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Optimization of Biodiesel Production from Pig Lard using Sodium Hydroxide as Catalyst

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ABSTRACT

The need for alternative sources of fuels has led to search on a new perspective which utilizes vegetable oils and animal fats to produce biodiesel fuels as substitute to the current petroleum-based fuel. This work was aimed at studying the process parameters of biodiesel production from pig lard using sodium hydroxide (NaOH) as homogeneous catalyst for the transesterification of triglycerides with methanol. The objective was to study the effect of catalyst dosage, methanol to oil ratio, reaction time and reaction temperature on lard methyl ester (LME) yield. The optimum value of LME yield of 92.2% was obtained at a methanol to oil ratio of 12:1, catalyst dosage 1 g, reaction time 30 mins and reaction temperature 75 ^{o}C. The LME was characterized for physicochemical properties and its results were compared to ASTM D6751 standard. The results showed that density, (0.8714 g/cm^3), specific gravity (0.8166), kinematic viscosity (4.56 mm^2/s), acid number (0.3 mgKOH/g) and flash point (148 ^{o}C), of the biodiesel produced were within the range of the standard. Thus, biodiesel produced from lard oil, methanol and sodium hydroxide could be used as renewable alternative to petroleum diesel.

1. INTRODUCTION

Biodiesel is a renewable energy composed of long-chain fatty acids that are reacted with an alcohol to produce a long chain alkyl ester. It is produced from virgin oils, waste vegetable oils, algae, oil from halophytes and animal fats (Ibifubara et. al., 2015). Biodiesel is commonly produced via a chemical process known as transesterification. The benefits of biodiesel over fossil diesel include its portability, readily availability, renewability, higher combustion efficiency, no sulphur, lower aromatic content, higher cetane number, higher biodegradability, better emission profile, safer handling, non-toxicity, similarities in physicochemical properties to diesel, making it an excellent fuel for compression ignition engines (Al Zuhair, 2007; Demirbas, 2009, Balat and Balat, 2010; Atadashi et al., 2010; Prabu and Anand, 2012; Ngoya et al., 2017).

The major constraint in wide spread use of biodiesel fuel is the production cost that includes the cost of raw materials and the process operation but in recent years, animal fats such as lard and tallow have been consistently used as a biodiesel feedstock in other to combat the high cost of production (Bello and Makanju, 2011; Kumar and Kant, 2013; Venkateswara and Rao, 2015; Narwal et al., 2015; Soliman *et al.,* 2014; Chinyere et al., 2017). Lard is a by-product obtained from pig that is most time considered as waste, but have high organic content which makes it suitable as a feedstock for biodiesel production. Several research studies have been carried out on the biodiesel production from lard and results reported have shown that it is viable for produce biodiesel yield above 90% (Mata et al., 2010; Azjargal, 2012; Mata et al., 2014; Marin et al., 2015; Chinyere et al., 2017).

The aim of this study is to achieve an optimum yield of biodiesel produced from lard by optimizing the process variables such as methanol to oil ratio, temperature and catalyst dosage

2. MATERIALS AND METHODS

2.1. Materials and Equipment

The major raw material used in this study was lard collected from a slaughterhouse in Benin City, Edo State. All reagents used were of analytical grade which include, sodium hydroxide, phenolphthalein, methanol, potassium hydroxide and benzene were purchased from Luco Consult Limited, in Benin City, Edo State. The following equipment were used during the experiment: calorimeter, viscometer, magnetic stirrer with hotplate, conical flasks, round bottom flask, measuring cylinder, beaker, separating funnel, burette, density bottle, pipette and thermometer.

2.2. Biodiesel Production

The size of the thick slab of lard obtained was reduced into small bits and heated to 55 °C slowly until it melted. The melted lard oil was clarified by removing impurities such as waxy materials, sediments and other residues. Clarified lard oil (100 g) was esterified using benzene as the solvent which was put into a 1000 ml flat-bottom flask on a magnetic stirrer at constant temperature of 65 ºC. For transesterification process in a closed system, 1 g of sodium hydroxide dissolved in excess methanol was heated and agitated to form a mixture of methoxide solution which was added to a constant mass of 100 g esterified lard oil at constant time of 30 mins for reaction to take place. After transesterification process, the mixture was allowed to settle under gravity for 24 hours in a separating funnel for products separation. The products formed are biodiesel i.e. lard methyl ester (LME) and glycerol. The bottom layer consisted of Glycerol, excess alcohol, catalyst, impurities and traces of unreacted fat which was drained off through the separator funnel. The upper layer consisted of biodiesel, methanol and some soap. LME (biodiesel) was washed with hot distilled water to remove the unreacted methanol, oil and catalyst present in the product while the washed biodiesel was further treated by drying on the hot plate to remove any trace of water. This process was repeated at varying temperatures, methanol to oil ratio and catalyst dosage of 45 ºC, 55 ºC, 65 ºC, 75 ºC, 85 ºC, 6:1, 8:1, 10:1, 12:1, 14:1 and 0.2 g, 0.4 g, 0.6 g, 0.8 g, 1.2 g, 1.4 g and 1.6 g respectively. The percentage yield of lard methyl ester was calculated by using Equation 1.

