



## Characterization and Physicochemical Properties of Biodiesel Produced from Castor Oil Using Refluxed Calcined Snail Shell

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### ABSTRACT

In this work, biodiesel was produced from castor oil using CaO obtained from snail shell as a catalyst. The castor oil was extracted using soxhlet extraction method and pretreated in order to upgrade its physicochemical properties for efficient transesterification reaction. The catalyst used was prepared from snail shell using the hydrothermal method and characterized using FTIR and TGA/DTA analysis. The yield of biodiesel produced is 99.68 %. The methyl ester yield was analyzed using GC-MS as 99.12 %. The major methyl ester compositions in the biodiesel produced are (86.18 %) 9- octadecenoic acid- 12- hydroxyl-, methyl ester, [R- (Z)], (10.06 %) 9- Octadecenoic acid [Z]-, methyl ester, (1.19 %) Hexadecanoic acid, methyl ester and (1.17 %) Methyl stearate. The physicochemical properties of biodiesel produced show that the biodiesel produced may be used in a diesel engine with little modifications or blend with conventional diesel.

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### 1. Introduction

The diminution of fossils fuels and increasing demand for conventional energy worldwide have been the main apprehension of scientist nowadays (Ismail *et al.*, 2016; Refaat *et al.*, 2008). An incessant supply of energy is crucial to support the human activities such as industrialization, construction, transportation, and agriculture. As the conventional energy sources are finite, there is a need to generate a sustainable alternative, non-conventional energy to support the civilization (Hribernik and Kegl, 2007; Ma *et al.*, 1999).

Biodiesel is defined by the European Parliament in Directive 2003/30/EC (DEPC, 2003) as a "methyl-ester produced from vegetable or animal oil, of diesel quality, to be used as biofuel". Biodiesel is characterized by its biodegradability, nontoxic, renewability, ease of production and agricultural origin (Knothe *et al.*, 2006). The CO<sub>2</sub> emissions of biodiesel combustion can be considered as recyclable by the growing plants, emissions of SO<sub>x</sub>, CO, unburnt hydrocarbons, and particulate matter are lower than those of petroleum diesel (Coronado *et al.*, 2009).

Transesterification of vegetable oils and animal fats is the primary way to make biodiesel (Encinar *et al.*, 2010). Transesterification is a three-step reversible reaction of vegetable oils or animal fats with a short-chain alcohol usually methanol to form fatty acid methyl esters (FAMES) and glycerol (Encinar *et al.*, 2010). The presence of a catalyst is needed. Among the alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol is used most commonly because of its low cost and its physical and chemical

advantages (polar and shortest chain alcohol). The stoichiometric ratio for transesterification requires three moles of alcohol. However, the molar ratio is associated with the type of catalyst used and higher molar ratios result in greater ester conversion in a shorter time (Ma and Hanna, 1999).

Heterogeneous base catalysts eliminate the need for the neutralization of homogeneous base catalysts with acids and the removal of water in the commercial production of biodiesel, thereby lowering its production cost (Cho and Seo, 2010). Among the heterogeneous catalysts, calcium oxide has derived researchers' attention because it is a cheap and abundantly available in nature as a limestone and also from seashells in the form of calcium carbonate, CaCO<sub>3</sub>. Calcium oxide can be reused up to 3 times in transesterification reaction which made it an economic catalyst. As the calcium oxide was derived from the natural source, it is environmentally friendly and causes no harm to the ecosystem. Thus, calcium oxide was suitable to be used in large-scale production of biodiesel for commercial purpose as it needs no post-treatment prior to its disposal to the environment (Kouzu *et al.*, 2008).

About chemical and physical characteristics, castor oil composition is 80-90 % ricinoleic acid, 3-6 % linoleic acid, 2-4 % oleic acid and 1-5 % saturated fatty acids (Scholz and da Silva, 2008). Ricinoleic acid is the main fatty acid from castor oil; this fatty acid possesses 18 carbons with three highly reactive functional groups: the carbonyl group in 1<sup>st</sup> carbon, the double linking or unsaturation in 9<sup>th</sup> carbon and the hydroxyl group in 12<sup>th</sup> carbon. This feature causes castor oil properties are different from other vegetable oils (Conceição *et al.*, 2007). The high content of ricinoleic acid, with a hydroxyl group, is the reason for castor oil has especially

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high viscosity and density. Castor oil is also characterized by its high stability, high hygroscopicity and its solubility in alcohol, which affects the transesterification reaction (Ogunniyi, 2006).

