6, 94.66gI²/100/g and 213mg/gKOH respectively. These values compared favorably with ASTM standards. Hence, chicken fat has the potential for the production of biodiesel.

Key Words: Esterification, Transesterification, KOH, methyl ester, methanol.

INTRODUCTION

The need for petroleum energy is on the high rise and according to Ivan Kolesnikov in 2011 who researched for British Petroleum Company under the ‘Evaluation of the Status of Global Energy’. He revealed the proven reserves to stand at 862 billion tons for coal, methane – 187 trillion m³ and petroleum – 1,383 billion barrels. He said considering the rate at which these resources are exploited, coal may finish by the year 2129; methane may vanish in the next 60 years while petroleum may stop to find its way to the refineries in 40 years ahead. Therefore, this called for research of raw materials to replace or compliment this important energy which the world relies upon as it is fast used up (Warabi, Kusdiana and Saka 2004). Today, various ways have been used for the analysis but none or little has shown the possibility as to the ease of readily getting it, the cost effectiveness, and the overall impact to human, plants and air. One among such likely alternatives is the transesterification of animal fat and used vegetable oil into biodiesel. The way petroleum products are known to emit some poisonous by-products to the atmosphere, fuels produced from animal fat and used vegetable oil has been recommended to be a good source of energy. (Warabi et al., 2004).

Biodiesels are fuels obtained from the transesterification of either animal fat or used/fresh vegetable oil which is tantamount to the diesel synthesized from petroleum (Pinto, Guariero, Rezende, Ribeiro, Torres, Lopes Pereira and Andrade 2005). It is made by using a process called transesterification reaction, which is the process of converting vegetable oil or animal fats into a material that powers an engine that uses diesel. The popular process of producing biodiesel is by the employment of base-catalyzed
transesterification reaction. It involves the use of a catalyst and an alcohol usually methanol or ethanol producing methyl-ester or ethyl-ester respectively. It is a non-toxic, biodegradable with excellent burning quality devoid of smoke which favors the choice of biodiesel as an alternative energy source. Furthermore, it has a reduced molecular weight, excellent viscosity and volatility. Many researchers such as Barnwal and Sharma (2005) have found high flash points and cetane number, good performance in lubrication and very low or no sulphur in biodiesel than fuels from crude oil.

About 34 years ago, the utilization of fossil fuels became worrisome because of the emission of its by-products to the atmosphere which obviously became the source of environmental hazard. In view of this, the synthesis of animal fat and used vegetable oil was brought back recommending transesterification as the best route to get this fuel as an alternative energy (Kondamudi, Strull, Misra and Mohapatra, 2006). Science has proved that transesterified fuel has no hazard on the environment and animals like that from crude oil. There are little or no polycyclic aromatic hydrocarbons or nitrated compounds in biodiesel like in petroleum products to cause respiratory or lung ailments such as asthma and cancer (Frank, Luc and Arnaldo, 2009).

The global challenge today is to step into intense research and find a way of getting a renewable feedstock of both animals and vegetable to freely compete with the petroleum industry without having food security problem or causing the imbalance of the existence between animals and plants. When these two problems are proved to be taken care of beyond all reasonable doubt, the cheaply produced biodiesel will drastically reduced the jet speed at which crude oil is exploited, thereby profoundly diminishing the green house effect experiencing in this millennium (Gerpen, 2005).

In recent years, oil prices have rapidly risen and posing deep worry for future availability of the world’s fossil fuel. This and the growing concern for our environment have created a larger market for renewable resources. The idea of using biodiesel instead of fossil diesel fuels has manifested as a way to minimize the net carbon left by emissions from compression ignition (CI) engines. Animal fats have their own share of problems in unmodified compression ignition engines. These problems include engine knocking, gumming of filters and injector lines, cold weather starting; plugging, serious wearing of engine linings, deposition of carbon or soot on top of both piston and engine and deterioration of engine lubricating oil.

Some of the disadvantages of using pure animal fats are because they always have minimal pour point, elevated viscosity, short flash point and minimal cetane number giving poor combustion (Pinto et al., 2005). To avoid some of these problems, a process be employed to minimize the viscosity of animal fats down to a level for complete combustion to take place in the engine like fossil diesel does. The various processes that have been postulated to do this work include; preheating, emulsification, pyrolysis, dilution and transesterification. Transesterification process proved to be the best and today it is the one that most people use for the reduction of the viscosity of animal fats and vegetable oils thereafter, if interested, can be mixed with the petroleum diesel at a percentage ratio of 20:80 (Gürü, Artukoglu, Keskin and Koca, 2009).

