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Original Research Article

PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL: EFFECT OF POTASSIUM HYDROXIDE CONCENTRATION ON YIELD

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Abstract - The production of biodiesel from waste cooking oil (WCO) is one of the technological advances geared toward the promotion of clean energy sources. This conversion process deriving value from waste material also addresses the ecological and environmental concerns of waste management. Transesterification of waste cooking oil in the presence of Potassium Hydroxide accomplishes the conversion of WCO to biodiesel. Sensitivity analysis on biodiesel yield was performed at various catalyst concentrations of 0.75%, 1.00%, 1.25% and 1.50% (by mass of WCO) under identical reaction conditions of 60^{O}C, reaction time of 60 minutes, 22g methanol and 100g of WCO. Catalyst concentration of 1.00% gave the maximum yield of 97.30%. Characterization of the biodiesel gave results which satisfied the American Society of Testing and Materials (ASTM) specification; density of 878kg/m^3 at 15^{O}C, kinematic viscosity of 4.70mm^2/s at 40^{O}C and flash point of 136^{O}C. Biodiesel is suitable for use in internal combustion engines as alternative fuel to petroleum based diesel.

Keywords: Waste Cooking Oil (WCO), Biodiesel, Triglycerides, Transesterification.

Introduction: Environmental concerns such as global warming and greenhouse gases emission, depletion of fossil fuel reserves and increasing global demand for fuels has caused researchers to find alternative fuels. Vegetable oils and fats of plant and animal origin respectively serve as raw materials for biodiesel production. Sources of vegetable oils include palm fruit, soya bean, peanut, canola, corn etc. Biodiesel being used as substitute for petro-diesel in internal combustion engines is gaining wider relevance. Biodiesel is a clean-burning fuel derived from vegetable oils or animal fat and is an advantageous alternative to fossil diesel fuel because of its biodegradability, bio-renewable nature, very low sulfur content and toxicity, low volatility or flammability, good transport and storage properties, higher cetane number, and its salutary atmospheric carbon dioxide balance

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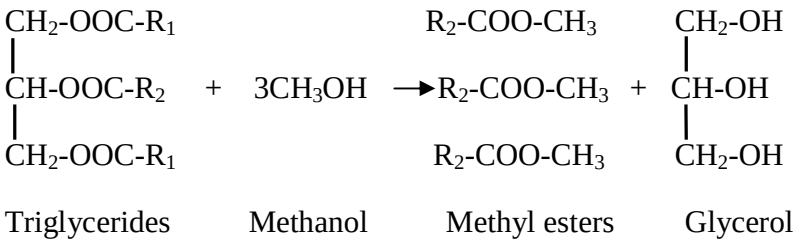
for production [1]. Oils and fats generally referred to as lipids are composed of triglycerides. Methods employed for biodiesel production from triglycerides include transesterification, blending, micro-emulsion and pyrolysis. A large number of scientists reported that transesterification reaction is the best method for biodiesel production [2]. This is because of the fact that this method is relatively easy, carried out at normal conditions, and gives the best conversion efficiency and quality of the converted fuel [3]. Under normal conditions, this reaction will proceed either exceedingly slowly or not at all, so heat as well as catalyst (acid, base or enzyme) are used to speed the reaction. Alkali and acid transesterification processes require less reaction time with reduced processing costs as compared to the enzyme catalyst process[4,5]. In base-catalyzed transesterification, lipids react with alcohol (typically methanol or ethanol) to produce biodiesel and glycerol as by-product. An alternative, catalyst-free method for transesterification uses supercritical methanol at high temperatures and pressures in a continuous process. In the supercritical state, the oil and methanol are in a single phase, and reaction occurs spontaneously and rapidly[6]. For the base-catalyzed esterification, methanol was chosen for the conversion process in the presence of potassium hydroxide catalyst in this study. The biodiesel in this process is methyl ester of fatty acids.



The utilization of edible oils has given rise to certain concerns as some of them are important food materials. In other words, the production of bio-fuels from human nutrition sources can cause a food crisis [7,8]. The main economic concern of biodiesel production is the high cost of oil but this problem can be solved with the utilization of waste cooking oil (WCO) as feedstock. Thus majority of researchers have used waste cooking oil and non-edible oils as feedstock. So that, the use of waste cooking oils is an effective way to reduce the cost of biodiesel production [9]. In addition, more than 80% of WCO is produced in households and controlling this disposal behavior can solve huge problems such as waste oil disposal and waste management [10, 11]. The effect of potassium hydroxide concentration on biodiesel yield was investigated with a view to determining the catalyst concentration corresponding to optimal yield. Characterization of biodiesel for basic fuel properties is based on American Society of Testing and Materials standard.