The review of the different research achievements on vegetable oils and biodiesel as an alternative fuel for a compression ignition engine were collated as follows: Ismail *et al.* (2016) conducted an experiment of biodiesel production from castor oil by using calcium oxide derived from mud clam shell. The calcium oxide synthesized from mud clam shell shows good catalytic performance and physicochemical properties as a heterogeneous catalyst for biodiesel production. The optimum parameters of calcium oxide catalyzed transesterification of castor oil were determined as 1:14 oil to methanol molar ratio, 3 % w/w catalyst concentration, 60 °C reaction temperature and 2- hours reaction time. Reusability test shows that the synthesized calcium oxide from mud clam shell is reusable up to 5 times.

Sanchez *et al.* (2015) studied the biodiesel production from castor oil under subcritical methanol condition using potassium methoxide catalyst. The effect of molar ratio and reaction temperature on alkyl ester formation was studied. It was concluded that by coupling the catalyst with subcritical methanol, biodiesel was synthesized from castor oil with a high yield.

Darnoko and Cheryan (2000) reported data on palm oil kinetics. It was observed that the rate of alkali-catalyzed (KOH) transesterification in a batch reactor increased with temperature up to 60 °C. The further increase in temperatures did not reduce the time to reach the maximum conversion. The free fatty acid and moisture content in the material are the key parameters for determining the viability of the vegetable oil transesterification process. Ma *et al.* (1999) studied the effect of free fatty acids and water content in the transesterification of beef tallow. The presence of water had more negative effects on the transesterification than free fatty acids. They concluded that for best results, the water content and the free fatty acid content in beef tallow should be kept below 0.06 % w/w and 0.5 % w/w respectively.

The objectives of this work were to extract, refine and study physicochemical properties of castor seed oil, to prepare catalyst from snail shell using the hydrothermal method and characterize it using Thermogravimetric Analysis (TGA) and Fourier transform infrared (FTIR), and finally to produce and determine the physicochemical properties of biodiesel produced and characterize it using GC/MS.

## 2. Material and Methods

### 2.1 Sampling and Preparation

The Castor seed was procured from Yandodo, Kano State. The seed was sundried to reduce the moisture content and it was then ground to reduce the particle size in preparation for extraction. The Castor seed was de-shelled. The de-shelled seed was oven dried at 90 °C for 45 minutes. The dried seeds were grounded using motor and pestle and weighed.

### 2.2 Oil Extraction Process

Extraction of castor oil was carried out by soxhlet extraction method as reported by Edison *et al.* (2012). The extracted oil had undergone some pre-treatment such as degumming with water to remove the easily hydratable phospholipids and metals, addition of phosphoric to convert the remaining non- hydratable phospholipids (Ca and Mg salts) into hydratable phospholipids and further neutralized of free fatty acids with slight excess of NaOH solution, followed by washing out of soaps and hydrated phospholipids (Nakarmi and Joshi, 2014).

### 2.3 Preparation of Catalyst

The Calcium oxide catalyst that was used in this study was synthesized from snail shell through hydrothermal method. The snail shell was obtained from local Danmadoh in Kano state. The snail shell was washed with 1% aqueous solution of sulfuric acid in order to remove dirt and stains on the shell surface. The shell was ground into powder size using motor and pestle. The snail shell powder was then thermally decomposed in a furnace at 800 °C for 3 hours. The calcined shell was then refluxed in distilled water at 105 °C for 6 hours. The sample was then filtered, oven dried at 120 °C for 2 hours. The refluxed calcined snail shell was recalcined at 800 °C for 2 hours using muffle furnace to produce fine calcium oxide (Ismail *et al.*, 2016).

