Evaluation of Biodiesel Blending of Cocos Nucifera Oil Methyl Ester Produced from Alkaline-Catalyzed Transesterification Reaction

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ABSTRACT *The prospect of using cocos nucifera Oil for production of biodiesel via transesterification reaction was investigated. The use of ethanol for the transesterification reaction instead of methanol was also evaluated. Test quantities of biodiesel were produced using 100 g, 20.0% and 0.8% of cocos nucifera Oil, ethanol and potassium hydroxide catalyst respectively at 50 °C reaction temperature and 2 h reaction time. The catalyzed transesterification reaction produced biodiesel yield of 10.4%. In order to produce alternative fuel, the biodiesel produced from the cocos nucifera Oil was subsequently blended with petroleum diesel and the blended properties characterized by ASTM standard fuel tests. The property of the blended alternative fuel was determined by comparing cloud point and pour point of the biodiesel blend.*

KEYWORDS: *Biodiesel; Blending; Cocos nucifera Oil; Transesterification reaction; Yield.*

INTRODUCTION

Energy crisis, environmental sustainability as well as the concern of the society on the depletion of world's non-renewable energy resources have aroused the interest of researchers in the quest for alternative fuels for over three decades [1-3]. Alternative fuels such as bioethanol, biogas, biohydrogen, and biodiesel have received wide attention by the scientific community [4-7]. Research efforts have led to commercial production of these fuels in countries such as Brazil, USA and some part of Europe [8-10]. However, intensive research is still ongoing to further improve on the state-of-the-art of these biofuels and to further boost their production by investigating possible potential feedstocks [11-14].

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One of the most promising feedstocks for production of alternative fuels is vegetable oil and their derivatives. The use of vegetable oil as fuel was first demonstrated by Rudolph Diesel who used peanut oil to power diesel engine [15]. Ever since, vegetable oils from coconut, soybean, sunflower, safflower, peanut, linseed, rapeseed, and palm oil have also been attempted [15]. However, the long term use of vegetable oils in diesel engine usually results in injector coking and thickening of crankcase oil which often leads to piston ring sticking [16]. Therefore, vegetable oils are rarely used directly in diesel engines due to the aforementioned limitations.

To overcome this problem, various modifications of vegetable oils have been employed such as transesterification, micro-emulsion formation and the use of viscosity reducers [17]. Among these options, transesterification has been considered as the most suitable modification because of the technical properties of alkyl esters obtained are nearly similar to petrodiesel [18]. Through transesterification, these vegetable oils are converted to alkyl esters of the fatty acids present in the vegetable oil. These esters are commonly referred to as biodiesel.

Biodiesel as an alternative fuel to petrol-diesel is renewable and sustainable [19]. The emissions produced from biodiesel are cleaner compared to petrodiesel [20]. Similarly, particulate emissions, soot, and carbon monoxide are lower since biodiesel is an oxygenated fuel [20]. In this present study, the production of biodiesel from ethyl esters of coconut oil using an alkaline-based catalyst will be investigated. The feasibility of blending coconut oil-biodiesel will also be investigated. The properties of the biodiesel produced and its blend will be compared.

EXPERIMENTAL SECTION

Materials

The coconut oil used for this study was purchased locally from Akpugo, Enugu State, Nigeria. Residues from the coconut oil were removed by filtering. Based on the previous report by [21], coconut oil mainly consists of triglycerides of which 98% can be fractionated to obtain 13 different groups according to the carbon numbers from 28-52. The Chemical used in the experiment includes 95% ethanol, potassium oxide, isopropanol, phenolphthalein solution 1.0%w/v. These chemicals were of Analytical Reagent (AR) grade and were used without any modification.