2. Materials and Methods

2.1 Raw Materials and Chemical Reaction:

The materials required for the methanolysis experiment are waste vegetable oil, methanol, potassium hydroxide and distilled water. The waste palm oil used for the experiment was obtained from Sammies eatery- located at Choba in Port Harcourt, Nigeria. Pre-treatment of the waste cooking oil was carried out to remove dirt, charred food and water in the feed stock. For the methanolysis of WCO using potassium hydroxide, biodiesel and glycerol were produced. The reaction mechanism for alkali-catalyzed transesterification was

formulated in three steps [12]. In the first step, diglyceride is obtained from triglyceride. From diglyceride, monoglyceride is produced and in the last step, glycerol is formed from monoglyceride. In all these reactions, fatty acid methyl ester (biodiesel) is produced. The glycerol phase is much denser than biodiesel phase. The two products were separated by gravity settling using separating funnel. The glycerol is drawn off at the bottom of the settling vessel leaving the biodiesel in the vessel. In some cases, a centrifuge is used to separate the two materials faster by screening both phases [13].

$$\text{Triglyceride} + CH_3OH \longleftrightarrow \text{Diglyceride} + RCOOCH_3$$

$$\text{Diglyceride} + CH_3OH \longleftrightarrow \text{Monoglyceride} + RCOOCH_3$$

$$\text{Monoglyceride} + CH_3OH \longleftrightarrow \text{Glycerol} + RCOOCH_3$$

A fixed quantity of feedstock and methanol were used at specified operating temperature, pressure and reaction time, maintained throughout the experiment for all batches. Due to economic consideration, larger amount of catalyst may not be profitable due to cost of the catalyst itself. Therefore, an optimization process is necessary to determine the optimum amount of catalyst required in the transesterification process [14,15]. Only the KOH catalyst ratio was varied for different batches to establish the quantity of catalyst (weight percent) corresponding to optimal yield. Three runs were performed for each catalyst concentration and the average yield for the given catalyst concentration was obtained.

2.2 Experimental Procedure and Analytical Method:

- In the first batch, 100g of WCO was heated at 120^{O}C for 5 minutes to remove moisture.
- 0.75g/100g WCO (0.75g of KOH) was weighed and dissolved completely in 22.0g of methanol, using the hot plate and magnetic stirrer to form potassium methoxide solution.
- The potassium methoxide solution formed was added into warm oil at 60^{O}C and then mixed vigorously using the magnetic stirrer. The 60^{O}C reaction temperature was maintained for 60 minutes.
- The reaction mixture was poured into separating funnel.
- The mixture was left for 24hours to allow separation by gravitational settling into clear liquid biodiesel on top and light brown glycerol at the bottom.
- Glycerol layer was drained off from the separating funnel leaving only biodiesel.
- The crude biodiesel was then purified by washing with warm distilled water to remove residual catalyst and methanol.
- The experiment was repeated twice (three runs for each catalyst concentration).
- The same procedure was repeated with KOH concentration of 1.00%, 1.25% and 1.50% (% weight of WCO).
- The mass and yield of biodiesel obtained were determined as stated below.

Average biodiesel obtained,

$$m\,(g) = \frac{m1+m2+m3}{n}$$

Where, m_1 = mass of biodiesel obtained in run 1, g

m_2 = mass of biodiesel obtained in run 2, g

m_3 = mass of biodiesel obtained in run 3, g

n = number of runs = 3

$$\%\ \text{w/w biodiesel yield} = \frac{(m\,x\,100)}{mo}$$

Where, m_O = mass of WCO

3. Table of Experimental Data and Figure

The materials and results of the experiment are given in the following tables and figure.

