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Synthesis of Biodiesel from Nigerian Waste Restaurant Cooking Oil: Effect of KOH Concentration on Yield

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Abstract: - Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground carbon- based resources. This has necessitated the search for alternative fuel from renewable sources. Waste cooking oil (WCO) has been identified as a renewable resource from which biodiesel can be produced. Methanolysis of WCO to obtain WCO biodiesel was employed via potassium hydroxide (KOH) catalyst. ASTM and EU standard fuel test performed on the WCO biodiesel gave reasonable result as alternative biodiesel fuel. The effect of KOH concentration on WCO biodiesel is investigated, with a view to identifying the catalyst concentration corresponding to optimal yield. Three replicated methanolysis experimental runs were employed out for each of the KOH concentration 0.5%, 0.75%, 1.0%, 1.25%, 1.50%, 1.75%, 2.0 % and 2.5% (by mass of WCO) under identical typical methanolysis reaction condition of 60^{o}C temperature, 60 minutes and 22% methanol (by mass of WCO). Results obtained gave 91.1%, 95.9%, 97.1%, 86.7%, 75.20%, 73.3%, 72.1%, 72.4% average WCO biodiesel yield for the respective feedstock ratio. THE KOH concentration 1.0% resulting in maximum WCO biodiesel yield (97.1%) is therefore recommend as optimum, within the constraint of the typical methanolysis process employed. Few standard fuel test results of the WCO biodiesel are within biodiesel specification. This finding will go a long way in improving energy security in Nigeria and the world in general.

Key-Words: - Waste cooking oil, Fossil diesel fuel, Transesterification, Optimum catalyst,

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1 Introduction

Nigeria currently produces over 2 billion gallons of oil a day, valued at approximately $40 billion a year [1]. Nigeria is the world's eighth largest exporter of crude oil [2]. Petrodollars account for 83 per cent of federal government revenue and about 40 per cent of GDP [3]. Some 85 per cent of the oil monies are accrued by 1 per cent of the population, with 70 per cent of wealth held in private hands abroad [1], while 70 per cent of the people of the Niger Delta live below the poverty line and the majority of Nigeria's oil and gas is consumed in developed countries. However, In the Delta, various stages of oil exploration and extraction cause tremendous environmental and social damage. These include seismic surveys, drilling, road and pipeline construction, river dredging and gas flaring. Long-standing pollution also results from pipeline leaks and oil spills. This has generated militancy from the local people (Ijaw) making successful oil prospecting a nearly impossible task for the multinational companies in Nigeria. As a result, the cost of extracting the reserves will go on increasing in Nigeria. Thus there is an urgent need to find alternative renewable forms of energy before mineral oil supplies run dry. Hence, in the medium (2008-2015) and long term (2016-2025), Nigeria envisions an energy transition from crude oil to renewable energy [4]. In spite of advanced exploration technologies, exploration is a game of diminishing return as less and less of oil is being found [5, 6,7]. Hence, petroleum products are unavailable to most Nigerians and are quite costly. Nigeria can decrease its dependence on refined petroleum product imports by an aggressive use of domestic, renewable energy options. This will not only reduce reliance on single-commodity economy as well as abate importation of refined petroleum products in Nigeria, but it will also strengthen the nation's energy security.

It was further argued that KOH produces a better quality biodiesel. In addition, at the end of the reaction, the reaction mixture can be neutralized with phosphoric acid resulting in potassium phosphate, which can be used as fertilizer. This will improve the economic return on investment. The choice of WCO was informed by the fact that many millions of tons of waste cooking oil are used in a variety of ways throughout the world [8] and the effective management and utilization of waste vegetable from the nation's thriving fast food and restaurant business would ensure a cleaner environment, serves as a veritable source of alternative fuel, and also reduce the nation's over-dependence on fossil fuel [9].

In this work, potassium hydroxide is used to catalyse the transesterification reaction between waste cooking oil and methanol. Reports abound in the literature on the production of biodiesel through transesterification of vegetable oil with alcohol using a suitable catalyst. Researchers in [10] used response surface methodology to optimize waste cooking oil using heterogeneous catalyst. Ayodeji et al. [11] reported that maximum yield of WCO biodiesel of 82.3 % was realized as a result of optimum concentration of 0.4g NaOH. However, not much preparation of biodiesel through was found on optimization of WCO biodiesel from Nigerian restaurant using KOH as catalyst. The present study reports a laboratory potassium hydroxide (KOH) catalyst. It further reports some fuel characteristics of the WCO biodiesel obtained through ASTM standard tests. The effect of KOH concentration on biodiesel obtained through ASTM and EU standard tests. The effect of KOH concentration on biodiesel yield is investigated, using the OVAT approach, with a view to determining the optimal catalyst .

