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Fuel Properties of Biodiesel from Snake Gourd Seeds Oil

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Abstracts:- The study investigates the potentials of Snake Gourd (Trichosanthes cucumerina) seed oil as an oil source for biodiesel production. The snake gourd oil was analyzed, transesterified and characterized using AOAC and ASTM standard methods and analytical procedures. The physicochemical properties of the oil were investigated prior to transesterification. The results showed that, snake gourd oil has an FFA of 1.30%, acid value of 2.59 mgKOH/g, saponification value of 321.08 mg/KOH/g and a refractive index of 1.37. Conversely, the result obtained from the snake gourd biodiesel (SGB) showed a flash point of 292.67°C, cloud point of 2.97°C, pH of 7.97, water content of 0.76%, specific gravity of 0.88, density of 870.95kg/m^3, kinematic viscosity of 0.26 mm^2/s and a cetane number of 84.60. These findings showed that Snake Gourd (Trichosanthes cucumerina) oil has potential for biodiesel production and can be used as an alternative to diesel fuel in diesel engines.

Keywords:- *Biodiesel, Snake Gourd, Transesterification, Diesel, Engines.*

I. INTRODUCTION

Carbon sourced fuels such as petroleum and natural gas have been the dominant sources of global energy supply over the years. However, the non-renewability, continuous depletion and non-environmental friendliness of these energy sources are a major concern to human health, continuous supply and air pollution (Awulu *et al.*, 2015).

Biodiesel is recommended as a substitute for petrol diesel because, biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly fuel with characteristic similar properties to petrol diesel and improved exhaust gas emissions (Ramakrishna *et al.*, 2013). Edible oils such as sunflower, soyabean, rapeseed, corn, and canola have been used for biodiesel production. Non-edible vegetable oils like Jathropha curcas and several others have also been found suitable.

Biodiesel production from edible oil sources has led to the effect of food versus fuel crises resulting in shortage global food shortage (Koh *et al.* 2011). Shifting attention to non-edible oil sources is observed to be more suitable especially in developing countries like Nigeria (Mustafa 2011).

Biodiesel can be produced through a process known as transesterification reaction which involves reacting oil with alcohol and a catalyst at a constant temperature (Mendes, 2011). The alcohol used are either methanol or ethanol, while NaOH and KOH has been adopted as the choiced catalyst in transesterification reactions. catalyzed by bases, acids, and enzymes (Knothe and Staidley, 2005).

Snake Gourd (*Trichosanthes cucumerina*) is a tropical plant that is generally believed to originate from India. Its existence was first discovered in the wild, but later domesticated. The wild specie could still be found in India and other parts of South East Asia, Australia, West Africa, Latin America and the Caribbean (Echo, 2006). The plant is known by different names in different part of Nigeria, among which include Okhuen (Hausa), Oke (Urhobo), Okengbo (Ijaw), Okwe (Igbo) and tomato Elejo (Yoruba). The plant is a member of the family C*ucurbitaceae*, which includes; watermelon, buffalo gourd and sponge gourd. Snake gourd has 70 genera and over 700 species. It is a climbing herbaceous with fruits 40-120 cm long. The unripe fruits are greenish and orange when ripe (Plate 1). A fruit of snake gourd weighs 0.5-1 kg, and contain 40 -70 seeds (Ekam, 2003). The seeds are yellow brown to earth brown with a rough body surface and one plant of a local variety produces 6 - 10 fruits per year, while improved varieties may produce up to 50 fruits per year. In West Africa, the red fruit pulp is used as a kind of cheap tomato paste (Adeniyi and Isiaka, 2013).

The objective of the current study is to investigate its fuel properties of biodiesel produced from snake gourd oil.

Plate 1: Snake Gourd Fruit

II. MATERIALS AND METHODS

Snake gourd seeds (SGS), snake gourd oil (SGO) and other laboratory reagents and apparatus were used for this study while employing AOAC and ASTM standard test methods for the determination of the physicochemical properties.

A. Production of the Biodiesel

The snake gourd biodiesel was produced in batches on laboratory scale 50 ml of the SGO was measured, filtered into 100ml beaker and placed on a magnetic stirrer. 2% m/m of potassium hydroxide (catalyst) pellets was weighed and completely dissolved in 100 ml methanol. The mixture was added to the oil and the entire content brought to a temperature of 60ºC. This mixture was maintained at this temperature with consistent mixing with the aid of the magnetic stirrer at a speed of 600 rpm for about half an hour. The mixture was then transferred into a separating funnel and left-over night for good separation of the glycerin phase at the bottom and biodiesel phase at the top. The glycerin was drained off and the biodiesel retained in the flask. The biodiesel was transferred into a beaker, washed with warm water and oven dried at 105ºC for 1hour to remove all traces of water before bottling.