Table .1: Transesterification Process Parameters

Experimental Conditions	**Values for all Runs**
WCO quantity (g)	100
Methanol quantity (g)	22
Reaction temperature (^{O}C)	60
Reaction time (minute)	60
KOH Concentration (%w/w)	0.75 – 1.50%wt. of WCO at 0.25% step

Table .2: Results of Mass of Biodiesel obtained for Three Runs of each Batch

Biodiesel Mass Obtained from Transesterification of WCO				
Batch	**Run 1, m_1 (g)**	**Run 2, m_2 (g)**	**Run 3, m_3 (g)**	**Average, m (g)**
1	95.10	95.80	96.20	95.70
2	97.20	97.70	97.00	97.30
3	87.30	86.70	87.00	87.00
4	75.10	75.60	75.80	75.50

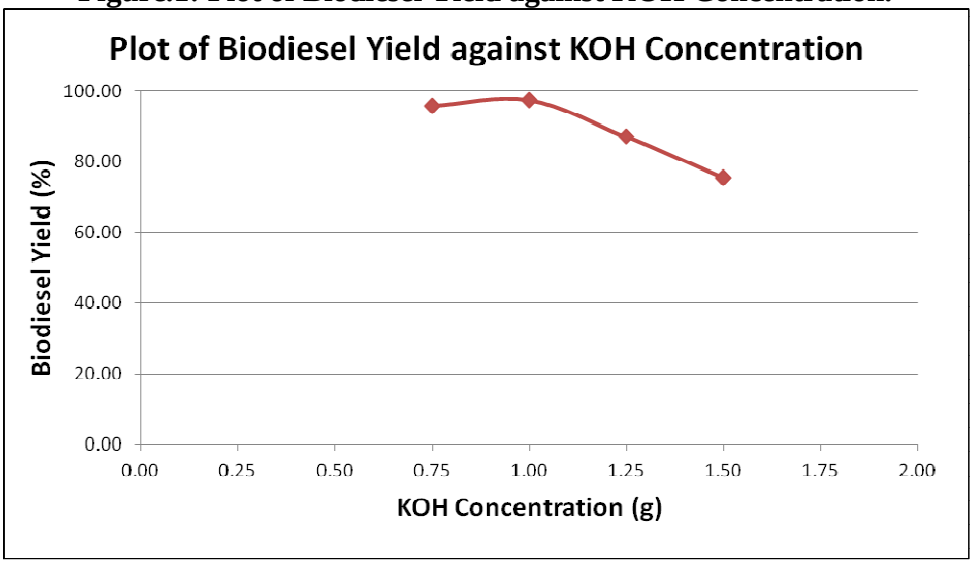
Table .3: Results for the four Batches of Transesterification of WCO with Varying KOH Concentrations.

Three-run Average Data for the four Batches of the Transesterification Experiments				
Experimental Condition & Parameters	Values of Experimental Data & Results			
	Batch 1	Batch 2	Batch 3	Batch 4
KOH Concentration (g)	0.75	1.00	1.25	1.50
Reaction temperature (^{O}C)	60	60	60	60
Reaction time (minute)	60	60	60	60
WCO quantity (g)	100.00	100.00	100.00	100.00
Methanol quantity (g)	22.00	22.00	22.00	22.00
Biodiesel obtained (g)	95.70	97.30	87.00	75.50
Glycerol obtained (g)	21.25	22.00	32.40	46.10
Losses (g)	5.50	2.70	2.60	0.40
Biodiesel from WCO Yield (%)	97.50	97.30	87.00	75.50

Table.4: Characterization of Biodiesel from WCO

Sample Batch	Properties		
	Density (kg/m^3)	Flash Point (^{O}C)	Kinematic Viscosity (mm^2/s)
Batch 1	880	139	4.64
Batch 2	878	137	4.70
Batch 3	876	134	4.74
Batch 4	877	132	4.71

Figure.1: Plot of Biodiesel Yield against KOH Concentration.



4. Results and Discussion

A base-catalyzed transesterification was carried out on waste cooking oil (WCO) in order to obtain biodiesel. Three replicates of each of the methanolysis experiment using different KOH concentrations, 0.75%, 1.00%, 1.25% and 1.50% (by mass of WCO), yielded average results for each batch of three-runs presented in Table 2. It was observed that for KOH concentration of 0.75%, 1.00%, 1.25% and 1.50% in relation to mass of WCO, under identical reaction temperature of 60^{O}C, 60 minutes reaction time and 22.0% of methanol (in relation to mass of WCO), biodiesel yield of 95.7%, 97.3%, 87.0%, and 75.5% were obtained. Also, 21.50g, 22.00g, 32.40g, and 46.10g of glycerol (by-product) were formed with the respective yields of biodiesel. The losses in each run of the experiment are obviously some unreacted alcohol, residual catalyst, and emulsion removed during the washing stage of the production process[16]. Results in Table 3 showed that increase in the KOH concentration results in increase in WCO biodiesel yield, only up to a certain concentration of KOH. Beyond this point, no further increase in biodiesel yield is achieved; hence an optimum concentration of the catalyst (KOH) exists. A plot of WCO biodiesel against KOH concentration showed peak biodiesel yield at 97.3% with corresponding KOH concentration of 1.0% as evident in Figure 1. KOH concentration of 1.0% (in relation to mass of WCO) can therefore be taken as optimum for KOH catalyzed transesterification with methanol under the stated reaction conditions. Characterizationof the biodiesel obtained from WCO gave density of 878kg/m^3 at 15^{O}C, kinematic viscosity of 4.70mm^2/s at 40^{O}C, and flash point of 136^{O}C. This indicates that biodiesel is suitable for use in internal combustion engines as alternative fuel to petroleum based diesel. It is recommended to operate plants designed for conversion of WCO to biodiesel at optimum catalyst concentration in order to maximize the yield of biodiesel.