Alcohols like ethanol or methanol are often used while butanol or propanol is seldom used for the conversion. In most cases acid catalysts used for the treatment of feedstock having FFA greater than 3 % are tetraoxosulphate (VI) and hydrochloric acids. In the same vein, transesterification utilizes sodium, potassium hydroxides as catalysts while sodium and potassium methoxides (mixture of sodium/potassium and methanol) are rarely employed. A very long period of time takes acid catalysts to effectively convert triglyceride to esters.

Fatty acid (FA) of the fat mixes with the alkaline catalyst, the most common among the catalysts is lye which is in the form of potassium hydroxide or sodium hydroxide and thus soap is produced. Park, Wang, Kim and Lee (2010) showed in their investigations on Chicken Fatty Methyl Esters (CFME) that the biodiesel produced has similar properties as diesel obtained from fossil which is contained by the Indian standard when potassium hydroxide was used with ethanol; hence fat oil is a potential material for conversion into biodiesel. Therefore, in this research, the catalyst to be used, potassium hydroxide will first be mixed with the alcohol, in this case, methanol, to create potassium methoxide; this will then be mixed with the fats to remove the glycerol molecule, leaving only the long fatty acid chain, which is biodiesel. Optimization of the transesterification reaction will be investigated with different methanol/oil ratio, reaction temperature, reaction time, catalyst concentration and stirring speed. The methyl ester obtained will be subjected to some conditions to find its suitability for use as fuel according to ASTM.

**Apparatus and Chemicals Used**

The following apparatus played a tremendous role in achieving the research conducted: thermometer, electric weighing balance, water bath with shaker, beakers, flasks, magnetic stirrer, syringe, bicep, spatula, others include, separating funnel, retort stand, flash point tester, cloud and pour point bath, viscometer bath and oven.

The reagents used were hydrochloric acid, sulfuric acid, methanol, isopropyl alcohol, potassium hydroxide, distilled water, phenolphthalein and chicken fat.

**METHODOLOGY**

Biodiesel production from chicken fat is treated in one-stage process if the FFA value is less than or equal to 3%
Figure 1 Transesterification of Triglycerides with Alcohol.

or two-stage process if the FFA value is more than 3%. The chicken fat was bought from Yaks and Yaks Farms, Ahmadu Bello Way, Jos, Plateau State of Nigeria. It was then taken to the Department of Science Laboratory Technology (SLT) laboratory, Plateau State Polytechnic, Barkin Ladi for dissolution in preparation for Gas Chromatography (GC), Mass Spectrophotometer (MS) and acid value analyses.

Pretreatment of the Chicken Fat

The chicken fat was bought from Yaks and Yaks Farms, Ahmadu Bello Way, Jos, Plateau state of Nigeria. It was then taken to the Department of Science Laboratory Technology (SLT) laboratory, Plateau State Polytechnic, Barkin Ladi where a representative sample was dissolved directly in isopropyl and another one mutilated. The two samples were taken to the National Research Institute of Chemical Technology (NARICT) Zaria, Nigeria for its analysis of molecular weight and percentage area using Gas Chromatography (GC) and Mass Spectrophotometer (MS).

The free fatty acid (FFA) of the chicken fat was determined and found to be 4.16%. This value must be treated to reduce it to ≤ 3% before the transesterification. The chicken fat was dissolved using a magnetic stirrer at 60˚C for 30 minutes after which it was cooled for another 30 minutes. The fat was filtered to remove bones, meat, feathers and other suspended substances. Using the electric weighing balance 50g of the fat was weighed and poured into a 500ml conical flask. 20% of sulfuric acid based on the weight of the fat and the methanol molar-to-fat ratio was weighed at 40:1. The sulfuric acid was mixed with the alcohol in a 250ml beaker and poured into the flask containing the fat. The mixture was inserted into a water bath with a regulated temperature of 60˚C and a speed of 150 rpm and timed for 1 hour 20 minutes. At the end of the pretreatment, the mixture was poured into a separating funnel and left there to settle overnight. Three layers were observed; the upper layer is the methanol, the middle layer is the water and the underneath layer is the chicken fat.

The FFA of the pretreated fat was analyzed again and found it to be 0.43% very good for transesterification.

