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Characterization of Coconut Oil and Its Biodiesel

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Authors' contributions

This work was carried out in collaboration between all authors. Author NAM designed the study, wrote the protocol and wrote the first draft of the manuscript. Author SAY managed the literature searches, analyses of the study. Author GMT performed the spectroscopy analysis and managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this research is to characterize biodiesel produced from coconut oil with a view to finding its suitability as alternative fuel for diesel engine.
Biodiesel are alternative diesel fuels usually obtained from renewable sources, mainly, vegetable and animal oils. Oil was extracted from coconuts bought from a local market in Kaduna State, Nigeria, which is one of the sources of vegetable oil, by wet milling method. The extracted coconut oil was degummed and the percentage yield was found to be 45.5% and it was characterized. Results obtained showed that the coconut oil has specific gravity, viscosity, free fatty acid, saponification value, iodine value, perioxide value and acid value of 0.912, 23 mm^2/s, 28.025 mg/g, 191.89, 121.1, 8 mol/kg and 14.025 mgKOH/g respectively. Biodiesel of the oil was produced using transesterification process. The percentage yield of the biodiesel was found to be 49.8% and it was also characterized. Results obtained showed that the biodiesel has specific gravity, viscosity, free fatty acid, acid value, saponification value, iodine value, calorific value, flash point, fire point, cloud point, pour point and cetane number of 0.89, 2.7 mm^2/s, 0.38 mg/g, 0.18 mgKOH/g, 154, 124.6, 49 MJ/kg, 100℃, 123℃, 0℃, -3℃ and 51 respectively. Some of the physicochemical properties of the biodiesel compared well with that of diesel and in the range of ASTM specifications.

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1. INTRODUCTION

The world is getting modernised and industralized day by day. As a result vehicles and engines are increasing but the energy sources used in these engines are limited and decreasing gradually. This situation leads to seek an alternative fuel for diesel engines [1]. Finite fossil fuels reserves, political economic health and enviromental (Ozone layer depletion, global warming, green house gases) issues and/concerns have prompted biodiesel as an alternative renewable and ecofriendly fuel [2]. According to Rao et al. [3], biodiesel is biodegradable and non-toxic and has low emission profiles as compared to petroleum diesel and the use of biodiesel will allow a balance to be sought between agriculture, economic development and the environment. The attractiveness of the use of biodiesel sterned from its enviromental benefits and its production from renewable resources. The ester of vegetable oil, animal fats are known as biodiesel [1]. Different types of vegetable oil have been used to produce biodiesel, notable among them are palm kernel oil [4], non-edible castor oil [5-7], mango seed oil [8], Jatropha oil [3,9-14], cotton seed oil [15], palm oil [16], soya bean [12, 17], melon seed oil [18], tigernut [19], baobab seed oil [20], Neem oil [21] and sapodilla seed oil [22].

Coconut has industrial and domestic uses of its different parts. The oil and milk extracts from coconut are commonly used in cooking and frying. The oil is widely used in making soaps and cosmetics. In order to diversify the use of the oil on one hand and finds its suitability as alternative for diesel engine on the other hand, it is therefore characterized, which is the main aim of this research work.

2. MATERIALS AND METHODS

2.1 Procedure for Coconut Oil Extraction

The coconut used for this study was purchased from the local markets in Kaduna state Nigeria. The extraction of coconut oil was done by splitting the coconut with a sharp cleaver, scraping the flesh of the coconut from the shell using a sharp knife, the nuts were cut into small pieces, mixed with 30 ml of water per batch and blended with a blender. The coconut milk was filtered, the filtered milk was left for 24 hours. As it sets the coconut milk and oil got separated and a layer of curd appeared at the top of the container, the curd was scooped out thereby leaving the crude coconut oil. This was done in line with the work of Teran and Yaman [23].

The crude coconut oil was degummed in line with the work of Igbum et al. [24], to remove phospholipids, calcium and magnesium salts of phosphatidic and lysophasidic acids which are emusifiers that mitigate the separation of glycerol which lowers the yield of nuetral oil.

