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Poultry Fat–A Cheap and Viable Source for Biodiesel Production

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***Abstract*—Negative environmental consequences of fossil fuels and concerns about petroleum supplies have spurred the search for renewable transportation biofuels. . Other various compelling issues like depletion of fossil fuels, significant cost increase in petroleum and its based products, negative health effects from petroleum based diesel drive an effort to develop and improve technology to make biofuels. Biodiesel (Methyl Esters) is a diesel replacement from vegetable oils. Chemically biodiesel is mono-alkyl esters of long chain fatty acids derived from renewable feed stock like vegetable oils and animal fats. Most of the research that is taking place is mainly concerning the use of biodiesel. Biodiesel can be a very successful fuel due to the fact that it reduces engine wear and there is an infinite number of materials to produce it. The key advantage of this fuel is that it is biodegradable, non toxic, simple to use, significantly kinder to the environment and better lubricity resulting in longer life for diesel engines. . Biodiesel has higher oxygen content (i.e. biodiesel is 11% oxygen by weight and contains no sulphur, reduces carbon di oxide emissions up to 80%,) than petroleum diesel and its use in diesel engines have shown great reductions in emission of particulate matter, carbon monoxide, sulfur, polyaromatics, hydrocarbons, smoke and noise. Transesterification is one among the various processes through which biodiesel is produced in presence of acid, base, homogeneous, heterogeneous or bio catalyst.. It is actually the replacement of alcohol group from an ester by another alcohol. Alkali catalyzed transesterification is considered to be the best amongst all methods available for the production of biodiesel from fresh oil.**

In the present investigation an attempt has been made to use chicken fat as low cost sustainable potential feed stock for biodiesel production by single step transesterification process. Effect of various process parameters such as amount of catalyst, temperature, amount of methanol and reaction time on biodiesel production was investigated. The optimal condition for processing 50 g of chicken fat was obtained. Under optimal conditions, the maximum yield of 95.2% chicken fat methyl esters was achieved by using 6:1 molar ratio of chicken fat to methanol, at 60oC, for a reaction time of 90 min in the presence 0.38gms of KOH catalyst. The fuel properties like Density, kinematic viscosity, acid value, cloud point, iodine value, saponification value, pour point and cetane value was estimated and was found to compare well with ASTM standards. Chicken fat was found to be highly suitable to produce biodiesel with recommended fuel properties.

Keywords Biodiesel, renewable fuel, triglycerides, glycerol, chicken fat.

I. INTRODUCTION

Biodiesel is an alternative fuel for diesel engines that is receiving great attention worldwide as it reduces the dependence on petroleum products, the energy crisis, global climate changes and environmental pollution and also non-toxic. Biodiesel and its blends can be used in diesel engines without any major modification. Many studies have shown that the fuel properties of biodiesel are very close to diesel fuel(Alptekin.A and Canakci.M, 2009, Kinast AJ, 2001). It is defined by ASTM that it is a fuel composed of Mono alkyl esters of long-chain fatty acids derived from renewable vegetable oils or animal fats (Ma and Hanna, 1999, Srivastava and Prasad, 2000). It has many advantages compared to diesel fuel as it has higher cetane number than diesel fuel, contains no aromatics, almost no sulfur and 10-12% oxygen by weight. Biodiesel fuelled engines produce less CO, HC and particulate emissions than petroleum diesel fuelled engines. (Canakci.M,2008).

In general, biodiesel is produced from high quality food-grade vegetable oils. The most common feedstock of biodiesel is rapeseed oil, soybean oil, etc., Using high-quality virgin oils makes biodiesel more expensive than diesel fuel. There fore low cost feedstocks are needed. Although Vegetable oil esters have certain advantages such as lower viscosity, lower flash point, higher vapour pressure and easier processing relative to animal fatty acid esters, they are non-economical and non-feasible due to the prohibitive cost and hence the major handicap is the high cost of biodiesel for its commercialization. Moreover, the use of vegetable oil leads to shortage of food while use of animal fat for human consumption is a health hazard.

