PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL

SINTEI EBITEI NELSON
ebitei4nelson@yahoo.com

AND

TRUST PROSPER GBARIENEMI

Department of Chemical Engineering,
Federal Polytechnic, Ekowe,
Bayelsa State, Nigeria.

ABSTRACT

The study looked at production of biodiesel from waste cooking oil. Two research questions were used in the study. The research is limited to the use of waste cooking oil to produce biodiesel through alkali-catalyzed transesterification process. Fuel properties of waste cooking oil and biodiesel produced will be analyzed and compared to ASTM D-6751 standards for biodiesel and ASTM D-975 Diesel fuel #2. In the conversion of WCO into biodiesel 71, 72 and 73 wt.% of the product were formed at 30^0C, 65^0C and 95^0C respectively. The fuel properties of the WCO and biodiesel produced were evaluated and compared with the biodiesel and fuel standards. Studies of some of fuel properties of biodiesel revealed that biodiesel had s viscosity of 4.7mm^2/s at 65^0C which fell within the standard limits of 1.9-6.0mm^2/s, but at 30^0C and 95^0C the viscosity were 9.1mm^2/s and 1.5mm^2/s. the methyl ester from waste cooking oil was discovered to have relative close fuel properties to the conventional diesel. Hence, the biodiesel can be used as alternative fuel for diesel engines.

Keywords: Biodiesel and Waste Cooking Oil

INTRODUCTION

Biodiesel is a non-toxic and biodegradable fuel that is made from vegetable oils, waste cooking oil, animal fats or tall oil (a by-product from pulp and paper processing). Biodiesel is produced from these feed stocks through a process called transesterification, by reacting the oil with an alcohol (usually methanol, although ethanol can also be used) and a catalyst (such as sodium hydroxide). The resulting chemical reaction produces glycerin and an ester called biodiesel. The majority of biodiesel is produced by this method compared with conventional diesel, biodiesel combusts better with a higher cetane rating and produces fewer life cycle greenhouse gas emissions (GHG), which contributes to climate change. Biodiesel blends a mixture of petroleum diesel and can also be used in any diesel engine. As biodiesel can be blended with diesel in any concentration, the blend level depends on economics, availability, the desired emission level, material compatibility and combustion characteristics. An increasing number of original equipment manufacturers are endorsing the use of lower biodiesel blends e.g.5% in their engines. Some manufacturers now extend warranty coverage for new diesel meets applicable standard.

Biodiesel production is based on transesterification of vegetable oil and fats through the addition of methanol. Presently, biodiesel is produced mainly from variety of oils like corn oil, canola oil, macadamia nut, sunflower, hemp oil, soybean, rapeseed, peanut, jatropha oil and rubber seed. Vegetable oils and animal fats usually have hydrophobic properties, which mean they are insoluble in water. Triglycerides are made up of 1 mol glycerol and 3 mol fatty acids. Fatty acids vary in terms of carbon chain length and number of unsaturated bonds (double bonds).

Currently, the major concern for biodiesel production is economic feasibility. In recent scenario, biodiesel production will not be favored without tax exemption and subsidy from government, as the production cost is higher than fossil derived diesel (Demirbas and Balat, 2006). The overall biodiesel cost consists of raw material (production and processing), catalyst, biodiesel processing (energy, consumables and labour), transportation (raw materials and final products) and local with national taxes (Haas et al, 2006). To date, most biodiesel plants are using refined vegetable oils as their main feedstock. Therefore, the cost of refined vegetable oils contributed nearly 80% of overall biodiesel production cost (Lam et al, 2009).

In order to overcome this limitation, biodiesel manufacturer are focusing their attention on using low-cost feedstock such as waste cooking oil in order to ensure economic viability in biodiesel production. Waste cooking oil is far less expensive than refine vegetable oils and therefore has become a promising alternative feedstock to produce biodiesel. In fact, generation of waste cooking oil in any country in the world is huge, and may result to environmental contamination if no proper disposal method is implemented. If a reasonable amount of waste cooking oil is successfully collected and converted to biodiesel, it will be sufficient to meet the European biodiesel production target at 10million tones in year 2010 (Lam et al., 2009). Apart from that, a recent study on the production cost of biodiesel can be reduced by more than half compared to virgin vegetable oil (Escobar et al., 2009). Hence the high cost of feedstock can be overcome if waste cooking oil is used for biodiesel production.

CHALLENGES OF BIODIESEL PRODUCTION

A number of challenges are associated with the production of biodiesel from waste cooking oil. The removal of undesirable compounds and the pretreatment of the waste cooking oil give an additional cost in biodiesel production and require better technologies.

Another challenge is the availability of waste cooking oil on the market. WCO collection from household, commercial or industrial sources can be achieved through grease traps through a holistic policy frame work. Industries have to adopt more energy-efficient technologies to improve its profitability and competitiveness.