B. Determination of Snake Gourd Oil Physicochemical Properties

➢ *Refractive Index*

The refractive index which measures the oil level of purity was determined with a Refractometer using the method described by AOAC. The snake gourd oil was dropped on the glass slide of the refractometer and a stream of water at 25°C circulated round the glass slide to keep its temperature uniform. Through the eye piece of the refractometer the dark portion viewed was adjusted to be in line with the intersection of the cross. At the no parallax error, the pointer on the scale pointed to the refractive index. This was repeated three times and the mean value recorded as the refractive index of the oil sample.

➢ *Acid Value and Free Fatty Acid*

The acid value and free fatty acid of the SGO was determined using the method described by AOAC (2000) and was calculated using equation 1 (AOAC, 2000).

$$AV = \frac{56.1VN}{W_o} \quad (1)$$

Where;

- AV = Acid value
- V = Volume potassium hydroxide (ml)
- N = normality of KOH
- W_o = Weight of the oil sample (g)

The free fatty acid (FFA) was obtained by multiplying the acid value by 0.503 (Akubugwo *et al.*, 2008) using equation 2.

$$\%FFA = 0.503 \times Acid\ value \quad (2)$$

➢ *Iodine Value*

The iodine number was determined using the sodium thiosulphate volumetric method described by AOAC (2000).

➢ *Saponification Value*

The saponification value was determined using the method described by AOAC (2000).

➢ *Specific Gravity and Density*

The specific gravity of the samples was determined using a 50 ml specific gravity bottle. The weight of the bottle was noted and recorded as W_1. The bottle was then filled with the oil sample and weighed, the weight was noted and recorded as W_2. The specific gravity bottle was washed dried and filled with water and weighed, the weight was noted and recorded as W_3. Equation 3 was used for calculating the SGO specific gravity and density was calculated using equation 4.

$$SG = \frac{W_5 - W_4}{W_6 - W_4} \quad (3)$$

Where:

- SG = Specific gravity
- W_4 = weight of specific gravity bottle (g)
- W_5 = weight of specific gravity bottle and oil (g)
- W_6 = weight of specific gravity bottle and water (g)

$$\rho = \frac{W_5 - W_4}{V_w} \quad (4)$$

Where;

- ρ = Density (kg/m^3)
- W_5 = weight of specific gravity bottle (g)
- W_4 = weight of specific gravity bottle and oil (g)
- V_w = volume of water (50.0 cm^3)

➢ *pH*

The pH was determined with a pH meter using AOAC, 1990 standard method for pH of oil and fats. The pH meter was immersed in a buffer 7 solution, allowed to equilibrate and adjusted to read 7 (neutral). It was removed from the buffer solution, rinsed and wiped gently with a clean piece of soft tissue paper. It was thereafter immersed in the oil sample and allowed for some time to equilibrate after which the readings were noted and recorded.

➢ *Water Content*

The water content was determined using AOAC (2000) standard methods. The water content for the sample was calculated using equation (5).

$$WC = \frac{w_w - w_d}{w_w - w_e} \quad (5)$$

- WC = water content (%)
- W_e = mass of empty beaker (g)
- W_w = mass of beaker and wet oil sample (g)

- W_d = weight of beaker and dry oil sample (g)

➢ *Peroxide Value*

The peroxide value was determined using the method described by AOAC (1990). About 1g of the oil sample was weighed into a clean boiling tube and 20ml of solvent mixture (20ml acetic acid + 20ml carbon tetrachloride) was added and boiled for 60 seconds. The content was then poured into a titration flask containing about 20ml of potassium iodide (KI) and titrated with 0.002M sodium thiosulphate solution, using starch as indicator. Blank titration was also carried out. The peroxide value was calculated using equation 6 (AOAC, 1990).

$$PV = \frac{(b-a)\times 0.002\times 100}{W_x} \quad (6)$$

Where;

- PV = Peroxide value
- a, b = standard solution of sodium thiosulphate solution for sample and blank
- W_x = weight of sample (g)

➢ *Flash Point and Fire Point*

The flash point and fire point were determined using the Pensky Marten (Open Cup) method described by AOAC (2000).

➢ *Cloud Point and Pour Point*

The cloud point and pour points were determined using the method described by AOAC (2000).

➢ *Kinematic Viscosity*

The kinematic viscosity of the oil was determined using a digital laboratory viscometer. 200ml of the samples at 40 ^{0}C were weighed into a beaker and transferred into the viscometer at a speed of 60 rpm. The viscometer was allowed to run for sometimes and reading were obtained and recorded in (mm/s^2). The kinetic viscosities of the samples were calculated by dividing the values obtained by the sample's density.

➢ *Cetane Number*

The cetane number of the biodiesel was determined using the formula proposed by Demirbas (1998).

$$CN = 46.3 + \frac{5458}{SV} - 0.225 \times IV \quad (7)$$

Where:

- CN = cetane number
- SV = saponification value
- IV = iodine value

III. RESULTS AND DISCUSSIONS

➢ *Physicochemical Properties of the Snake Gourd Oil*

The results from Table 1 showed that the SGO has a refractive index of 1.37. These results are similar with the study by Nzikou *et al.*, (2010) who reported a refractive index of 1.36-1.37 for the crude oil of pumpkin seeds. The refractive index is an important parameter that indicates the level of purity, rancidity and concentration of oils.