$$\%\ \text{Yield} = \frac{\text{Weight of lard methyl ester}}{\text{Weight of lard oil}} \times 100\% \quad (1)$$

2.3. Characterization of Lard Methyl Ester

The properties of LME such as density, acid value, specific gravity, flash point and kinematic viscosity were characterized using standard procedures of American Society for Testing and Materials (ASTM) methods of analysis D6751 (ASTM, 2008). The ASTM standard was compared with that of the lard methyl ester. These selected properties contribute to the performance of lard methyl ester (biodiesel) fuel for diesel engine.

3. RESULTS AND DISCUSSION

3.1. Characterisation of LME

The physical and chemical properties of biodiesel from lard methyl ester were characterized. American Society for Testing and Materials (ASTM D 6751) for biodiesel was used as the standard to verify if the LME met the specifications for the consumers. Table 1 shows the properties of LME and its comparison with ASTM D6751. It was observed that all the properties were within the range of American Society of Testing and Materials values. This implies that the biodiesel produced could perform well when used in a diesel engine. The acid number reported in literature varies from 0.22 to 0.4, Kinematic viscosity varies from 4.5-5.08, density varies from 0.870 - 0.875 and flash point varies from 140-150 (Mata et al., 2010,) for lard methyl ester which did not deviate from the obtained result in the research.

Table 1: Physicochemical properties of lard methyl ester compared with ASTM D6751

Properties	Lard methyl ester	ASTM D6751
Acid number (mgKOH/g)	0.30	< 0.5
Density (g/cm^3)	0.8714	0.8746
Kinematic viscosity at 40^{o}C	4.56	1.9-6.0
Flash point (^{o}C)	148	>130
Specific gravity @15/15^{o}C	0.8166	0.8344

3.2. Effect of Methanol to Oil Ratio on Biodiesel Production

In this study, varying methanol to oil molar ratio of 6:1, 8:1, 10:1, 12:1 and 14:1 during 30 min reaction time at constant temperature 65 °C and catalyst concentration of 1 g was studied using 100 g of lard oil. Figure 1 shows the plot of experimental results obtained in the transesterification reactions in which a gradual increase of biodiesel yield was observed at the initial period of the experiment.

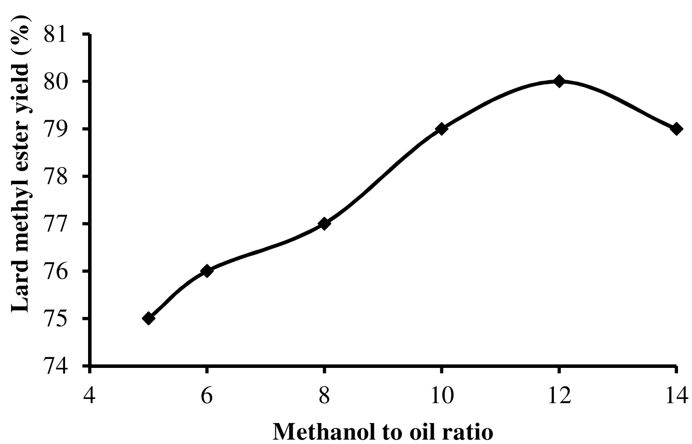

Figure 1: Effect of methanol to oil ratio on lard methyl ester yield

Increase in alcohol to oil ratio resulted in driving the reaction towards total completion by producing more LME as a desirable product. The optimum yield of 80.0% of biodiesel was achieved at 12:1 molar ratio of methanol to oil molar ratio. The optimum methanol to oil ratio reported in previous literature widely varies from 6 to 12 depending on the feed stock, catalyst, molecular weight of alcohol (Mata et al., 2010; Arumugam and Ponnusami 2017) This is due to the presence of sufficient methanol that was able to disperse the oil and catalyst phases which enabled the mixture become more miscible for the reaction to proceed to completion (Sarantopoulos et al., 2014). Any attempt to increase the methanol to oil ratio above 12:1 resulted in decrease in the biodiesel yield owning to saturation of the oil phase in the alcohol phase.

