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REACTION TEMPERATURE FOR BIODIESEL PRODUCTION FROM WASTE COW FAT BASED SOURCES

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ABSTRACT

Animal fat waste constitutes some of the most relevant waste and the treatment of such waste is quite costly because environmental regulations are quite strict. Part of such costs might be reduced through the generation of bioenergy. Persistent global energy and fuel crises have shown that fossil fuels are limited source of energy that was ultimately exhausted. Biodiesel production from cow fat were treated in one stage process if the FFA value is less than or equal to 3%. The oil was characterized for physical and chemical properties such as viscosity, FFA content, and density. Fatty acids content in oil was determined with GC-MS analysis. From the FTIR analysis of animal fat oil extract, it shows that the functional group (-OH) was best depicted at the Characteristic absorptions of 3468.8 cm^{-1} and (C=H) was best at 1741.0 cm^{-1}. The flash point showed the measure of flammability of fuels and thus an important fuel safety criterion. The biodiesel fuel had a flash point of 133.20℃ and this satisfies the standard. The yield of biodiesel increased with reaction temperature increase and the values properties were within biodiesel standard.

Keywords: Temperature, Reaction, Alkali Catalyst, Biodiesel, Cow fat, transesterification reaction

INTRODUCTION

The major part of all energy consumed worldwide comes from petroleum, charcoal and natural gas with the exception of hydroelectricity and nuclear energy. However, these sources are limited, and could be exhausted by the end of the next century (Schuchardta *et al.,* 1998) thus, looking for alternative sources of energy is of vital importance. Securing the supply of fossil fuel has seen wars, human rights abuses and environmental destruction just to control the source of this fuel. Vegetable oils are known to be a renewable source of energy though its energy balance is still disputable (Zhou *et al.,* 2008).

Historically, it is believed that Rudolf Diesel himself started research with respect to the use of vegetable oils as fuel for diesel engines (Lang *et al.,* 2001). In the following decades, the studies became more systematic and, nowadays, much is known about its use as fuel. Despite being energetically favourable, the direct use of vegetable oils in fuel engines is problematic. Due to their high viscosity (about 11 to 17 times higher than diesel fuel) and low volatility, they do not burn completely and form deposits in the fuel injector of diesel engines. In Rudolph Diesel’s 1893 paper “The Theory and Construction of a Rational Heat Engine” the German inventor described a revolutionary engine in which air would be compressed by a piston to a very high pressure thereby causing a sufficiently high temperature to ignite non volatile oils. His first working engine could run on various vegetable oils, leading him to envision in 1911 that “the diesel engine can be fed with vegetable oils and will help considerably in the development of the agriculture of the countries which use it” (Balat and Balat, 2008). Sincenearly all research has focused on how to improve the performance of the engine when using biologically based diesel fuel.

The term biofuel includes liquid or gaseous fuels for the transport sector that are predominantly produced from biomass. A variety of fuels can be produced from biomass resources including liquid fuels, such as ethanol, methanol, biodiesel, gaseous fuels, such as hydrogen and methane. Liquid bio fuels are primarily used to fuel vehicles, but can also fuel engines or fuel cells for electricity generation. World production of bio fuels rose by some 20 percent to an estimated 54 billion litres in 2007 and these gains meant bio fuels accounted for 1.5 percent of the global supply of liquid fuels, up by just 0.25 percent from the previous year (Worldwatch Institute, 2011; Monfort, 2008). The justification for biodiesel as an alternative fuel is that it is remarkably the only alternative fuel currently available that has an overall positive life cycle energy balance. It yields as much as 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle compared to only 0.83 units for petroleum diesel (Sheehan *et al.,* 2005). However, it is widely accepted that bio fuels are neither a panacea, nor without their disadvantages and risks. Major drawback is that converting edible vegetable oils like sunflower, soybean and canola to fuel will almost certainly compromise food security (especially within the global market context).