2.2 Degumming of the Crude Coconut Oil

The crude coconut oil was mixed with 3% hot water and 0.05% of 75% phosphoric acid in line with the work of Abitogun et al. [25]. The mixture was agitated mechanically for 30 minutes at 70℃ [24] and allowed to settle for 45 minutes after which the phosphotide(gum) and other impurities were drained off from the reaction vessel. The degummed coconut oil that was obtained was characterized.

2.3 Determination of Percentage Yield of the Coconut Oil

The nuts were weighed before extraction and degumming by weighing scale made in China by Dapeng and this weight was referred to as theoretical oil yield. The extracted and degummed oil was weighed with the same weighing balance and this weight was referred to as actual oil yield

$$\text{\% Oil yield} = \frac{Actual\ oil\ yield}{Theoretical\ oil\ yield} \times 100\% \qquad (1)$$

2.4 Characterization of Coconut Oil

Some of the physico-chemical properties are determined using standard method in other to know the characteristics of the oil. Density, specific gravity, saponification value, iodine value, perioxide value, acid value and free fatty acid were determined by using AOAC [26] method. Moreso viscosity Using Brookfield DV-E Viscometer was determined according to AOAC [26] method.

2.5 Production of Biodiesel from the Coconut Oil

Transesterification Process was adopted for the production of the biodiesel. So, 0.5 g of sodium hydroxide pellet was mixed with 30 ml of methanol inside a strong heat resistance glass beaker. The mixture was stirred vigorously until sodium hydroxide pellets dissolved and formed a strong base known as methoxide ($NaOCH_3$). 100 ml of the treated coconut oil was poured into the reactor and heated gently at 65℃, in line with the work of Igbokwe and Nwafor [27] and the methoxide was added and the mixture was stirred vigorously for 1 hour in order to obtain a homogeneous mixture. The mixture was poured into a separating funnel and made to settle for 24 hours. The mixture separated into two layers with the biodiesel floating on top and glycerine at the bottom so the biodiesel was decanted The raw biodiesel was washed with water to remove some traces of soap and other contaminants and the water was allowed to settle down before removing it by draining. The washed biodiesel was collected into a beaker and gently heated in an oven at 105℃ to evaporate the excess water and methanol in the biodiesel.

2.5.1 Determination of percentage yield of biodiesel

The treated or degummed coconut oil was weighed before the transesterification process by weighing scale made in China by Dapeng and this weight was referred to as theoretical yield. The biodiesel produced was weighed with the same weighing scale and this weight was referred to as actual yield

$$\% \text{ Biodiesel yield} = \frac{Actual\ biodiesel\ yield}{Theoretical\ biodiesel\ yield} \times 100\% \qquad (2)$$

2.6 Characterization of the Biodiesel

The biodiesel obtained through transesterification process was characterized to know the fuel properties. Density, specific gravity, viscosity, acid, iodine and saponification values were determined using the same method for the characterization of the degummed extracted coconut oil. Flash point and fire point were determined by using Pensky-Martins apparatus by ASTM D93 method. The calorific value was determined by using Hewlett Adiabatic bomb calorimeter model 1242. Cetane number was obtained numerically by the relation enunciated by Bunkyakiat et al. [28].

3. RESULTS AND DISCUSSION

The percentage yield of oil from coconut was found to be 45.5% and the results obtained from the characterization of coconut oil are presented in Table 1.

Table 1. Physicochemical properties of the produced coconut oil

Properties	Values
Specific gravity	0.912
Density (kg/m^3)	912
Viscosity at 40℃ (mm ^{2}/s)	23
Free fatty acid (mg/g)	28.025
Saponification	191.89
Iodine	121.1
Perioxide (mol/kg)	8
Acid (mgKOH/g)	14.025

The percentage yield of biodiesel from the coconut oil was found to be 49.8% and the determined fuel properties of the produced biodiesel, conventional fossil fuel diesel and America Society of Testing and Materials(ASTM) specifications stated by Singh and Padhi [9], are depicted Table 2.