### 2.4 Transesterification of Castor Seed Oil

The transesterification was carried out in 500 cm<sup>3</sup> two necks round bottom flask as reactor equipped with condenser, thermometer and hotplate magnetic stirrer. The 45 g of refined castor oil was initially charged into the reactor, and then preheated to 50 °C. In order to maintain the catalytic

activity, the solution of 0.225 g (0.5 wt%) of CaO (refluxed calcined snail shell) in 9.169 g (1:6 oil to methanol ratio) methanol was freshly prepared so that prolonged contact with the air would not diminish the effectiveness of the catalyst through interaction with moisture and carbon dioxide. The solution was preheated to 50 °C in the water bath and then added to the preheated oil after which the reaction was timed at 1 hour and the agitation was kept at 300 rpm. After the reaction time, the mixture was allowed to settle under gravity for 24 hours in the separating funnel. Two distinctive layers were formed: the upper layer consisted of methyl ester, methanol traces, residual catalyst, and other impurities, whereas the lower layer consisted of glycerin, excess methanol, catalyst, and other impurities. After separation from the glycerin layer, the methyl ester layer was centrifuged and then purified by washing with hot distilled water at 60°C until the washing water had a pH value similar to that of distilled water (Nakarmi and Joshi, 2014). The hot distilled water-to-crude methyl ester ratio was 1:1. To prevent the possibility of losing the methyl ester due to emulsion formation, the washing was done gently. After then the weight of biodiesel was taken and yield was determined.

### 2.5 GC- MS Analysis of Biodiesel Produced

The oil composition and methyl ester content were assayed using a GC/MS machine in the multi-purpose laboratory in Ahmadu Bello University (ABU), Zaria.

### 2.6 Physicochemical Properties

The physicochemical properties of biodiesel produced, crude and refined castor oil were determined. The pour point, cloud point and flash point were analyzed using methods as reported by Faduka, (2001). The moisture content, pH value, specific gravity, refractive index, acid value, saponification value and iodine were determined through the method as reported by Akpan *et al.* (2006) and Kyari, (2008). The kinematic viscosity was analysed using cannon viscometer model 2020 as described in cannon manual, (2017), the API gravity and cetane index were determined by the methods ASTM D1250 and ASTM D611. The cetane number and the high heating value was determined by methods reported by Mohibbe *et al.*, (2005), and Sivaramakrishnan and Ravikumar, (2012).

## 3. Results and discussion

The physicochemical properties of biodiesel produced, crude and refined castor oil were determined and presented in Table 1. The acid value which is an important parameter to be considered in base-catalyzed transesterification, as high acid value resulted in high soap formation (Kyari, 2008), increasing difficulties in separation of biodiesel and hence, affect the biodiesel yield. The refined castor oil has lower acid value than crude castor oil which indicates the efficiency of pretreatment of oil for base-catalyzed transesterification.

### 3.1 Catalyst Characterizations

#### 3.1.1 Physical Observation

The colour of the ground snail shell was ash colour, after calcination the colour changes to fairly white and after the catalyst was refluxed and recalcined, the colour was completely transformed to brightly white. The ground snail shell was granular but after refluxing and recalcination (thermal hydration) it becomes finely pulverized, which indicates an increase in surface area, hence, indicate improve catalytic activity and basicity of the refluxed calcined snail shell.

#### 3.1.2 FT – IR Analyses

The infrared spectrum of ground snail shells (mainly CaCO<sub>3</sub>), calcined snail shell (mainly CaO) and refluxed calcined snail shell (mainly CaO) were analyzed using FT-IR machine, and collated in Table 2. A sharp peak can be seen at 1450cm<sup>-1</sup> of ground snail shell (calcium carbonate), the absorption peaks correspond to C-O symmetrical stretching vibration of carbonates (Garcia *et al.*, 2008). The absorption peaks at 1650 cm<sup>-1</sup> and 2350 cm<sup>-1</sup> correspond to C=O stretching vibration of carbonates. The two weak peaks at 950 cm<sup>-1</sup> and 875 cm<sup>-1</sup> correspond to the out-of-plane bending vibration of C-O bonds of carbonates. Upon calcination, the calcium carbonate was thermally decomposed into calcium oxide and loses carbonate. Thus, this leads to the decrease of characteristics peaks of carbonates on the IR spectrum of the synthesized calcium oxide. The reduced intensity of absorption band which corresponds to carbonates can be seen at 2200cm<sup>-1</sup>, 1650cm<sup>-1</sup>, 1450cm<sup>-1</sup>, 920 cm<sup>-1</sup>, and 800cm<sup>-1</sup> on the IR spectrum of calcium oxide from snail shell (there is a higher reduction in the intensity of the refluxed calcined snail shell (Galván-Ruiz *et al.*, 2009).