The vegetable-oil derivative ‘biodiesel’ offers several advantages as an alternative fuel for diesel engines. These include improved fuel performance and lubricity, a higher cetane rating than petro-diesel, a higher flashpoint that makes it safe to handle, lower toxicity to plants and animals, reduced exhaust emissions, and the fact that it is simple to phase in and out of use (Ma and Hanna, 1999; Zhang *et al.,* 2003; Encinar *et al.,* 2002; Sivaprakasam and Saravanan 2007). It is a local renewable source of energy and highly biodegradable (Meng *et al.,* 2008; Ahn *et al.,* 1995).

Economically it reduces imports and affords improved security of energy supply. It also improves the quality of the environment with less and far less pernicious soot generated from the exhaust of vehicles. Biodiesel can be blended at any level with petroleum diesel to create a biodiesel blend that can be used in compressionignition (diesel) engines with little or no modification as the superior lubricating properties of biodiesel increases functional engine efficiency. Biodiesel not only has low viscosity, lower carbon monoxide emissions (Ryan *et al.,* 1984) but also is simple to use, non toxic, essentially free of sulphur aromatics (Srivastava and Prasad, 2000). Its higher flash point makes it safer to store and the presence of a higher amount of oxygen (up to 10%) ensures more complete combustion of hydrocarbons.

Historically, energy continues to be the pivot of the economic and social development of all countries around the world and Africa is endowed with significant quantities of both fossil and renewable energy (RE) resources. According to Davidson *et al.,* (2007), although energy has brought great economic prosperity, the way it is produced and used is inefficient and has adversely affected local, regional and global environments, hence the ongoing debate about making the energy systems more environmentally friendly. Strategies to develop energy resources must be extremely mindful of both the environmental pollution problems (through carbon monoxide, ozone forming hydrocarbons, hazardous particulates, acid rain-causing sulphur dioxide etc.) and the threat of ‘‘climatic change’’ associated with the use of fossil fuels, the latter as a result of the accumulation of certain greenhouse gases (GHGs) in the atmosphere (mainly carbon dioxide, methane and nitrous oxide that trap heat in the lower atmosphere and leads to global warming).

As adopted by the third conference of parties (COP3) in Kyoto, Japan in 1997, attempts have been made to agree to legally binding obligations on most developed countries to reduce their GHG emissions by an average of 5.2% below 1990 levels by 2012 (Amigun, *et al.,* 2008a). In South Africa, the transport sector contributes some 16% of its greenhouse gas emissions, the greatest in Africa (Nolte, 2007). Of this, diesel fuel contributes about 17 % or 11,705,000 tonnes of CO2 equivalent. An additional 1,622,000 tonnesis released from diesel fuel used for electricity generation (Wedel, 1999). Therefore South Africa has chosen to set a limit on its green house emissions and increase its use of renewable energy sources. Reports indicate that greenhouse gas emissions are predicted to quadruple unless the government alters course (Schalkwyk, 2008).

In December 2006, the draft bio fuels strategy was approved by the South African cabinet to be implemented in consultation with industries. The draft strategy proposes a 4.5 % bio fuels industry development in South Africa and will achieve 75 % of the country’s renewable energy target of over a billion litres of bio fuels by 2013. It has however not made good progress in developing its bio fuels policy, hampering the potential growth of the sector in Africa’s biggest economy. Recent progress in the Brazilian and other developed countries bio fuels programme has highlighted the enormous opportunities that are open to African countries to reduce their dependency on imported oil and make meaningful contributions towards minimizing GHG emissions (Al Zuhair, 2007).

The Stern Review on the economics of climate change has also publicized the economic necessity to limit global warming (Stern, 2006). An accelerated release of fossil entombed CO_2 due to human activity is now generally accepted as a major factor contributing to the green house effect (Houghton *et al.,* 2001). The poor distribution of fossil fuel resources makes over 70 % of countries on the African continent dependent on imported energy resources, which again supports the development of abundant renewable energy resources. Animal fats are attractive feedstock for biodiesel because their cost is substantially lower than the cost of vegetable oil.