LITERATURE REVIEW

Waste Cooking Oil

Currently, world oil and fats production is about 154 million tonnes (MPOC, 2008). This figure refer to the production of 17 major ois and fats, comprising from vegetable oils (i.e. soyabean, cottonseed, groundnut, sunflower, rapeseed, sesame, corn, olive, palm, palm Karnel, coconut, linseed and castor) and animal fats/oils (i.e. butter, lard, tallow, grease and fish oil). Most of these oils are used for deep frying processes, after which could cause disposal problem. Some serious water contamination may occur if no proper disposal method is used. Such scenario does not only contribute to pollution problems but is also harmful to the health. The harmful compounds may enter the human food chain during meat consumption (Kulkarmi and Dalai, 2006). Since frying improves the taste of food, it has become a common method in food preparation. During frying, oil is heated under atmospheric condition at temperature of 160-190^{0}C (Gazmuriad Bouchon, 2009) for relative long period of time. In addition, the same oil or fat is used several times, mainly because of economic reasons. However, continuously using the same oil or fat for frying will cause various physical and chemical changes in the oil, depending on the type of oil and oil composition. Some physical changes observed in vegetable oil after frying are the increase in viscosity, increase in specific heat, change in surface tension and change in color (Cvengros and Cvengrosova, 2004).

However, if waste cooking oil is to be made feedstock for biodiesel production, the amount of polar compound in the waste cooking oil, especially free fatty acid (FFA) must be taken into consideration as it will greatly affect the transesterification reaction. Refined oil usually contains less than 0.5wt. % FFA whereas for waste cooking oil, FFA contents range between 0.5 and 15wt.% (Gerhard Knothe and Krahl, 2004).

Hydrolytic Reaction

The hydrolysis of triglycerides occurs when steam produced during the preparation of food. Part of the water quickly evaporates, but a certain part dissolved in the oil or fat and induces its cleavage to give fatty acids, glecerol, monoglycerides and diglycerides concentration (Kulkarni and Dalai, 2006).

Homogeneous Base-Catalyzed Transesterification

Currently, biodiesel is commonly produced using homogeneous base catalyst, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH) (Felizardo et al., 2006, Kulkarni and Dalai, 2006). These catalysts are commonly used in the industries due to several reasons such as low reaction temperature with atmospheric pressure, high conversion achievement with minimal time, generally available and economic to consume (Lotero et al., 2005). In fact, it was reported that the rate for base-catalyzed reaction would be 4000 times faster compared to acidic catalyst (Fukuda et al., 2001, Kulkarni and Dalai, 2006). However, the use of this catalyst is limited only for refined vegetable oil with less than 0.5wt.% FFA (Wang et al., 2006) or acidic value less than 1 mg KOH/g (Felizardo et al., 2006). Some researchers reported that base catalyst can tolerate higher content of FFA.

PURPOSE OF THE STUDY

The main objectives of this work are:

1. To determine the percentage of alkali-catalyzed transesterification of waste cooking oil.
2. To determine the viscosity, cloud point, and pour point of waste cooking oil prepared at 65^0C for methyl esters as compared to those of diesel fuel.

RESEARCH QUESTIONS

The following research questions were used as a guide for the study:

1. What is the percentage conversion of alkali-catalyzed transesterification of waste cooking oil?
2. What is the viscosity, cloud point, and pour point of waste cooking oil prepared at 65^0C for methyl esters as compared to those of diesel fuel?

SCOPE OF THE STUDY

The research is limited to the use of waste cooking oil to produce biodiesel through alkali-catalyzed transesterification process. Fuel properties of waste cooking oil and biodiesel produced will be analyzed and compared to ASTM D-6751 standards for biodiesel and ASTM D-975 diesel fuel #2.

METHODS

Materials

Waste cooking oil was procured from Omega, Mr Biggs and Chicken Republic fast food joints and bulked in Benin City, Edo State, Nigeria. Chemicals were purchased at Whosco Ventures NIG Ltd within Benin City and of analytical grade.

- Anhydrous methnol (MeOH), 99.8%

- Sodium hydroxide (NaOH), 4.5g
- Hydrochloric acid (HCl), 37-38% pure
- Potassium iodide (KI)
- Carbon tetrachloride (CCl_4)
- Carbon tetrachloride ($K_2C_{12}O_7$)
- Sodium thiosulfate ($Na_2S_2O.5H_2O$)
- Fullers Earth
- Wijs solution (which contains iodide monochloride and acetic acid), n-hexane, and silica gel (28-200 Mesh)

Apparatus used are round bottom flask with ground neck, filter paper, separation funnel, gallen Kamp oven, Buchner funnel, reflux condense, weighing balance, rotary evaporator RE 100, magnetic stirrer, desiccator, bioreactor and beaker.

Purification of Waste Cooking Oil (WCO)

The waste cooking oil obtained from Omega, Mr. Biggs and Chiken Republic fast food joints contained some food debris and other solid impurities. It is a mixture consisting of water, solid particles, free fatty acids (FFA) and many other chemicals. The WCO was filtered under a vacuum using a Buchner funnel. The residue on the weighed filter paper was washed with n-hexane until clear from oil stain. The washed filter paper was dried lin the oven at 103^oC for 4h cooled in dessicators and weighed again, the solid content (dirt) was determined by difference (the weight of the filter paper after filtration- the weight before filtration). Water was removed by mixing WCO with 10wt.% (40g) silica gel followed by stirring the mixture and vacuum filtration. This step was conducted twice to ensure complete removal of water.