Chemically, Biodiesel can be produced by transesterification, which is a three step reversible reaction that converts the initial triglycerides into a mixture of Fatty acid Methyl Ester(FAME) and glycerol in the presence of a catalyst usually homogeneous or heterogeneous(Han et al, 2009). Alcohol such as ethanol, methanol, butanol can be used in the transesterification. The most commonly preferred catalyst are sulphuric, sulfonic, and hydrochloric acid as acid catalysts and sodium hydroxide, sodium methoxide, potassium hydroxide as alkaline catalyst. Acid catalyst are too slow to be suitable for converting triglycerides to biodiesel. However, they appear to be quite effective at converting FFAs to esters.

Rendered animal fats and restaurant waste oils are appealing feedstock to produce biodiesel. They are sold commercially as animal feed. If the free fatty acid level is less than 15% it is called yellow grease and if it is above 15% it is called brown grease. The price of virgin vegetable oil is about two times more than that of animal fat, but drawbacks of using animal fat as a raw material for Biodiesel production is its physical properties which could be eliminated by adding necessary amount of alcohol, catalyst for a required period of time. Therefore the price of feedstock can be reduced about 50% with using low grade animal fat. However, they often contain significant amounts of FFA. The fats with high FFA cannot be converted to biodiesel using alkaline catalysts which have been used with good results for vegetable oils. FFA's reacts with an alkaline catalyst and thus soaps are produced

Investigations have shown that chicken fat is a promising feedstock for biodiesel production. The purpose of the present study is to produce biodiesel from chicken fat with high FFA. Therefore, optimization of the transesterification reaction was investigated with different methanol/oil ratio, reaction temperature, reaction time, Catalyst amount. The obtained ester was characterized by determining its fuel properties according to standard test methods.

II. MATERIALS

The chicken fat was obtained from a slaughter house. The fat was washed, cleaned with de-ionized water and was free of flesh and skin. The solid fat was melted at around 65°C. This was then filtered, centrifuged and decanted to remover other suspended particles. The processed fat which was homogeneous in nature was stored in air tight opaque plastic jars to prevent oxidation. The free fatty acid (FFA) of the chicken fat was determined and found to be 1.65 mg of KOH/gm of fat. All the analytical grade reagents were bought from the local chemical supplier.

III. METHODS

A. *Transesterfication*

Biodiesel production for chicken fat transesterification does not need the pre-esterification step as the acid value of the melted fat was well below 2%. Hence alkali was used for the transesterification of chicken fat. The parameters such as alcohol to oil molar ratio, catalyst amount, reaction temperature and reaction time were analyzed. Experiments were conducted in a laboratory-scale setup which considered of 250cc glass flasks with air tight caps and a water cooled condenser that returned any vaporized methanol to the reacting mixture. The flasks were kept in an oil bath maintained at 60° C, just below the boiling point of methanol. The mixture was stirred using an agitator at the same rate for all runs. At various time the progress of the reaction was monitored by measuring the acid value. The fatty acid profile of chicken and mutton fat is given in Table 1 and the properties of chicken fat and mutton fat are shown in table2. Its FFA content was determined by the standard titrimetry method.

TABLE 1. FATTY ACID PROFILE OF CHICKEN FAT

Fatty acid	C:N [a]	Chicken Weight%
Lauric Acid	12:0	-
Myristic Acid	14:0	0.7
Myristoleic Acid	14:1	0.3
Palmitic Acid	16:0	25.2
Palmitoleic Acid	16:1	7.8
Stearic Acid	18:0	5.9
Oleic Acid	18:1	40.5
Linoleic Acid	18:2	18.4
Linolenic Acid	18:3	0.7

[a]C, no of carbon, N, no of carbon-carbon double bond

B. *Alkali Catalysed transesterification*

In alkali transesterification, calculated amount of KOH was dissolved with the required amount of methanol and was poured into the preheated oil (melted chicken fat) in the flask. The reaction was conducted for various times and at 900rpm speed. After the reaction was completed for melted chicken fat, the reaction mixture was allowed to be separated into two layers. The bottom is the brownish red colour and containing the impurities and crude glycerol was drawn off. The esters along with the catalyst remained in the upper layer were then separated from the reactant mixtures. The transesterified product (biodiesel) after separation was first distilled to remove the unreacted methanol and then washed 2-3 times with hot water to remove the dissolved glycerol in the biodiesel phase.