It is very evident in Tables 1 and 2 that the specific gravity of the coconut oil reduced from 0.912 to 0.89 after transesterification process to produce its biodiesel. In comparison, the specific gravity of the biodiesel is slightly higher than that of diesel of 0.85.

Viscosity of the coconut oil prior to transesterification as seen in Table 1 is 23 mm^2/s. It reduced drastically after transesterification to 2.7 mm^2/s. However, the viscosity of the biodiesel is 0.1 mm^2/s higher than that of diesel but in the range of ASTM standard. Viscosity is one of the important criteria in evaluating diesel quality. High viscosity leads to operational problems including engine deposits [29]. Although the biodiesel has higher viscosity which will have poor injection and atomization performance, it offers lubrication and protection of the moving parts of engine more than diesel [21].

The free fatty acid and acid value of the coconut oil dropped considerably from 28.025 mg/g and 14.025 mgKOH/g as seen in Table 1, to 0.38 mg/g and 0.18 mgKOH/g as seen in Table 2 respectively, for its biodiesel.

This perhaps showed an effective transesterification process of producing the biodiesel. The acid value of the biodiesel is lower than that of diesel but in the range of ASTM specification as evident in Table 2. It should be noted that acid value measures directly the FFA

Table 2. Fuel properties of biodiesel produced from coconut oil, conventional fossil fuel diesel and ASTM specifications

Properties	Biodiesel	Diesel	ASTM D6751-02 specification
Specific gravity	0.89	NA	NA
Density (kg/m^3)	800	850	875-900
Viscosity (mm^2/s)	2.7	2.6	1.9-6.0
FreeFatty acid (mg/g)	0.38	NA	NA
Acid value (mgKOH/g)	0.18	0.35	<0.8
Saponification value	154	NA	NA
Iodine value	124.6	NA	NA
Calorific value (MJ/Kg)	49	NA	NA
Flash point (℃)	100	70	>130
Fire point (℃)	123	NA	NA
Cloud point (℃)	0	NA	NA
Pour point (℃)	-3	-20	NA
Cetane number	51	46	NA

NA means not available

contents of the biodiesel, it helps to state the corrosive nature of the fuel, its filter clogging tendency and the amount of water. This parameter can also be used to measure freshness of the biodiesel. The higher the acid value the lower the quality of fuel [8]. So the the biodiesel produced from the coconut oil can be termed to be of good quality.

The perioxide value of the coconut oil was found to be 191.89 mg/g as depicted in Table 1. The saponification values of biodiesel were found to be 154 mg/g as reflected in Table 2. The high saponification value of the coconut oil as compared to that of its biodiesel is clear indication that the oil is normal triglyceride and it is very useful in the manufacture of cosmetics.

The iodine value of the oil was found to be 121.1 and that of biodiesel was found to be 124.6. According Belewu et al. [14], high iodine value shows high unsaturation of the oil. In this regard, the low iodine value of the oil and the biodiesel depict low unsaturation of the oil and biodiesel.

The net calorific value of biodiesel was found to be 49 MJ/Kg as shown in Table 2. The cloud and pour points of biodiesel were found to be very high as evident in Table 2. This is important for engine operation in cold or cooler environment [9].

The flash point and fire point of the biodiesel were found to be 100℃ which is higher than that of diesel and 123℃ respectively, as shown in Table 2. According to Raja and Lee [10], flash point and fire point are important temperature specified for safety during transport, storage and handling and according to Tanwar et al. [21], liquid fuel with a high flash point can prevent auto-ignition and fire hazards at high temperature during transportation and storage periods, so the higher flash point of the biodiesel is advantageous for its transportation and storage.

The cetane number of the biodiesel was found to be 51 which are higher than that of diesel of 46 as reflected in Table 2. High cetane number shortens the engine delay period and promotes smooth combustion [27]. So it is evident that the biodiesel produced posses this positive attribute.

4. CONCLUSION

Coconut oil was characterized and biodiesel was produced from it and also characterized in this study. From the results obtained and discussed, it is very evident that coconut oil is a good feedstock for biodiesel production and the biodiesel can be used in convectional diesel engine without modification because of close fuel properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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