This is partly because the market for animal fat is much more limited than the market for vegetable oil. Also, much of the animal fat produced is not considered edible by humans. In addition, the price of virgin vegetable oil is about two times more than that of animal fat, although the 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 and catalyst. Thus, the price of feedstock can be reduced about 50% with using low grade animal fat. Methanol, ethanol, propanol or butanol are examples of alcohols which can be used for transesterification and the monoesters are named methyl esters, ethyl esters, propyl esters or butyl esters, respectively.

Statement of the Problem

Petro-diesel contributes significantly to global warming and increased green-house gas emissions. Biodiesel derived from non-edible feed stocks such as castor and neem oil serve as a renewable means to reduce the increased demand for petro-diesel, thus reducing strain on fossil fuel reserves. 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 arebecause they always have minimal pour point, elevated viscosity, short flash point and minimal cetane number giving poor combustion. 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.

Aim and Objectives of the Study

The aim of this research work is to determine the effect of temperature on the production of biodiesel using cow fats. The objectives of this research work include:

i. To investigate the physicochemical properties of the cow fats.
ii. To determine quality of biodiesel produced from cow fats.

MATERIALS AND METHODS

Biodiesel production from cow fat were treated in one stage process if the FFA value is less than or equal to 3%

Materials

Methanol, sulphuric acid, potassium hydroxide, cow fats, sodium sulphate, transesterification reactor, water bath, beakers, separating funnel, evaporation apparatus, thermometer and conical flasks. The cow fat was farms in Mubi. It was taken to the Department of Pure and Applied Chemistry, Adamawa State University Mubi for dissolution in preparation for Gas Chromatography (GC), Mass Spectrophotometer (MS) and acid value analyses.

Materials and Methods

Methods Oil characterization

The oil was characterized for physical and chemical properties such as viscosity, FFA content, and density. Fatty acids content in oil was determined with GC-MS analysis.

Fatty acid methyl ester (FAME) analysis

The compositions of each methyl ester were determined in duplicate using a gas chromatographer equipped a flame ionisation detector and an auto injector.

Other analysis

The density, kinematic viscosity, and flash point of each methyl ester were determined in duplicate according to the procedure of SNI [2010].

Oil transesterification

The oil was transesterified in 500 mL three neck flask that is equipped with hotplate, thermometer, magnetic stirrer and reflux condenser. Biodiesel production was be made with reacting 100 gr liquid cow fat and methanol with ratio molar oil : methanol (1 : 6), ratio THF : methanol was varied (0,5 : 1, 1 : 1, 2 : 1, 2,5 : 1, 3 : 1 (v/v)) and amount of sodium hydroxide used (0,8 wt%) at various reaction time (10, 15, 20 minutes) and various reaction temperature (40^{o}C, 50^{o}C, 60^{o}C). Reactant was be stirred with magnetic stirrer at 350 rpm to keep the suspension and temperature uniform along the reaction.

One-Step Alkali-catalyzed Transesterification Reaction

The alkali-catalyzed transesterification was performed in a transesterification reactor in accordance with the conditions. After the transesterification reaction was completed, the crude biodiesel mixture was allowed to settle overnight and then separated into two layers. The bottom layer having a brownish red color crude glycerol which contained other impurities (excess catalyst, and excess methanol etc) was drained using a separating funnel. The methyl esters along with the remaining impurities such excess catalyst and excess methanol etc in the upper layer wastransferred into the evaporation unit for the removal of excess methanol. The resultant biodiesel was then washed severally with acidified warm water to remove the remaining catalyst and the dissolved glycerol in the biodiesel phase.

RESULTS AND DISCUSSION

Results

Results of the FTIR analysis of Animal fat (Cow) extract

From the FTIR analysis of animal fat oil extract, it showed that the functional group (-OH) was best depicted at the Characteristic absorptions of 3468.8 cm^{-1} and (C=H) was best at 1741.0 cm^{-1}.