Transesterification

50g of fat oil was measured, poured into a 250ml beaker. The methanol molar to fat ratio was measured to 3:1 by the help of a syringe. The catalyst concentration of 0.50% was weighed using an electric balance. The catalyst was added to the alcohol in the mixing bottle and capped, shaken gently for a few minutes until it was completely dissolved, forming a mixture of methanol and hydroxide (methoxide). This was then transferred unto the fat in the conical flask, capped very well then heated to 30˚C for 60 minutes in a water bath at a speed of 150 rpm. Having the mixture attained to the reaction time required, it was removed and emptied inside a 125ml funnel for separation into layers which took the whole night. These stages were repeated by keeping fixed amounts of fat oil sample, methanol molar to fat oil ratio, catalyst concentration, reaction time and varying the temperature of reaction in multiples of 10˚C starting from 30˚C to 70˚C.

Having done with the procedure above, the following equation was used for the calculation of the respective yield.

\[
\text{Yield (wt \%) = \frac{\text{Desired Product (in grams)}}{\text{Feed (in grams)}} \times 100 \times 1.0}
\]

The various yields were calculated in relation to the different temperatures. The temperature corresponding to the highest yield becomes the next temperature to be kept constant.

In the second experiment, the conditions that were kept constant are temperature, methanol molar to fat ratio,
catalyst concentration and varying reaction time (60, 70, 80, 100 and 120 minutes). After calculating the percentage yield, the reaction time corresponding to the highest value of yield becomes the next reaction time to be kept constant. The reaction time, amount of catalyst and temperature were kept constant and varied the methanol molar to fat oil ratio (4:1, 5:1, 6:1, 7:1 and 8:1).

In the last experiment, the methanol molar to fat oil ratio corresponding to the highest yield was maintained constant along side with constant reaction temperature and reaction time and varying catalyst concentration (0.75%, 1.00%, 1.25%, 1.50% and 1.75%).

**Washing and Drying of the Homogeneously Produced Biodiesel**

Warm water of between 45°C and 50°C was passed through the esters which allowed soluble material, excess catalyst and other impurities stocked to the water and settled to the bottom of the vessel. The water was removed from the vessel periodically until the wash water was clearly drained out. Drying was done by heating
slowly to about 110°C until all moisture present was evaporated and the pop sound was no longer heard. The diagram is shown in Figure 3.

**Characterization of the Produce Biodiesel**

The following parameters were analyzed for ease of comparison with ASTM standard. Specific gravity, density, cloud point, flash point, kinematic viscosity and pour point. Others include iodine value (IV), acid number, cetane number distillation characteristics and bottom sediments and Water (BSW).

**RESULTS**

**Esterification**

The value of Free Fatty Acid obtained in 4.2 which is quite higher than 3% called for esterification of the chicken fat to reduce the FFA. The procedure in section 3.5 was employed and thereafter the acid value of chicken fat was determined again and found to be 0.43%.

**The Effect of Reaction Temperature**

In Figure 3, only the reaction temperature was varied maintaining other parameters constant. The biodiesel yield was calculated using Equation 1.0

The yield increased with increased in temperature but decreased as the reaction temperature approached 64.7°C the boiling point of methanol where the larger part of it vaporized and affected the movement of the bulk of gas to the liquid part. At the same time elevated temperature accelerated the formation of soap. The temperature of 60°C, 60 minutes time taken for the conversion, 3:1 ratio of methanol to fat and 0.50wt% catalyst amount gave 92.40% the optimum yield of biodiesel (Figure 3.). Similar results were observed by Marchetti, Miguel and Errazu, (2007).

**The Effect of Reaction Time**

The extent of time of reaction that took the biodiesel to be converted was studied in the range of 70 to 120 minutes. As it was noted from the result, increase of reaction time from 70 minutes to 80 minutes sharply decreased the conversion but a subsequent increase in reaction time steadily increased the yield. At 120 minutes the conversion increased to 91.40%. Further increase in the reaction time may increase the conversion. Therefore, the reaction time of 120 minutes at 60°C reaction temperature, ratio of methanol alcohol to fat of 3:1 and 0.50wt% the quantity of catalyst was referred to as one of the suitable reaction period the methyl ester was synthesized (Figure 4).
The Effect of the Ratio of Methanol alcohol to chicken Fat

The ratio of methanol alcohol to fat is a critical constituent which influences the alteration of oil or oil to biodiesel. Transesterification reaction is a balance process that requires more quantity of methoxide to shift forward the formation of the product. In order to get higher yield of ester, higher molar ratio of alcohol to fat say 7.5:1 is needed. Here, it was deduced that at a temperature of 60°C, introducing 5:1 molar ratio of methanol alcohol and fat oil, the amount after conversion was deceased but at 6:1 the quantity sharply increased. The reason may be that more quantity of methoxide and chicken fat affects the removal of glycerol due to the rise in the solubility of glycerin if continued to be mixed, and then it will assist in driving the state of rest backward hence reducing the quantity of ester produced. With further increase in the ratio of methanol to fat, the conversion decreased (Figure 5), hence the quantity produced increased as the volume
of MeOH increased to a point and began to decrease after reaching its highest yield of 93.00%. This corresponds to 6:1 the ratio of methanol to oil, a temperature of 60˚C, 120 minutes reaction time and 0.50wt% catalyst concentration.