Transesterification reaction of triglycerides in coconut oil

The transesterification reaction of triglycerides in coconut oil to produce biodiesel is represented in Equation (1).

$$\begin{array}{l} CH_2-OCOR^1 \\ | \\ CH_2-OCOR^2 \quad + \; 3R'OH \xleftrightarrow{\text{Catalst}} \\ | \\ CH_2-OCOR^3 \end{array} \qquad (1)$$

$$\begin{array}{lll} R^1OOR' & & CH_2-OH \\ + & & | \\ R^2OOR' & + & CH-OH \\ + & & | \\ R^3OOR' & & CH_2-OH \end{array}$$

Ethanol was used for the transesterification reaction in this study instead of methanol commonly used. A stock solution of ethoxide was prepared by dissolving 0.8 g of KOH in 75 mL of ethanol and the mixture agitated in a 250mL conical flask for about 8 h to ensure proper dissolution of the KOH pellets. The experiment was conducted using a 250 mL conical flask positioned in a mechanical shaker with a speed of 300 rpm. The coconut oil (100 mL) was pre-heated to 60 ºC and added to the conical flask on the molar ratio of 3:1. The mixture was further agitated for about 120 minutes. At the end of the reaction time, the mixture was left overnight to allow cooling to room temperature and for effective separation of the biodiesel and glycerol.

Recovering of the biodiesel

The biodiesel formed on the oil layer was heated using a rotary evaporator to remove excess ethanol and subsequently washed with water to remove impurities and glycerol. The washed biodiesel was separated from glycerol and other impurities using separating funnel. Excess water was removed from the biodiesel by further drying in a rotary evaporator. The concentrations of the biodiesel and the triglycerides in the oil phase were determined using Gas Liquid Chromatography (GLC) according to the procedure by *Chang et al.* [22] while the ethanol and the glycerol in the aqueous phase were measured using high-performance liquid chromatography

based on the procedure by [23]. Karl-Fischer titration was employed to determine the water content [24].

Free fatty acid determination

In order to determine the free fatty acid content in triglycerides, the free fatty acid was esterified as represented in Equation (2). The method previously described by *Muik et al.* [25] was employed for the determination of the free fatty acid.

$$RCOOH + R' \rightarrow RCOOR' + H_2O \quad (2)$$

Blending of biodiesel

The biodiesel produced was blended with conventional petrol-diesel to give ASTM blending standard of B10, B20, B40, B60, B80, and B100. This was achieved by using a homogenizer mounted on a clamp and rotated at speed of 4000 rpm.

Estimating the viscosity of the blends

The viscosity of the biodiesel blends can be estimated from Equation 3 and compare with the measured viscosity [26].

$$\log \eta_g = m_1 \log \eta_1 + m_2 \log \eta_2 \quad (3)$$

Where η_B, η_1 and η_2 are the kinematic viscosity of the blend, component 1 and 2 respectively (mPa.s) while m_1 and $m_2$are the mass fraction of component 1 and 2 respectively.

RESULTS AND DISCUSSION

The biodiesel produced and the different blends were analyzed for properties such as viscosity, density, pour point, cloud point, heat content, and cetane number in order to ascertain that the products conform to the set standards for biodiesel [26].

Viscosity

The viscosities of the biodiesel blends were examined at different temperatures ranging from 15 to 60 °C using JP SELECTA digital viscometer. Fig. 1 shows the variation between the different biodiesel blends and viscosity. It can be observed that the viscosity of the biodiesel blends increases with an increase in the amount of biodiesel in the ratio. The viscosity of the blends varies in the range of 3.15 to 4.65 mPa.s, which are higher than the conventional petrodiesel. The result shows that B100