2 Material and Methods

2.1 Experimental

Transesterification process for PKO was carried out using the Central Biotechnology Laboratory equipment of the Federal University of Agriculture,

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Abeokuta, Nigeria. Values of process parameters selected (Table 4) are within ranges, which have produced successful results from earlier reports [12, 13]. Waste cooking oil (WCO) was donated by Mr. Biggs's (UAC Restaurants Limited), Sango, Ogun State, Nigeria. Methanol (99.8%) used is analytical grade product of Aldrich Chemicals, England and acetic acid were obtained from Uche Scientific Company Limited, Lagos. Other major materials used include thermometer, separating funnels, scales and magnetic stirrer.

Table 1 Transesterification Process parameters

Experimental Conditions	**Values for all experimental runs**
WCO quantity (g)	100
Methanol quantity (g)	22.0
Reaction temperature ^oC	60
Transesterification time (min)	60
KOH amount variation	Varies with experimental batches

2.2 Transesterification Protocol Varying KOH Concentration

In the first batch, 100g of WCO is heated at 120°C for 5 minutes to remove the moisture. Then, the free fatty acid (FFA) content of waste cooking oil was determined. 0.5 % KOH wt. of WCO was weighed and dissolved completely in 22.0g of methanol, using the hot plate and magnetic stirrer to form potassium methoxide solution. This was added into warm oil (at 60 °C) and then mixed vigorously using the magnetic stirrer. 60 °C of reaction temperature was maintained through 60 minute. Loss of reagents (especially methanol) to the atmosphere was prevented. The reacted mixture was poured into a separating funnel. The mixture was left for 24 hours to allow separation by gravitational settling into a clear golden liquid biodiesel on top and light brown glycerol at the bottom (Fig. 1). Glycerol layer was drained off from the separating funnel leaving only crude biodiesel. The crude biodiesel was then purified by washing with warm water to remove residual catalysts or soaps and to bring down the pH of the biodiesel to about 7. Excess methanol and residual catalyst were washed from the biodiesel using water as earlier detailed and reported (Usta, 2005). The procedure was replicated three times and average yield of the biodiesel and glycerol was evaluated. The same procedure was repeated with catalyst concentration at 1%, 1.5%, 2%, and 2.5% weight of waste cooking oil.

Fig. Transesterification process

2.3 Variation of KOH Amount and Fuel Characterization

Additional experiments were conducted to study the effects of varying KOH concentration on the WCO biodiesel yield using the same process parameters in Table 1, with KOH amount varied between 0.5-2.5 % wt. of WCO at 0.5% step. Some physical properties of the biodiesel fuel produced were tested together with commercial grade Philips diesel fuel purchased from a fuel station at Ifo, Nigeria. Specific gravity and viscosity measurements were made using the Thermal-Hydrometer apparatus and Viscometer respectively, following ASTM standards D1298

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and D445. Detailed procedures for apparatus following ASTM standards D25100-8 and D97 respectively. Detailed procedures for are available elsewhere [14].

3 Result and Discussion

3.1. Suitability of Nigerian Restaurant WCO biodiesel as fuel

In characterizing the PKO biodiesel as alternative diesel fuel, the PKO biodiesel produced using 100.0 g WCO, 22.0 g methanol, 60º C reaction temperature, 60 minutes reaction time and 1.0 % KOH concentration alongside the petroleum diesel, used as control, were analysed for fuel properties including specific gravity, viscosity, acid value and flash point. Results obtained are presented in Table 2.

3.2. Effect of KOH concentration on PKO biodiesel Yield

Three replicates of each of the laboratory transesterification experiments using different KOH concentrations, 0.5 %, 0.75 %, 1.0 %, 1.25 %, 1.5 %, 1.75 % , 2.0 %and 2.5 % (by mass of WCO), yielded average results presented in Table 3, representing three-run average results for experiment batches 1-8 (batch1- batch 8). From Table 3, different values of average WCO biodiesel yield, glycerol formed and losses recorded for the seven batches of the transesterification experiments are evident. From Table 3, it is observed that for KOH concentrations 0.5 %, 0.75 %, 1.0 %, 1.25 %, 1.5 %, 1.75 % and 2.0 % (in relation to mass of WCO) under identical typical transesterification reaction conditions of 60º C temperature, 60 minutes duration and 22.0 % methanol (by mass of WCO), WCO biodiesel yield of 91.1 %, 95.9 %, 97.1 %, 86.7 %, 75.2 %, 73.3 % ,72.10 and 72.4 % were obtained. Similarly, 25.40 g, 21.30 g, 22.20 g, 32.70 g, 46.40 g, 46.50 g, 47.40g and 45.20g glycerol were formed with the respective yields of the biodiesel. The losses recorded in each run of the experiment are obviously some unreacted alcohol, residual catalyst and emulsion removed during the washing stage of the production process. Similar observations have been made by [15].

Results in Table 3 also revealed 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 PKO biodiesel yield is achieved; hence an optimum concentration of the catalyst (KOH) exists.

A plot of WCO biodiesel yield against KOH concentration showed a peak PKO biodiesel yield at 97.1 % with a corresponding KOH concentration of 1.0 % as evident in Figure 1. KOH concentration 1.0 % (in relation to WCO mass) can therefore be taken as optimum for KOH catalyzed PKO transesterification with methanol under reaction conditions of 60^{o}C temperature, 60 minutes duration and 22.0 % methanol (by mass of WCO).