Preparation of the Biodiesel (methyl esters)

Exactly 400g of WCO was transferred into a round bottom flask with ground neck, 105ml of absolute methanol in which 4.5g of NaOH (1.125% wt. of oil was dissolved to give methanol NaOH) was added to a co reflux condenser attached to the set up which is mounted on a water bath. The flask is rotated while heating at 95^0C at 200 revolutions per minute (rpm). The reaction was carried out for 1h after 1h of stirring the mixture which slowly became clear an less viscous was transferred to a separating funnel and was allowed to rest for 6h. The dark glycerol layer, which separates, could be removed. The upper layer was washed several times with distilled water at 60^0C until aqueous washing is neutral to phenolphthalein. The separation of the aqueous was usually very slow due to the formation of soap. The biodiesel (organic layer) was dried over anhydrous sodium sulphate and filtered properly. The experimental procedure was repeated at 30^0C and 65^0C. The chemical property of the biodiesel was analyzed using PORIM method.

RESULTS

RESEARCH QUESTIONS 1

What is the percentage conversion of alkali-catalyzed transesterification of waste cooking oil?

Table 1: *Percentageconversion of Alkali-Catalyzed Transesterification of Waste Cooking Oil*

Run	Catalyst Concentration (wt.%)	Temperature(^{0}C)	Methanol to oil molar ratio	1min	5min	10min
1	0.5	30	6:1	16.5	44.5	53.6
2	0.5	65	6:1	27.5	61.8	66.0
3	0.5	95	6:1	34.6	66.6	71.6
4	1.0	30	6:1	61.5	76.8	84.3
5	1.0	65	6:1	72.5	81.9	83.6
6	1.0	95	6:1	75.4	82.2	84.1
7	1.5	30	6:1	81.7	86.8	90.1
8	1.5	65	6:1	78.9	87.3	90.0
9	1.5	95	6:1	81.5	90.4	99.9

The effect of reaction temperature on ester concentration was studied at 6: 1 methanol to oil molar ratios using 0.5, 1.0, and 1.5 wt.% NaOH. Table 1 shows an ester concentration profile of transesterification of waste cooking oil with 6:1 methanol to oil molar ratio using 0.5% NaOH respectively. It is evident from this table that the higher reaction temperature is favoure by higher ester formation rate. Also, table 1 illustrates higher conversion at higher reaction temperatures. The reason for this behavior is due to the endothermic nature of the reaction. The higher reaction temperature would favor endothermic reaction, thus increasing the rate of reaction as well as the ester concentration. However, reaction temperature did not show any significant impact on conversion when using the higher catalyst loading (1.5 wt. %). This is because the reaction was driven close to completion at higher catalyst loading. Results from this part of the study also suggest that the higher ester concentration can be obtained at higher reaction temperature.

RESEARCH QUESTIONS 2

What is the viscosity, cloud point, and pour point of waste cooking oil prepared at 65^{0}C for methyl esters as compared to those of diesel fuel?

Table 2: *Viscosity, cloud point, and pour point of waste cooking oil prepared at 65^0C for methyl esters as compared to those of diesel fuel*

Sample	Viscosity@65^0c	Cloud Point (^{0}c)	Pour Point (^{0}c)
W C O	8 7 . 1	-	-
WCO ester	4.7	18	14
Diesel #2	3.5	-5	-15
ASTM	1.9- 6.0	NA	NA

Higher cloud and pour point of esters may be due to the presence of polymerized ester during transesterification. This may be due to that of Omega, Mr. Biggs, and Chicken Republic fast food joints to have over used the oil before discarding. The cloud and pour point of methyl esters was lesser value compared to the reference diesel #2. These results fit well with the previous research of Lang et, al 2001. From these results it is clear that waste cooking oil derived esters would be a suitable candidate as a diesel fuel substitutes in tropical countries and not as suitable at B100 in colder climate conditions such as in Russia. However, weaker blends (B5), winterization of waste cooking oil, or some additives may assist the application of esters in colder temperature.

CONCLUSION

In conclusion, the ester yield obtained from the one-step transesterification process ranged from 71 to 73 wt.%. The yield of biodiesel varies with the quality of feed stock. Also, the rate of formation of esters can be increased by increasing reaction temperature or catalyst concentration. The 6:1 alcohol to oil molar ratio was found to be optimum for transesterification reactions. Further, the feed stock, WCO used in this study must have been used to fry different types of materials and over used too.

RECOMMENDATIONS

The findings of the study lead to the following recommendations:

1. Emission testing should be performed when esters derived from fresh vegetable oil or waste cooking oil is used in a diesel engine.
2. The storage storability is another important property of biodiesel. Study on storage storability of diesel derived from waste cooking oil is recommended.

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