**The Effect of Catalyst Concentration**

Alcoholysis of chicken fat in the presence of varying amounts of KOH catalyst ranging from 0.75wt% to 1.75wt%; 6:1 ratio of methanol and fat at the agitation time of conversion of 120 minutes. Figure 6 indicates the yield of CFME. For lower catalyst concentration of 0.75wt%, the catalyst was significant to speed up completely the conversion. Therefore, 1.00wt% of KOH catalyst produced the best quantity of biodiesel from chicken fat up to 93.40% at 60˚C. From Figure 6.0, increased in the amount of catalyst beyond the optimum value, the quantity of the biodiesel produced will diminish because soap forms at increased volume of catalyst and reverse reaction may be aided.

---

**Table 1.** Comparison of Characteristics Properties between the Standards of Diesel, Biodiesel and CFME Produced by Homogeneous Catalysts

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Diesel (ASTM) (Lapeurta et al., 2008)</th>
<th>Biodiesel (ASTM) (Lapeurta et al., 2008)</th>
<th>CFME (Homogeneous Catalyst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard number</td>
<td>ASTM D975</td>
<td>ASTM D6751</td>
<td>ASTM D6751</td>
<td></td>
</tr>
<tr>
<td>Composition</td>
<td>Hydrocarbon</td>
<td>(C10–C21)</td>
<td>(C12-C22)</td>
<td></td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>0.85</td>
<td>0.88</td>
<td>0.866</td>
<td></td>
</tr>
<tr>
<td>Density (15 ˚C)</td>
<td>kg/m³</td>
<td>0.834</td>
<td>0.84 - 0.90</td>
<td>0.877</td>
</tr>
<tr>
<td>Viscosity (40 ˚C)</td>
<td>m²/s</td>
<td>4.10</td>
<td>1.50 - 6.00</td>
<td>4.40</td>
</tr>
<tr>
<td>Flash Point</td>
<td>K</td>
<td>333–353</td>
<td>373–443</td>
<td>428</td>
</tr>
<tr>
<td>Cloud Point</td>
<td>K</td>
<td>258–278</td>
<td>258–289</td>
<td>267</td>
</tr>
<tr>
<td>Pour Point</td>
<td>K</td>
<td>243–258</td>
<td>258–289</td>
<td>265</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>40–55</td>
<td>48–60</td>
<td>50.60</td>
<td></td>
</tr>
<tr>
<td>Saponification</td>
<td>mg/hKOH</td>
<td></td>
<td></td>
<td>213.18</td>
</tr>
<tr>
<td>Acid Value</td>
<td>mKOH/g</td>
<td>max 0.50</td>
<td>max 0.50</td>
<td>1.112</td>
</tr>
<tr>
<td>FFA</td>
<td>%</td>
<td>max 0.50</td>
<td>max 0.50</td>
<td>0.566</td>
</tr>
<tr>
<td>Iodine Value</td>
<td>gI₂/100g</td>
<td></td>
<td></td>
<td>94.66</td>
</tr>
</tbody>
</table>

**Figure 6.** The Effect of the Amount of Catalyst on the Produced Biodiesel
CONCLUSION

Result of Characterization of the Biodiesel Produced from Chicken Fat Oil

The production of chicken fat methyl ester (CFME) involved the titration of the feedstock in order to ascertain its acid value (AV) and free fatty acid (FFA) which was found to be 8.32mgKOH/g and 4.16% respectively. The esterification of the feedstock became necessary because of the FFA was more than 3.00%. This was done using sulfuric acid and methanol thereby reducing the FFA to 0.43%. Thereafter, the conversion of the chicken fat to CFME was achieved by the use of alcohol (methanol) and KOH catalyst. This was made by varying the reaction temperatures, reaction times, methanol to fat ratios and catalyst concentrations. The highest biodiesel produced from 50.00g of chicken fat was 93.40% at 60°C reaction temperature, 2 hours reaction time, and 6:1 ratio of methanol alcohol to fat and 1wt % concentration of catalyst.

The values from characterization revealed that specific gravity, density, kinematic viscosity, pour point, flash point, cetane and iodine values of CFME produced respectively met the literature values and ASTM D6751 acceptable standard values (Table 1 above).

REFERENCES