**Table 1:** Physicochemical properties of crude and refined castor oil, and biodiesel produced

Properties	Crude castor oil	Refined castor oil	Biodiesel	Method ASTM	Biodiesel limit	Diesel limit
Yield %	41.29±1.54	28.09±0.50	99.68±0.00 <sup>a</sup>			
Acid value (mg <sub>KOH</sub> /g)	4.49±0.40	2.81±0.20	99.12±0.00 <sup>b</sup>	-	-	-
Refractive index	1.47±0.00	1.44±0.00	2.53±0.00	ASTM D664	≤0.8	-
Saponification value (mg <sub>KOH</sub> /g)	182.53±1.19	169.91±0.20	1.46±0.00	-	-	-
Iodine value (gI <sub>2</sub> /100g)	81.53±1.35	78.22±1.80	183.63±2.00	-	-	-
Kinematic Viscosity (mm <sup>2</sup> /s)	233.00±2.00	159.00±3.00	82.57±1.00	-	-	-
Specific gravity	0.96±0.01	0.92±0.00	7.32±0.50	D445	1.9- 6.0	1.3- 4.1
Free fatty acid (mg <sub>KOH</sub> /g)	0.96±0.01	0.92±0.00	0.92±0.00	D6751	0.86- 0.90	0.82- 0.88
Ester value (mg <sub>KOH</sub> /g)	2.24±0.20	1.40±0.10	1.26±0.00	-	-	-
Flashpoint (!)	-	-	181.10±0.00	-	-	-
High heating value (MJ/Kg)	225.00±1.00	190.00±1.00	161.00±1.00	D93	100- 170	60-80
Cetane number	-	-	40.66±0.00	D21663	-	42.80-45.36
Cloud point (!)	-	-	57.45±0.00	D6751	48- 65	40- 55
Pour point (!)	-	-	5.20±0.00	D2500	-3 to 12	-15 to 5
			-15.90±0.00	D97	-15 to 10	-25 to -15

Key: a is a yield obtained from raw biodiesel, b is a methyl ester contents of biodiesel analyzed using GC/MS. Values are Arithmetic Mean±Standard Deviation of three replicate determinations.

**Table 2:** FT-IR Results of ground, Calcined and Refluxed Calcined Snail Shell

Nature of the Peak	Range (cm <sup>-1</sup> )	Functional Group
Broad	3870- 3300	O-H stretching vibration (peak decreased upon calcination and refluxing)
Short peak	3000- 2900	C-H stretching vibration
intense	1650	C=O stretching vibration (peak intensity significantly decreased upon calcinations and refluxing)
medium	1450	C-O stretching vibration
short	950 and 875	C-O out of plane bending vibration
Sharp peak	500	Ca-O (peak sharply increased upon calcinations and refluxing)

A sharp peak around 500cm<sup>-1</sup> of the infrared spectrum corresponds to functional group Ca-O from calcium carbonates. The Ca-O peak intensity reduced as calcium carbonate was decomposed into calcium oxide (Galván-Ruiz *et al.*, 2009). The absorption band in the range of 3651–3870 cm<sup>-1</sup> on the infrared spectrum corresponds to a hydroxyl group. The absorption peak of the hydroxyl group is normally ascribed to the presence of calcium hydroxide. The existence of hydroxyl group resulted from absorption of atmospheric moisture during FT-IR analysis which subsequently formed calcium hydroxide. This phenomenon was common due to the high hydrophilicity nature of the compound (Tan *et al.*, 2015).