3.3. Effect of Catalyst Dosage on Biodiesel Production

The transesterification of lard oil was carried out with different dosage of homogeneous sodium hydroxide catalyst ranging from 0.2 g –1.6 g at constant temperature of 65 °C, reaction time of 30 min and lard methyl ratio of 12:1. It is evident from Figure 2 that at catalyst dosage of 0.6 g, the lard methyl ester yield rose to 88%, increased to 88.2% at a catalyst dosage of 1 g then dropped to 88% again at a catalyst dosage of 1.2 g. The addition of more catalyst did not give significant improvement in the percentage yield of lard methyl ester produced. It is worthy to note that the yield of biodiesel increased as the catalyst dosage increased. More catalyst load signifies more active ions of the sodium hydroxide catalyst available to speed up the formation of the LME with the excess methanol and limiting lard making the reaction to take place to a certain or reasonable extent (Jon 2019). It is also observed form Figure 2 that the rate of LME yield however reduced with increased catalyst dosage beyond 1.2 g. This may be because the catalyst had become excess and disturbed the interaction between the methanol and lard which caused difficulty in the further increase in the yield. It also could be that the lard which is the limiting reactant had been exhausted or used up. The optimum yield of LME (biodiesel) and amount of catalyst for the transesterification reaction using lard oil and methanol is 88.2% and 1 g respectively Figure 2.

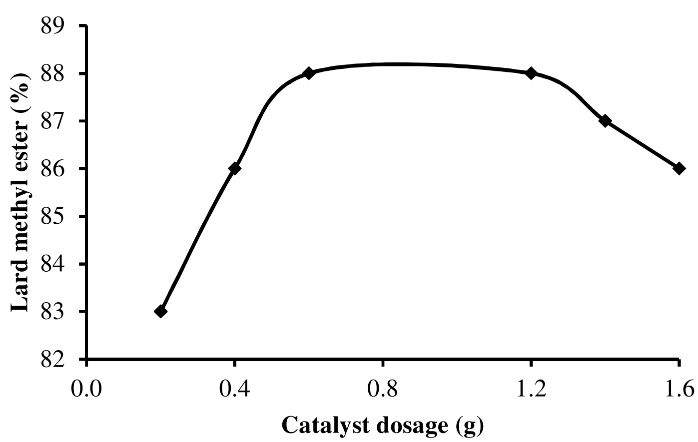

Figure 2: Effect of catalyst dosage on lard methyl ester yield

3.4. Effects of Temperature on Biodiesel Production

Temperature is one of the factors that affect the performance of the biodiesel production process. Figure 3 depicts the effect of temperature on the yield of lard methyl ester (biodiesel) with temperatures varied from 45 °C to 85 °C at constant alcohol to oil ratio of 12:1, catalyst dosage of 1 g and reaction time of 30 minutes. It is worthy to note that biodiesel yield increased from 70% to an optimum yield of 92.2% at a temperature of 75 °C. It is evident that increase in reaction temperature increases reaction rate which enables the reaction to go to total completion due to the reduction in viscosity of oils (Hee-Yong et al., 2012). A decrease was observed in the yield as a result of further increase in the temperature, and this may be as a result of evaporation of the methanol at higher temperature because of its low boiling point at 68 °C. The high yield at 75 ^{o}C may be due to the esterified process using benzene before transesterification using methanol in a closed system. The longer the alkyl chain the higher the boiling point of the ester.

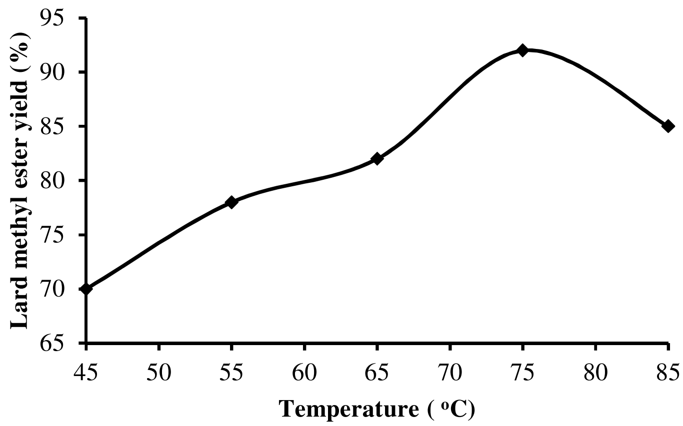

Figure 3: Effect of temperature on lard methyl ester yield

4. CONCLUSION

The effects of different operating parameters such as, catalyst dosage, reaction temperature and methanol to lard oil ratio on the yield of lard methyl ester were analyzed. The optimum condition of the parameters that yields 92.2% of lard methyl ester was attained at methanol to lard oil molar ratio 12: 1 with 1 g sodium hydroxide catalyst in 30 minutes at 75 °C. The result obtained from the characterization of biodiesel shows that the physicochemical properties of lard methyl ester such as density, viscosity, heating value, acid number and flash point value were found to be within the range of the ASTM D6751 standards. In conclusion, the use of sodium hydroxide as a catalyst in the transesterification process of lard oil with methanol was achievable at moderate processing varying parameters.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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