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Production of Biodiesel from Nigerian Restaurant Waste Cooking oil using Blender

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Abstract- Cost of biodiesel produced from virgin vegetable oil through transesterification is higher than that of diesel fuel and cost associated with conventional technique (batch reactor) is enormous. To minimize the cost, waste cooking oil and domestic blender, which was modified as reactor was explored as feedstock and reactor respectively. Laboratory scale quantities of methyl ester of WCO (MEWCO) were synthesized and characterized as diesel fuel. KOH was employed to catalyse the transesterification process of WCO with methanol using 100g WCO, 22.0g methanol, 1.0% KOH at 60^oC reaction temperature and 60 minutes reaction time. The process was replicated and average results evaluated. A moderately high yield (96.6 $\pm$ 0.45 wt. %) of WCOME was obtained under classic reaction condition. The fuel properties of WCOME measured were found to fulfil both ASTM D6751 and EN 14214 biodiesel standards. In addition, the fuel properties were analogous to other waste cooking oil methyl ester produced by other researchers using conventional techniques/ reactors. This confirms suitability of the blender modified as a reactor for domestic production of biodiesel from restaurant waste cooking oil.

Keywords- Transesterification, Waste cooking oil, Characterization, Flash point

1. Introduction

Energy is an essential driving factor to socioeconomic development in our present society. Its impact touches all aspect of human endeavours such as agriculture, health, education, transportation among others. Petroleum based fuels are the major fuel source used in transportation sector in most of the developing nations. Its combustion generates emissions which are nuisance to environment and adversely affect human health. It has been established that these emissions are carcinogenic [1]. However, climate change and increase in pump price has also redirected research interest to renewable energy resources. The renewed interest to the quest for greener fuels sources is a topical issues that gain wide societal and political interest especially for its reduced greenhouse emissions, biodegradability, sustainability as well its competitive nature to fossil fuels and food supply [2,3].

Biodiesel is derived from vegetable oil or fat via transesterification reaction. According to American Society for Testing and Material (ASTM), biodiesel is conceived to be mono alkyl ester of long chain fatty acids derived from a renewable lipid feedstock. Their main drawback is price, which is higher than oil-derived diesels. The high cost of vegetable oils, which could be up to 75% of the total manufacturing cost, has led to the production costs of biodiesel becoming approximately 1.5 times higher than that for diesel [4, 5]. Nevertheless, the price of waste cooking oils (WCO) is 2–3 times cheaper than virgin vegetable oils. Consequently, the total manufacturing cost of biodiesel can be significantly reduced [5]. In addition, it is on the record that every year: many millions of tons of waste cooking oil are collected and utilized in a variety of ways throughout the world [6]. This oil that nonetheless contains foreign material and heavy chemicals are often disposed in manners that contaminate our soil and water. Hence, the proper management and utilization of waste cooking oil from the nation's thriving fast food and restaurant businesses would pave way for a hygienic environment, serves as a veritable source of renewable energy and reduce the nation's over-dependence on fossil fuel. In addition, the utilization of waste frying oils diminishes the problems of contamination, because the reusing of these waste greases can reduce the burden of the government in disposing of the waste, maintaining public sewers, and treating the oil wastewater. The fact is, so far, that only a very small percentage of these oils has been collected and used for soap production.

Biodiesel has been produced using various reactors namely; batch/ continuous reactors, microwave irradiation, batch oscillatory, etc. Each of reactors has been associated with one problem or the other; while the details are elsewhere discussed in [7]. This has reduced domestic production of biodiesel. Limited studies were, however, found on blender reactor in transesterification of triglyceride in the literature. Alamu et al. [8] used blender, as reactor, in producing biodiesel from palm kernel oil. However, there is no work on production of biodiesel from restaurant waste cooking oil using blender. This work reports production of WCO biodiesel via transesterification of the waste cooking oil with methanol using alkali- catalyst, KOH, while the waste cooking biodiesel produced is characterized as alternative diesel fuel through ASTM standard tests for basic fuel properties.