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Table 2: Fuel Properties of WCO methyl ester

Fuel Characteristics	Unit	Waste Cooking oil methyl ester	ASTM Standard D6751	EU Standard EN 14214
Specific gravity@ 15^{o}C	g/cm^3	0.879	0.880	0.86-0.90
Viscosity @ 40	^{o} c	4.72	1.9-6.0	3.5- 5.0
Flash point	^{o} c	139	>120	>120
Acid value	Mg KOH/g	0.459	<0.8	<0.50

Table 3. Results for the eight batches of experiment with varying KOH concentration

	Three-run average data for the eight batches of the transesterification experiments							
Experimental Conditions	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8
KOH quantity (g)	0.5	0.75	1.00	1.25	1.50	1.75	2.00	2.25
Reaction temperature (^{o} C)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Reaction time (min.)	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Waste cooking oil (WCO) quantity (g)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Methanol quantity (g)	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
WCO biodiesel	91.10	95.90	97.10	86.70	75.20	73.30	72.10	72.40

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obtained (g)								
Glycerol obtained (g)	25.40	21.30	22.20	32.70	46.40	46.50	47.40	45.20
Losses (g)	3.70	3.90	2.40	3.70	2.30	4.60	3.10	3.00
WCO biodiesel yield (%)	91.10	95.90	97.10	86.70	75.20	73.30	72.10	72.40

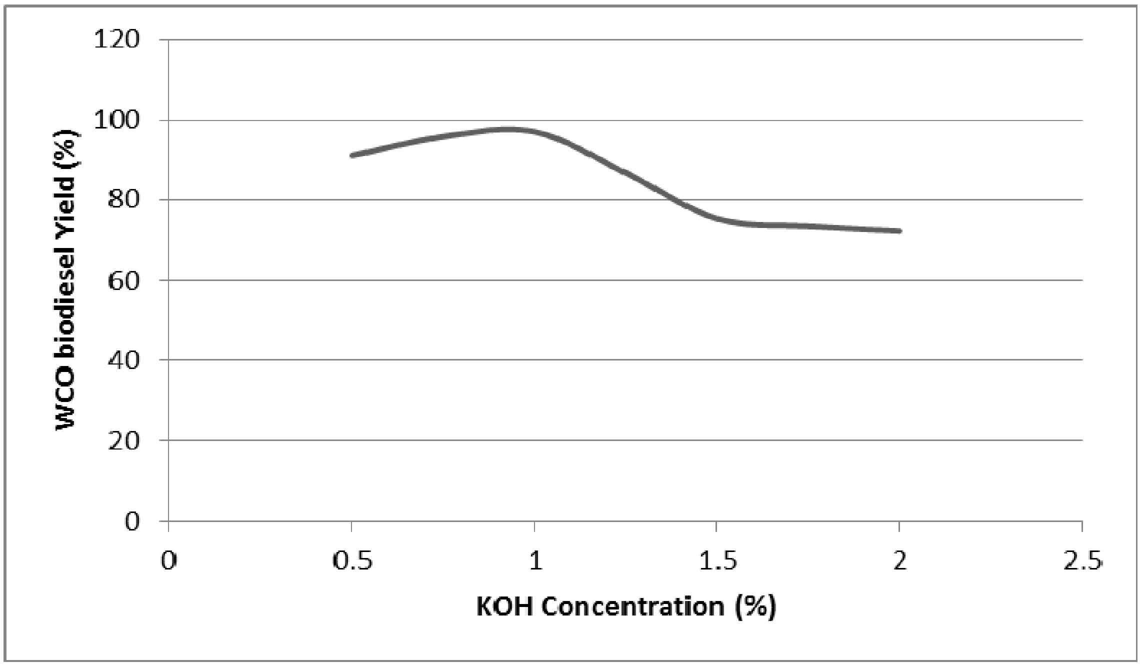

Figure 1. Variation of KOH concentration with % WCO biodiesel yield through

4 Conclusion

From the laboratory preparation and fuel tests of PKO biodiesel, as well as the effect of KOH concentration on biodiesel yield studied the following conclusions can be drawn:

- Laboratory-scale Nigerian WCO biodiesel gave promising results as alternative diesel fuel with fuel properties in good agreement with previous works and within limits set by international biodiesel standards.
- For KOH concentrations 0.5 %, 0.75 %, 1.0 %, 1.25 %, 1.5 %, 1.75 % , 2.0 % and 2.5 % (by mass of WCO) under identical typical

transesterification reaction conditions of 60º C temperature, 60 minutes duration and 22 % methanol (by mass of WCO), WCO biodiesel yields of 91.1 %, 95.9 %, 97.1 %, 86.7 %, 75.2 %, 73.3 % ,72.1%and 72.4 %. were obtained.

- ❖ A maximum PKO biodiesel yield of 97.1 % was obtained with KOH concentration of 1.0 % under typical transesterification reaction conditions of 60º C temperature, 60 minutes duration and 22.0 % methanol (by mass of WCO).

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