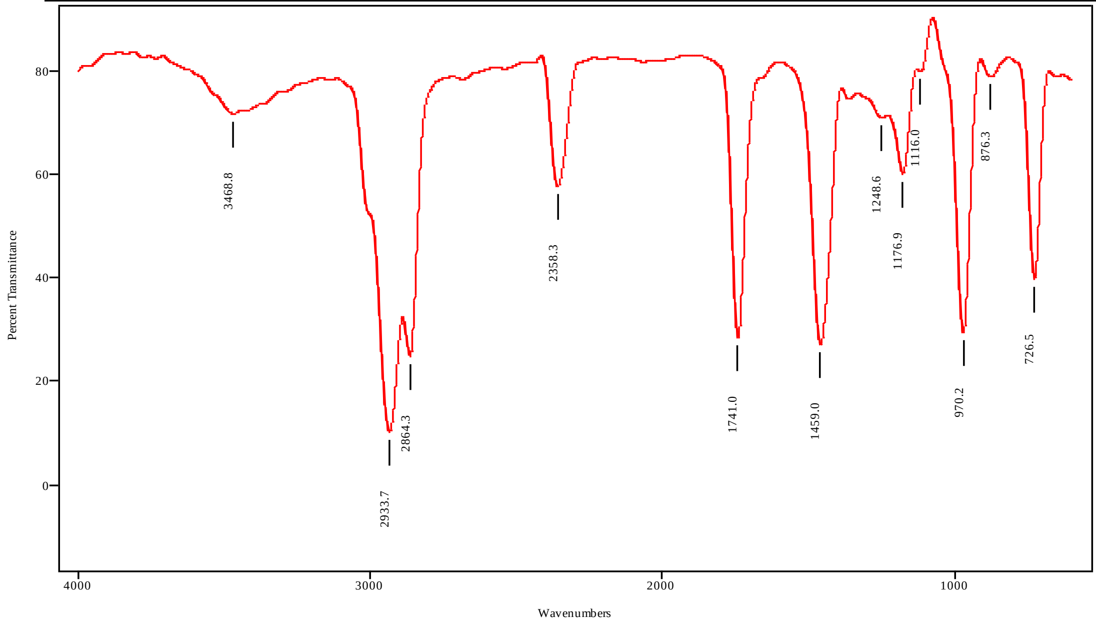
Table 1: Fourier Transform Infrared (FTIR) Spectral peak values and Functional groups for Animal fact oil Biodiesel extract

S/No	Characteristic absorptions cm^{-1}	Type of vibration	Functional group	Range
1	3468.8	Strong	-OH alcohol	3550 – 3200
2	2864.3	Medium	C-H alcohol	3000- 2840
3	1741.0	Strong	C=O acidhalide	1815 – 1785
4	1459.0	Strong	-OH alcohol	1550 – 1350

Fig. 4.1 FT-IR Spectra of animal fat oil.

Manual Peak Pick Results

Sample Filename	Animal Fat Biodiesel.spc
File Title	11/16/2021 01:48:55 title
Date	Nov 11 01:55:11 2074



Biodiesel production through transesterification

Through the transesterification of cow fat oil, biodiesel was created. It was reported that the transesterification of animal fat (cow) with 1% catalyst maintained 8.1 of the methanol to oil ratio at 2 hours of reaction time at 50°C temperature resulted in a production of 30.6% biodiesel.

It was discovered that while transesterification of animal fat (cow) using 1 weight percent of catalyst while maintaining 8.1 methanol to oil ratio for 2 hours reaction time at 55oC temperature resulted in a yield of 38.4% biodiesel, transesterification of animal fat (cow) using 1 weight percent while maintaining 8.1 methanol to oil ratio for 2 hours reaction time at 60oC temperature resulted in a yield of 62.1 biodiesel.