2. Experimental

2.1. Material and Method

Waste cooking oil (WCO) was donated by Mr. Biggs's (UAC Restaurants Limited), Sango, Ogun State, Nigeria. Fatty acid composition of the oil was shown in Table 1. Methanol (99.8%) used is analytical grade product of Aldrich chemicals Germany; while the KOH used was also an 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 continuous blender reactor.

Table 1. Fatty Acid Composition

Component	Value
Lauric, $C_{12:0}$	3.0
Myristoleic, $C_{14:1}$	2.3
Stearic, $C_{12:0}$	1.9
Oleic, $C_{18:1}$	12.4
Linoleic,$C_{18:2}$	9.6
Others (unidentified)	48:2

A 1.25 litre wet and dry mill multi-speed blender (pulsematic, Germany) was modified and the continuous blender reactor was a 1.25 litre capacity with an incorporated 500W electric heating element (240V, Semyem Electronics, Japan). The blender has a clear glass with stainless steel cutting blades. The temperature was monitored and controlled with a temperature controller (Kazuki, model kzz200 DT, Kazuki China) of 2^{o}C accuracy connected together with a T-type thermometer. The blender was operated at full power

2.2. Alkali Catalyzed Transesterification of Restaurant Waste Cooking Oil

The method of laboratory scale biodiesel production employed by Chitra et al. [9] is adopted in this work. 22.0g of methanol was measured and poured into a plastic container through a funnel. 1.0g of KOH was carefully added to the plastic container and was securely tightly. The container was placed on a shaker for about 5minutes until the KOH completely dissolved in methanol, forming potassium methoxide. 100.0 g of waste cooking oil pre-heated to 60^{o}C in an oven and was poured into the blender. The prepared potassium methoxide from the plastic container was carefully poured into the waste cooking oil. The blender was secured tightly, switched on and the agitation was maintained for 60minutes. The resulting product poured into a separating funnel mounted on a clamp stand and was allowed to settle down overnight. It was observed that the resulting mixture from the reaction had settled into yellow biodiesel on the top with the black glycerol at the bottom of the separating funnel . The ester was washed with water three times. Small amount of acetic acid (2.5ml/l of the oil) was used in the first washing. At the end of the process, the ester was heated to 90^{o}C at vacuum to remove any water left from the oil. The final ester became golden yellow. The procedure was replicated three times and average biodiesel yield as well as glycerol yield was measured. Ester yield results (given as percentages) were related to the weight of oil at the start (weight ester/weight of oil).

2.2.1. Biodiesel fuel characterization

Biodiesel fuel properties of waste cooking oil methyl esters (WCOME) were determined using standard test methods (ASTM D6751). The following fuel properties were measured experimentally: acid value (ASTM D664), kinematic viscosity (ASTM D445), density (ASTM D5002), flash point (ASTM D93) and higher heating value (ASTM D4809) as shown in Table 3.

3. Results and Discussions

WCO was subjected to alkaline-catalysed transesterification to afford WCOME employing classic reaction conditions reported previously [10] - [12]. 96.62g WCOME, 22.23g glycerol, with 2.23g losses. These losses are obviously some un-reacted alchol, residual catalyst and emulsion removed during the washing stage of the production process [13]The results stated are averages of three different experimental runs. Detailed results for each of the experimental runs are presented in Table 2.

Table 2. WCO-METHANOL- KOH transesterification results

Experimental Conditions	1st Run	2nd Run	3rd Run	Average
Reaction temperature (°C)	60	60	60	60
Reaction time (min.)	60	60	60	60
Waste cooking oil (WCO) quantity (g)	100	100	100	100
Methanol quantity (g)	22.00	22.00	22.00	22.00
KOH (catalyst) amount * (g)	1.00	1.00	1.00	1.00
WCO biodiesel obtained (g)	97.07	96.20	96.60	96.62
Glycerol obtained (g)	22.10	22.40	22.20	22.23
Losses (g)	2.10	2.30	2.70	2.37
WCO biodiesel yield (%)	97.07	96.20	96.60	96.62

* By weight of 100g WCO

Table 3. Characterization of Experimental Waste Cooking Methyl Ester in Comparison with, ASTM and EU Standard, Esters from Used cooking oil and Fossil Diesel