### 3.1.3 DTA/TGA Analysis

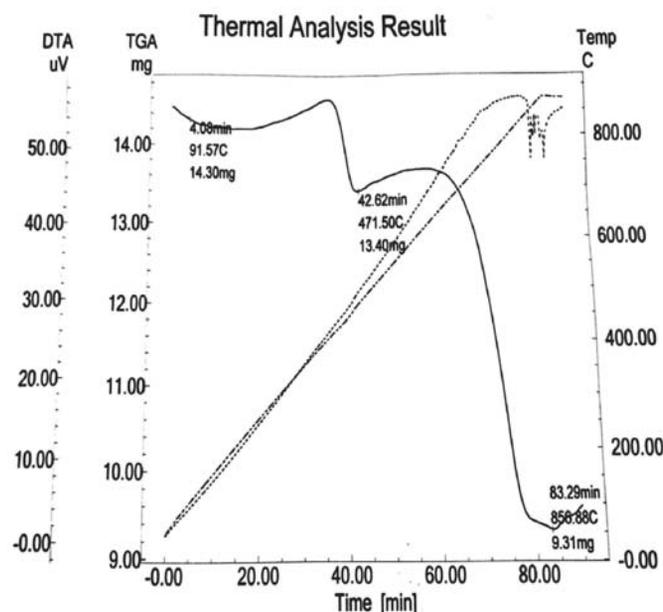
The TGA and DTA curves prepared of CaO catalyst from snail shell in Fig. 1, show that the initial weight of refluxed calcined snail shell at 14.50 mg, as the temperature rises 91.57 °C at 4.08 minutes, the weight started to reduced to 14.30 mg which might be due to the loss of moisture absorbed due to its high hydrophilicity (Tan *et al.*, 2015). Since the thermogravimetric analysis was carried out in an air medium, the catalyst absorbed carbonate [1], this leads to the rapid increases in the weight of the catalyst to 14.70 mg at 30 minutes. As the temperature rises above 471 °C at 42.62 minutes, the compound decomposes rapidly and weight reduces to 13.40 mg. However, (Fig. 1) the TGA and DTA curves of prepared CaO catalyst showed the significant weight loss at 856.88 °C (from 13.40 to 9.31 mg) at 83.29 which may be due to loss of extremely low volatile impurities and carbonates bounded to the surface of CaO respectively (Tan *et al.*, 2015). Then the curve stabilized, which indicate the end of thermal decomposition.

## 3.2 Physicochemical properties of biodiesel produced

### 3.2.1 Biodiesel Yield

The percentage yield of the biodiesel obtained is 99.68%. The amount obtained is economically significant and it indicates substantial improvement toward obtaining expected theoretical yield (100%). The high yield may be as a result of the refining of the oil and significant improvement of the activity of the prepared catalyst. The yield obtained

which is high than (96.7%) that obtained by Ismail *et al.* (2016) and 98% obtained by Saribiyik *et al.* (2010). The comparative yield of 99.58% by Birla *et al.* (2012) was obtained by transesterifying waste frying oil with methanol in the presence of calcined snail shell, and similar yield of 99.50% was obtained by Chen *et al.* (2013).

**Fig. 1 :** Thermogravimetric analysis of refluxed calcined snail shell

### 3.2.2 Acid Value

The acid value of the biodiesel oil is  $2.53 \pm 0.00$  mgKOH/g which is greater than (0.567 mgKOH/g) obtained by Asmare and Gibbiye (2015) of castor oil biodiesel and less than (3.8 mgKOH/g) obtained by Al-Harbawy and Al-Mallah (2014) for castor oil biodiesel. Also, the value is greater than the maximum value as specified by ASTM as indicated Table 1. Hence, direct use of the oil might cause corrosion in the engine fuel system and the biodiesel may decompose into different products. Hence, the oil should be neutralized prior to storage or use in the diesel engine.