IV. RESULTS AND DISCUSSION

A. *Transesterification*

Alkaline catalyzed transesterification was run using a pretreated sample that had an acid value of 1.65 mg KOH/g for chicken fat. Following this process, an yield of 95.2% for chicken fat. The fuel properties of chicken fat methyl esters (CFME) along with melted chicken fat and diesel are summarized in Table2. It can be seen that CFME biodiesel had comparable fuel properties with those of diesel and were within the limits prescribed in the Indian standards.

TABLE 2. COMPARISON OF PROPERTIES OF CHICKEN FAT METHYL ESTERS, AND DIESEL.

Properties	CFME	Diesel	ASTM standards for Biodiesel	Method
Density at 15 °C kg/m^3	870	830	860- 900	D4052
Kinematic Viscosity at 40 °C mm^2/s	4.386	2.6	1.9 – 6	D445
AV mg of KOH/gm of oil	0.16	0.35	<0.8	D664
cloud point, °C	0.8	-8	NA	D2500
Iodine value, G I_2/100 gm	80	NA	115	D1959

AV – Acid Value

B. Optimisation of transestertification process

The percentages of yield of methyl esters are presented as graphs for the different amounts of methanol to oil ratio, reaction temperature, and catalyst amount. The percentage of yield of methyl esters is calculated by using equation (1)

$$\text{Yield(wt\%)} = \frac{\text{Desired Product (Methyl esters (in gms))}}{\text{Feed (melted Chicken fat (in gms))}} \times 100 \quad \text{-(1)}$$

C. Effect of Catalyst amount & Reaction Temperature

Methanolysis of Chicken fat was carried out with KOH as a catalyst at a concentration of 0.34 – 0.41 gms of KOH with MeOH/oil molar ratio of 6:1 at stirring speed of 900 rpm, reaction time 90 min. Figure 1 shows the yield of chicken fat Methyl Esters vs. catalytic concentrations at different reaction temperature. For lower catalytic concentration of 0.35gms of KOH was insignificant to catalyze the reaction to completion. However, 0.38 gm of KOH was optimal for chicken fat methyl esters in the reaction with a yield of 95.2% for chicken fat at 60^{o}C. Increasing the catalyst amount above the optimal value decreased the yield due to the fact that, soap formation occurs at higher amounts of catalyst and also backward reaction was favored at high catalyst concentration. It is also observed that the reaction achieved a maximum yield at 60^{o}C for all amounts of catalyst added. For higher reaction temperature, the yield decreased as the reaction temperature was very close to the boiling point of Methanol where most of the Methanol would be in the vapor phase which actually affects the Mass transfer between the gas and liquid phase and also the higher temperature accelerates the side saponification reaction of triglycerides. Similar results were observed by J.M. Marchetti et al, 2007, Y. Wang, S. Zhang, 2007.

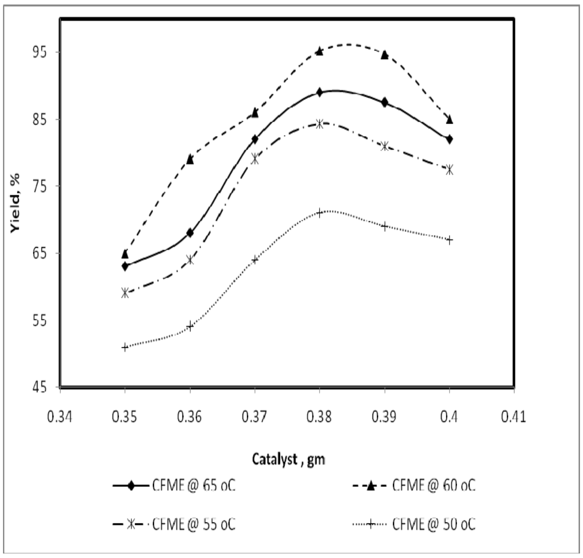

Figure 1. Effect of amount of catalyst and Reaction temperature on chicken fat (Reaction Time: 90 min, Molar ratio of MeOH:Oil : 6:1)