Property	Unit	Waste Cooking oil methyl ester[a]	ASTM Standard D6751-02[b]	EU Standard EN 14214[b]	Phan and Phan[c]	Ecinar et al. [d]	Al-widyan and Al-Shyoukh [e]
Specific gravity@ 15oC	g/cm3	0.879	0.880	0.86-0.90	0.88	0.890 @25 o c	0.8737
Viscosity @ 40	o c	4.72	1.9-6.0	3.5- 5.0	4.89	4.8	14.94 cst@20 o c
Flash point	o c	139	>120	>120	120	177	109
Acid value	mg KOH/g	0.459	<0.8	<0.50	0.43	- *	- *
Heating value	mJ/kg	41.25	- *	- *	- *	- *	- *

*not specified, [a]resent study; [b][13]; [c] [14; [d] [15]; [e] [16]

3.1. Density

Density is important parameters for diesel fuel injection system. A higher density for biodiesel results in the delivery of a slightly greater mass of fuel since fuel equipment operates on a volume metering system. The density of WCOME (0.879g/cm^3) was within the range of ASTM standard D6751-02 and EN 14214 standards. Moreover, the density of WCOME was observed to be in good agreement with that of waste cooking biodiesel reported by other researchers [14] - [16] as shown in Table 3.

3.2. Kinematic Viscosity

Kinematic viscosity is a measure of fluid resistance to flow. It is the primary reason why biodiesel is used as an alternative fuel instead of neat vegetable oils and animal fats ultimately lead to operational problems such as engine deposits when used directly as fuels. The kinematic viscosity of WCOME measured at 40°C was 4.72mm^2/s and found to be in conformity with the biodiesel standards; ASTM D6751-02 and EN 14214 (see Table 3). The value of kinematic viscosity of WCO biodiesel in the present study is slightly lower than that of Phan and Phan [14], Encinar et al. [15] and Al-widyan and Al-shyoukh [16] but is higher than viscosity of fossil diesel.

3.3. Flash Point

Flash point is the lowest temperature at which fuel emits enough vapour to ignite. Biodiesel has a high flash point usually more than 100°C, while conventional diesel fuel has a flash point of 77°C [17]. The biodiesel produced from WCOME has a flash point of 139 °C and this satisfies the minimum requirement of both standards as provided in Table 3. The flash point of WCOME is lower than that of waste cooking oil biodiesel of Encinar et al. [15] by (38°C), but higher than that of waste cooking oil methyl ester of Phan and Phan [14] by (19°C) ; Al-widyan and Al-shyoukh[16] by (30°C). Additionally, the high flash point of waste cooking biodiesel (139°C) compared to petroleum diesel (74-80°C) makes it safer to handle.

3.4. Heating Value

Higher heating value (HHV) is a measure of the energy produced when the fuel is burnt completely, which also determines the suitability of biodiesel as an alternative to diesel fuels. From Table 3, the HHV of WCOME produced was 41.25 MJ kg-1. The heating value is not specified in the biodiesel standards ASTM D6751 and EN 14214 but is prescribed in EN 14213 (biodiesel for heating purpose) with a minimum of 35 MJ/kg. Moreover, references [18]- [20] reported the HHVs of tobacco seed oil biodiesel, egusi seed oil biodiesel and sunflower oil biodiesel to be 39.81, 39.97 and 45.2 MJ kg-1, respectively, which are in agreement with what is obtained for WCO biodiesel

3.5. Acid Value

The AV is a simplistic method for monitoring fuel quality. The AV of the WCO biodiesel was 0.459 mg KOH/g

(Table 3). This result satisfied the maximum AV of 0.50 mg KOH/g set in ASTM D6751 standard.

4. Conclusion

From the laboratory scale production and characterization of methyl ester of WCO (biodiesel) studied, the following conclusions can be drawn:

- A maximum WCOO biodiesel yield of 96.6 % 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) A maximum WCOO biodiesel yield of 96.6 % 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).
- Laboratory-scale Nigerian restaurant 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.
- Feasibility of domestic production of restaurant waste cooking oil biodiesel using blender modified reactor is realistic.

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