### 3.2.3 Saponification Value

The saponification value of the biodiesel as presented in Table 1 is  $183.63 \pm 2.00$  mgKOH/g which is comparable with the result (182.40 mgKOH/g) for castor oil biodiesel obtained by Encinar et al. (2010) and (179.06 mgKOH/g) obtained by Al-Harbawy and Al-Mallah (2014). The saponification is useful for the detection of oil or fat with a high proportion of the lower fatty acid (Mohibbe et al., 2005). Ester value is a measure of the amount of saponifiable glyceride in the oil (Omahu and Omale, 2017). The ester value was determined by subtracting the acid value from the saponification value. The biodiesel has a high ester value of  $181.10 \pm 0.00$  mgKOH/g and this was justified by the GC/MS analysis which indicates 99.1212% fatty acid methyl ester contents.

### 3.2.4 Iodine Value

The more iodine is attached, the higher is the iodine value, and the more reactive, less stable, softer, and more susceptible to oxidation and rancidification is the oil/ fat (Sokoto et al., 2011). In Table 1, the iodine value of the biodiesel produced is  $82.57 \pm 1.00$  gI<sub>2</sub>/100g which is greater than (58.34 gI<sub>2</sub>/100g) obtained by Al-Harbawy and Al-Mallah (2014). And, similar result (82.49 gI<sub>2</sub>/100g) was obtained by Encinar et al., (2010). The iodine value obtained shows low degree of unsaturated fatty acid methyl esters and coincided with GC/MS results, which show major methyl esters (9- octadecenoic acid - 12- hydroxyl-, methyl ester, [R-(Z)]- (86.1838%), 9- octadecenoic acid [Z]-, methyl ester (10.0618%)) which are monounsaturated compounds. The iodine value is within ASTM specification for Biodiesel (Table 1).

### 3.2.5 Kinematic Viscosity

Kinematic viscosity is the most important property of oil because it affects the fluidity, lubricity and atomization of the fuel (Srinibas and Satyarthi, 2011). Whereas the viscosity of produced biodiesel as presented in Table 1, was about  $7.32 \pm 0.50$  mm<sup>2</sup>/s at 40 °C. The value is slightly lower than 9.8mm<sup>2</sup>/s determined by Rengasamy et al. (2014). Exactly 95.4% reduction was achieved in kinematic viscosity by a transesterification reaction. The obtained result is not within the ASTM standard (1.9-6.0 mm<sup>2</sup>/s). The similar kinematic viscosity values castor oil biodiesel of 14.85 and 24.0mm<sup>2</sup>/s were observed by Encinar et al., (2010) and Srinivas et al., (2011) respectively. The reason for the higher viscosity of the castor oil biodiesel is due to the presence of hydroxyl group in its 12th carbon molecular structure of 9- octadecenoic acid, 12-hydroxyl-, methyl ester [R-(Z)]- which is the predominant ester in the oil, as reported by Deshpande et al. (2012). Therefore the direct use of the biodiesel produced may lead to poor combustion and increases exhaust emission. Hence, the produced biodiesel may be used as fuel by adding additives or by blending with petrodiesel.

### 3.2.6 Specific Gravity

The specific gravity is a key fuel property, which affects the mass of fuel injected into the combustion chamber. This property directly affects the engine performance characteristic because the fuel injection pump meter works on by volume, not by mass (Rengasamy et al., 2014). After transesterification process, the specific gravity of biodiesel as presented in Table 1 was reduced to  $0.92 \pm 0.00$ . The obtained value is slightly greater than the specification of biodiesel ASTM D6751 standard. A similar result was observed by Encinar et al. (2010) which found that the specific gravity of castor oil biodiesel was 0.917 using 1 wt% of potassium methoxide as catalyst. The specific gravity of obtained biodiesel was observed to be slightly higher than that of the conventional diesel. This result indicates that the slightly greater mass of obtained biodiesel may be delivered into the diesel engine.

### 3.2.7 Flash Point

The flash point is the minimum temperature at which fuel gives momentary flash on ignition under specified test conditions. It is an important parameter for storage, handling and safety of the fuel. The flash

point of biodiesel produced at optimum yield in Table 1 is  $161.00 \pm 0.00$  °C. This value is within the standard of 100 to 170 °C as indicated in the ASTM standard. The flash point value obtained is higher than 205 °C and 200 °C obtained by Encinar et al., (2010) and Srinivas et al., (2011) respectively. Based on the results, the produced biodiesel is considered to be safer for storage and handling purposes when compared to the conventional diesel.