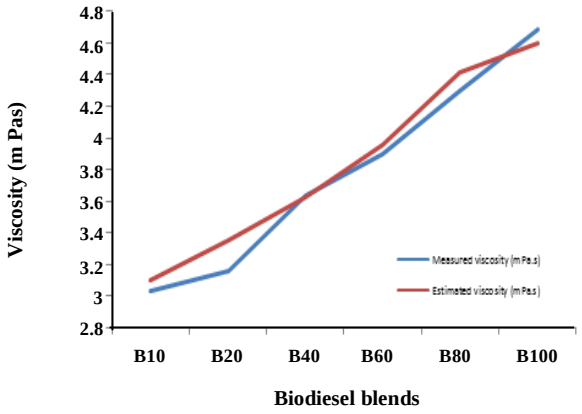

Fig. 1: Measured and estimated viscosity of biodiesel blends

is more viscous than diesel fuel. The high viscous fuel would exhibit almost a solid stream of the spray pattern in the combustion chamber of an ignition engine and so cold starting of the engine would be difficult. Hence, using B100 fuel in the existing diesel engine would require modification of the engine so that fuel supply exerts high spray pressure to achieve the desired spray pattern inside the engine cylinder.

The estimated viscosities of different blends are validated using the measured values (Fig. 1) and the predicted (estimated) values are close to the measured values. The trends observed for the estimated and measured viscosity of the coconut oil biodiesel in the study is in agreement with the previous study with blends obtained from waste-cooking oil biodiesel, sunflower biodiesel and soybeans oil biodiesel [27-28].

Cloud point and pour point

The measured values of the cloud and pour points of the different biodiesel blends are represented in Fig. 2. One of the major challenges in biodiesel produced from transesterification of vegetable oil is the low-temperature flow properties measured as a function of cloud and pour points. Based on the observed trend in Fig. 2, blending coconut oil biodiesel with conventional petrodiesel has good low-temperature properties compared to petrodiesel. Furthermore, the cloud and pour point of the blends increases as the proportion of the biodiesel in the blends increases. The results obtained show that B10 has the best cold flow properties followed by B20, B40, B60, B80, and B100. This can be attributed to the degree of saturation of the parent oil. The additive response

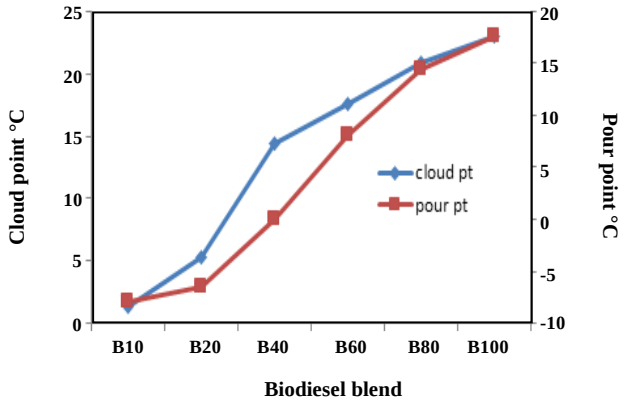

Fig. 2: Cloud point and pour point of biodiesel blends.

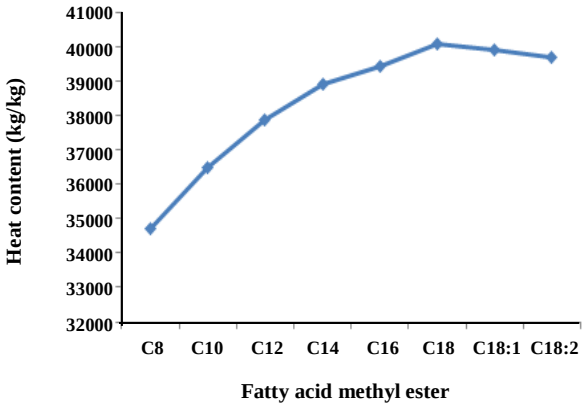

Fig. 3: Heat content of fatty acid methyl ester.