Also 81.3% biodiesel yield was obtained from transesterification of animal fat (cow) using 1wt% of catalyst 8.1 methanol ratio of oil at 2 hours time reaction at 65^{o}C temperature. The biodiesel 84.5% was obtained after running the sample for the fifth as shown in table 1.It was finally noted that 84.5 biodiesel yield was achieved from transesterification of animal fat (cow) using 1 w% of catalyst 8.1 methanol ratio of oil was maintained at 2 hour reaction time at 70^{o}C temperature. The biodiesel obtained from cow fat was calculated using the equation below.

Biodiesel yield (%) = weight of oil/weight of cow fat x 100.

Table 2: Biodiesel yield with Catalyst concentration, time and temperature Sulphuric acid is used for Esterification processCatalyst concentration: NaOH in 50ml of Methanol

Catalyst concentration (wt%)	Molar Ratio Methanol:Oil	Temperature(°C)	Time	Biodiesel yield (%)
1	8:1	50	2 Hour	30.6
1	8:1	55	2 Hour	38.4
1	8:1	60	2 Hour	62.1
1	8:1	65	2 Hour	81.3
1	8:1	70	2 Hour	84.5

Residual animal fat biodiesel properties

Pour point: Pour point is the temperature at which the amount of wax that comes out of solution issufficient to gel the fuel and prevent it from being poured hence not able to flow.The pour point from the cow fat biodiesel was 5.2°C

Flash point: Is a measure of flammability of fuels and thus an important fuel safety criterion. The biodiesel oil had a flash point of 133.20℃ and this satisfies the standard.

Kinematic viscosity: Viscosity is an important property of biodiesel since it affects the operation of fuel injection equipment, particularly at low temperatures when the increase in viscosity affects the fluidity of the fuel or leakage at high temperature when too thin. The kinematic viscosity of biodiesel produced was 5.528mm^2s^{-1}.

Table 3: Animal Fat Biodiesel parameters

Parameter	Biodiesel
Viscosity at 40 °C, mm^2 /s	5.528
Flash point (°C)	133.2
Cloud point (°C)	9.2
Pour Point (°C)	5.6

Table 4: Results of the GC-MS analysis of cow fat

Retention time	**Area (%)**	**Molecular weight**	**Compound name**	**Molecular Formula**
12.929	0.45	268.4	7-Hexadecanoic acid methyl ester9, heptadecenoic acid, methyl ester 2.	$C_{17}H_{32}O_2$
13.100	5.71	270.4507	Hexadecenoic acid, methyl ester.	$C_{17}H_{34}O$
14.371	0.16		n-hexadecenoic acid, methyl esters of hexadecenoic acid methyl ester.	$C_{17}H_{34}O$
15.109	3.26	270.4507	n-hexadecenoic acid, methyl esters, ascorbic acid 2,6-dihedeconaote	$C_{17}H_{34}O_2$

Conclusion

Animal fats, which are typically found as waste from butcher shops, meat packing plants, and kitchens, can be used as a feedstock for making biodiesel. The generation of biodiesel from animal fats can be done in a variety of ways, depending on the operating circumstances during transesterification. Alternative pretreatment methods exist as well, and they largely depend on the moisture and FFA content of such residues. Because it is quicker than acid catalysis and less expensive than the majority of other catalysts, including acid catalysts and lipases, alkaline catalysis is still preferred at industrial facilities that produce biodiesel. Although much researches have been published on heterogeneous acid and enzyme catalysts which avoid the challenges of water and FFA in animal fats, biodiesel producers have not yet adopted these technologies. The following conclusions were drawn from this work:

i. Yield of biodiesel increase with reaction temperature increase.

ii. The properties values are within biodiesel.

iii. Cow fat is very suitable as low-cost feedstock for biodiesel production.

The price of the raw materials required to make biodiesel is a crucial factor in determining the cost of the fuel, with waste animal fat being less expensive than waste vegetable oil. Chicken fat can be used as a suitable stock material for the synthesis of biodiesel, paying attention to the results that were obtained.

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