### 3.2.8 Cloud Point and Pour Point

The cloud point is the temperature at which dissolved solids are no longer completely soluble, precipitating as a second phase giving the fluid a cloudy appearance (Rengasamy et al., 2014). While the pour point is carried out to determine the freezing point of the sample. In Table 1, the cloud and pour point of the biodiesel are 5.2 and -15.90 °C and a similar result was obtained by Rengasamy et al. (2014) (6 °C). Sumathi et al. (2008) which observed that the cloud point for castor oil biodiesel produced using acid/base catalyst was 3 °C. All the values of pour point and cloud point of the biodiesel obtained are within ASTM standard as presented in Table 1. The result of the study suggests that the obtained biodiesel may be used as fuel at low temperatures as it met the ASTM standard of pour and cloud point.

### 3.2.9 Refractive Index

This is the measure of the extent to which radiation is refracted on passing through the interface between two media. It indicates the clarity of the oil. The refractive index of the biodiesel obtained is  $1.47 \pm 0.00$ . A similar result was obtained by Nakarmi and Joshi, (2014), and (1.467) was obtained by Al-Harbawy and Al-Mallah (2014). The value of the refractive index produced of the biodiesel show that the oil contained minimal or no particulate matter.

### 3.2.10 Cetane Number

Generally, the higher the cetane number, the shorter the ignition delay and the higher the propensity of the fuel to ignite (Mukhtar, et al., 2015). A fuel of higher cetane number gives lower delay period and provides smoother engine operation. Biodiesel has a higher CN than petro-diesel because of its higher oxygen content (Sivaramakrishnan and Ravikumar, 2012). The cetane number of the biodiesel calculated in Table 1 is  $57.45 \pm 0.00$ , similar result (57.11) was obtained by Asmare and Gibbiye (2014). The result obtained is high than (50) of castor oil biodiesel obtained by Ingle and Nandedkar (2016) and lower than 80 obtained by Saribiyik et al. (2010). The value calculated is within the ASTM standard range 48 – 65 and its appreciable good.

### 3.2.11 High Heating Value of Biodiesel Produced

One important parameter of biodiesel fuel is the higher heating value which represents the amount of heat transferred to the chamber during combustion and indicates the maximum amount of energy available in a fuel (Demirbas, 2008). It determines the suitability of the material as an alternative to diesel fuel. The High heating value calculated is 40.66 MJ/Kg as presented in Table 1, which indicate the biodiesel produced contained appreciably high amount of energy. Similar results 40.5 MJ/Kg of castor biodiesel was determined by Asmare and Gibbiye (2014).

### 3.2.12 GC-MS Analysis of Biodiesel Produced

The percentage compositions of fatty acids methyl esters in the biodiesel produced at optimum yield were determined using GC/MS. The relative abundance of the methyl esters, show the presence of hexadecanoic acid methyl ester (1.19%), 9- octadecenoic acid (Z) - methyl ester (10.06%), methyl stearate (1.18%), 9-Octadecenoic acid-12-hydroxy-, methyl ester, [R-(Z)]- (86.18%), and oxacyclotetradecane -2,11-dione-, methyl ester (0.5089), this resulted to 99.1212 % total methyl ester produced. And the other compounds detected which are not methyl ester are L-Arabinitol (0.7797%) and 13-Hexyloxacyclotridec-10-en-2-one (0.0991%).

## 4. Conclusions

The studies of biodiesel production from *R. communis* (castor seed) oil using refluxed calcined snail shell (CaO) revealed: The pretreatments improved the physicochemical properties and efficiency of castor oil used in biodiesel production. The prepared catalyst through thermal hydration method shows significant improvement in its catalytic activity by producing significant amount (99.68 %) of biodiesel yield. The physicochemical properties of the biodiesel produced show that the oil may be used in a diesel engine with little modification or maybe use as an additive to conventional diesel.

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