D. Effect of Methanol/ Oil ratio

The alcohol/oil ratio is one of the important factor that affects the reaction. The variation in the yield of methyl esters with different methanol to oil molar ratio for various reaction time is shown in fig 2. It is also observed that the percentage yield increases with increase in excess amount of MeOH. Transesterification is an equilibrium reaction in which a large excess of MeOH is required to drive the reaction to the right. For maximum conversion to the ester, a molar ratio varying from 3:1 to 7:1 was used. The high molar ratio of MeOH to vegetable oil interferes with the separation of glycerin because there is an increase in solubility. When glycerin remains in solution, it helps drive the equilibrium to back to the left, lowering the yield of esters. It is advisable to use molar ratio of methanol/oil ratio of 6:1 since increase in the amount of methanol does not show a significant increase in the yield. However on an industrial scale increasing the amount of methanol would not be a problem since methanol can be recovered from glycerol and methyl esters phase. However increasing the consumption of methanol will inevitably increase its recovery cost. It was also observed that there was significant increase in the yield up to 90min and thereafter it became almost constant for higher reaction time. It was found that for a reaction time of 90min and methanol/oil ratio of 6:1 the yield was optimum

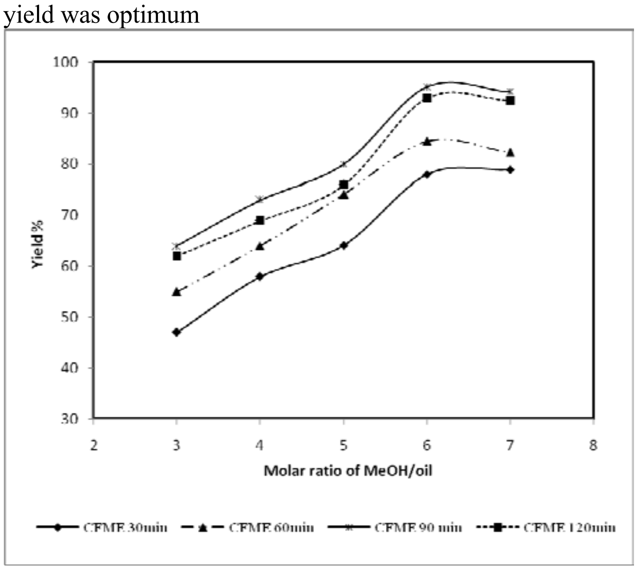

Figure 2. Effect of molar ratio of MeOH/oil and Reaction time on chicken fat (Reaction Time : 90 min, catalyst /oil wt% :0.38 gm of KOH/gm for chicken fat)

V. CONCLUSION

The study on the biodiesel production process, optimization of chicken fat showed that the quantity of catalyst, amount of methanol, reaction temperature and reaction time are the main factors affecting the production of methyl esters. The optimal values of these parameters for achieving maximum conversion of oil to esters depended on the chemical and physical properties of these fats. The following conclusions are drawn from the study.

- Addition of excess catalyst causes more triglycerides participation in the saponification reaction leading to a marked reduction in the ester yield
- Biodiesel production process is incomplete when the methanol amount is less than the optimal value. Operating beyond the optimal value, the ester yield would not be increased but will result in additional cost for methanol recovery.
- Sufficient reaction time should be allowed to ensure complete conversion of triglycerides into esters. However, excess reaction time did not promote the conversion but favors the reverse reaction of transesterification which resulted in a reduction of ester yield.
- The optimal reaction conditions for production of methyl esters from chicken and mutton fat are established as follows. The reaction time of 90 min at $60^{o}C$, 6:1 molar ratio of methanol to oil and 0.38gm of KOH/gm of oil for chicken fat for 50ml of chicken fat.
- Results of present study clearly demonstrated that the use of chicken fats is very suitable as low cost feed stocks for biodiesel production.

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