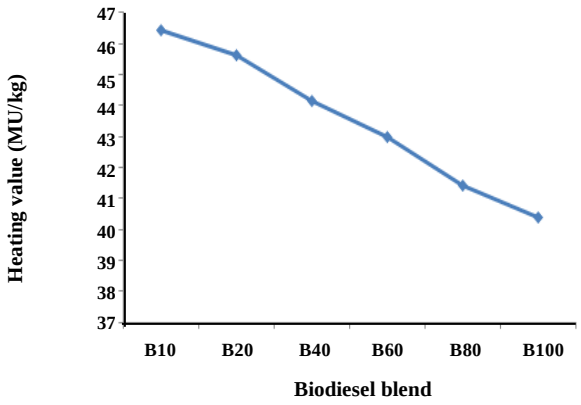

Fig. 4: the Heating value of biodiesel blends.

observed by coconut oil-biodiesel blends in terms of their cloud and pour points has also been previously observed by *Sarin et al.* [29] and *Sirisomboon et al.* [30] for jatropha- and palm oil-blends.

Heat content and heating values

The energy density of the biodiesel as a fuel is measured by estimating the heat content. In this study, ASTM 2382 method was applied to measure the heating value of biodiesel and their blends [31]. The heat content and heating values of the fatty acid methyl ester and the different blends are shown in Figs. 3 and 4 respectively. It can be observed that the heat content increases with increases in carbon number of the fatty acid methyl ester with C8 and C18 having the lowest and highest values respectively [32]. Also, the heating values increases as the ratio of carbon and hydrogen to nitrogen and oxygen increases [31]. From Fig. 4, it is observed that the heating values of the blends decreased with an increase in the proportion of biodiesel in the blends with B10 and B100 having the highest and lowest heating values respectively. *Benjumea et al.* [33] had earlier reported that heating values increase as the ratio of carbon and hydrogen to oxygen and nitrogen in the blends increases. This explains why B100 has the lowest heating value due to the presence of oxygen in a high ratio to carbon and hydrogen.

Cetane number

This property determines the ignition tendency of the pure fatty acid methyl ester. Cetane number was calculated theoretically based on the known values of the heat content of pure methyl ester components of the fuel from [34]. The cetane numbers of the pure fatty acid methyl esters are represented in Fig. 5 with stearic acid (C18) having the highest value (81) while acrylic acid (C8) has the lowest value (33.6). The cetane number increases with an increase in the carbon number of the fatty acid methyl ester. However, the trans (C18.1) and cis (C18.2) fatty acid methyl ester did not follow this trend as there was a decrease in their cetane number. The cetane number of the fatty acid methyl ester is influenced by the types of chemical structure. High cetane number were observed for C16 and C18 due to the fact that the cetane number increases with a chain length of the carbon [35]. The presence of double bond has been reported to

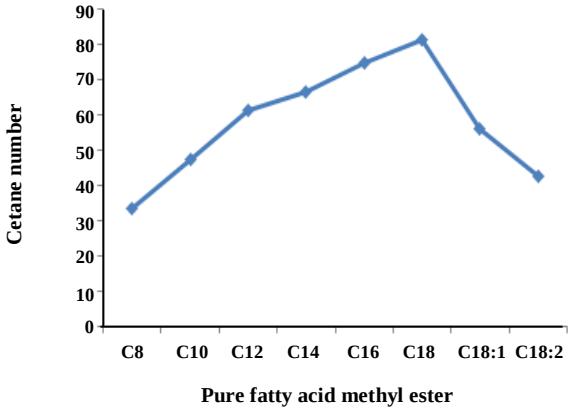

Fig. 5: Cetane numbers of pure fatty acid methyl ester.

cause a decrease in cetane number of fatty acid methyl ester which explains the trend observed for C18:1 and C18:2 [31].

CONCLUSIONS

The potential of using *Cocos nucifera* Oil as feedstock for the production of biodiesel has been reported. The *Cocos nucifera* Oil (100 g) was employed in a KOH catalyzed transesterification reaction for production of test quantities of biodiesel. The process catalyzed transesterification reaction yielded 10.4% biodiesel. The biodiesel produced from the *Cocos nucifera* Oil was blended with petroleum diesel to obtain alternative diesel fuel (Blended biodiesel). ASTM standard fuel tests were employed to analyze the properties of the blended biodiesel. The tested properties were in good agreement with the ASTM standard for fuel tests.

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