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References

1. Tanja C, Siegfried P, and Weidner E, Biodiesel-Transesterification of Biological Oils with Liquid Catalysts: Thermodynamic Properties of Oil-Methanol-Amine Mixtures, Industrial & Engineering Chemistry Research, 2005, 40, 9535-9541.
2. Meher LC, Sagar DV, and Naik SN, *Technical Aspects of Biodiesel Production by Transesterification – A Review*. Renew Sustain Energy Rev, 10, 2006, pp.248-268.
3. Shahid EM, Jamal Y, Shah AN, Rumzan N, and Munsha M, Effect of Used Cooking Oil Methyl Ester on Compression Ignition Engine. Journal of Quality and Technology Management, VIII (II), 2012, 91–104.
4. Muniyappa PR, Brammer SC, and Noureddini H, (1996) "Improved Conversion of Plant Oils and Animal Fats into Biodiesel and Co-Product," Bioresource Technology, Vol. 56, No. 1, (1996), pp. 19-24.
5. Dorado MP, Ballesteros E, Lopez FJ, and Mittel-bach M, "Optimization of Alkali-Catalyzed Transesterification of Brassica Carinate Oil for Biodiesel Production," Energy Fuels, Vol. 18, No.1, 2004, pp. 77-83.
6. Bunkyakiat K et al, "Continuous Production of Biodiesel via Transesterification from Vegetable Oils in Supercritical Methanol". Energy and Fuels (American Chemical Society), 2006, 20 (2): 812–817.
7. Pimentel D, Marklein A, Toth MA, Karpoff MN, Paul GS, McCormack R, Kyriazis J, and Krueger T, *Food Versus Biofuels Environmental and Economic Costs*. Hum Eco, 37(1), 2009, pp.1-12.
8. Srinivasan S, *The Food versus Fuel Debate a Nuanced View of Incentive Structures*. Renewable Energy, 34(4), 2009, pp.950-954.
9. Arifin SF, Production Of Biodiesel From Waste Cooking Oil And Palm Oil Using Batch Transesterification Process, Universiti Malaysia Pahang, Thesis, 2009.
10. Alcantara R, Amores J, Canoira L, Fidalgo E, Franco MJ, Navarro A, Catalytic Production of Biodiesel from Soya bean Oil. Used Frying Oil and Tallow. Biomass Bioenergy, 18, 2000, pp.515-527.
11. Chhetri AB, Watts KC, Islam MR, *Waste Cooking Oil as an Alternate Feedstock for Biodiesel Production*. Energies, 1, 2008, pp.3-18.
12. Ecky EW, *Esterification and Interesterification*. Journal of American Oil Chemists' Society, 33, 1956, pp.575-579.
13. Garlapati VK, Kant R, Kumari A, Mahapatra P, Das P, and Banerjee R, Lipase Mediated Transesterification of Simarouba Glauca Oil: a new feedstock for biodiesel production. Sustainable Chemical Processes, 2013, 1(11), 1- 6.
14. Kansedo JB, Synthesis of Biodiesel from Palm Oil and Sea Mango Oil Using Sulfated Zirconia Catalyst. Msc Thesis, Universiti Sains Malaysia, 2009.
15. Jagadale SS, and Jugulkar LM, Review of Various Reaction Parameters and Other Factors Affecting on Production of Chicken Fat Based Biodiesel, International Journal of Modern Engineering Research, 2(2), 2012, 407-411.
16. Enciner JM, Gonzalez JF, Rodriguez JJ, and Tajedor A, *Biodiesel Fuel from Vegetable Oils Transesterification of Cynara Cardunculus L. Oils with Ethanol*. Energy Fuels, 16, 2002, pp.443-450.