The FFA which measures the percentage of free fatty acids of the SGO was found to be 1.30%. The FFA of the snake gourd oil found was similar to the value of 1.21% reported by Adeniyi and Isaika (2013) for snake gourd oil. The FFA value of 1.30% falls within recommended range of 0.5 – 1.5% for oils which do not require alkaline pretreatment prior to transesterification and oils of high quality Onoh *et al*. (2018). The oil has an acid value of 2.59mgKOH/g which is similar to the 2.58mgKOH/g value reported by Onoh *et al.* (2018) for African pear seed oil.

The saponification value of the SGO was found to be 321.08meq/KOH/g which was slightly higher than the 317.27meq/KOH/g reported by Adeniyi and Isiaka (2013). The high saponification value showed that the oil has low molecular weight (200meq/KOH/g and above) and suitable for soap making (Schinas *et al.*, 2008), hence separation of products will be exceedingly difficult. Oils with high saponification values also account for low biodiesel yield when not properly separated.

The iodine value of the SGO was found to be 9.98gI_2/100g which was less than the value reported for African pear oil which was 23.9gI_2/100g (Onoh *et al.*, 2018). The iodine value of the SGO (9.98 gI_2/100g) falls within (0 – 100 gI_2/100g) for non-drying oils and oils that at liquids at room temperature (Omotoso *et al.*, 2011).

Table 1 Physicochemical Properties of Snake Gourd Oil

Properties	**value**
Refractive index	1.37
FFA (%)	1.30
Acid value (mgKOH/g)	2.59
Saponification value (meq/KOH/g)	321.08
Iodine value (100gI_2/100g)	9.98

➢ *Fuel Properties of the Snake Gourd Biodiesel*

The results reseed in Table 2 shows that, the snake gourd biodiesel (SGB) has a water content of 0.76%. the value found was higher than the 0.025% reported by Oladeji (2015) for biodiesel produced from watermelon.

The density of the SGB was found to be 870.95kg/m^3. This value was within the range of 860 – 900kg/m^3 for biodiesels recommended by ASTM D6751. Muhamed and Hamza (2008) reported a similar value for crude sesame seeds oil. Fuel density directly affects fuel performance, as some of the engine properties, such as cetane number, heating value and viscosity are strongly connected to density. The density of the fuel also affects the quality of atomization and combustion. The high density of the SGB is an indication of high fuel quality.

The specific gravity of the SGB was 0.88 similar to the ASTM D6751 specifications of 0.88 but lower than the 0.92 reported by Adeniyi and Isiaka (2013). Specific gravity is an indication of fuel composition, fuels with low specific gravity (< 0.80) burns faster while fuels with high specific gravity (>0.80) are slow burning fuels (Wenqiao *et al.*, 2004). The high specific gravity (0.88) of the SGB shows that it is a slow burning fuel.

The kinematic viscosity of the SGB was 0.26 mm^2/s. The value was lower than the 3.73 mm^2/s and 1.02 mm^2/s reported by Adeniyi and Isiaka (2013) and Awulu et *al.* (2015) for snake gourd seed biodiesel and biodiesel produced from mixture of rubber seed and calabash seed oil respectively. The kinematic viscosity of an oil is an important parameter that affects its flow properties and lubricating ability. ASTM D6751 recommended 1.9 – 6.0 mm^2/s for biodiesels. Values lower than this may cause leakages in fuel systems while higher values lead to decrease fuel flow rate resulting to delays in mixing of air and fuels in the combustion chamber (Dharma *et al.*, 2016). The kinematic viscosity of the SGB is an indication that the fuel has potential to improve fuel economy by reducing friction and lowering greenhouse gases.

The pH of the SGB was found to be 7.97. Sarker (2016) reported a similar pH value of 7.8 for biodiesel from jatropha curcus oil. The recommended value for pH of biodiesel according to ASTM D6751 is ~ 7.

Table 2 Fuel properties of SGB and ASTM standards

Properties	SGB	ASTM D6751
Water content (%)	0.76	0.050 max
Density (kg/m^3)	870.95	860 - 900
Specific gravity @ 25°C	0.88	0.88
Kinematic viscosity @ 40°C (mm^2/s)	0.26	1.9 - 6.0
pH	7.97	7
Flash point (°C)	221.33	130.0 min
Fire point (°C)	255.33	-
Cloud point (°C)	3.67	Report value
Pour point (°C)	0.33	– 15 - 10
Cetane number	84.60	47 min

The peroxide value of the SGB was found to be 4.56meq/kg. The low peroxide value of the SGB is an indication that the biodiesel is fresh and less susceptible to further oxidation and can be stored for a long time.

The flash point of the SGB was 221.33°C. These values are higher than those reported by Akpan *et al.* (2006) for the biodiesel produced from coconut oil, which was 210°C. The high flash point (< 200°C) of the SGB indicates that it is non-flammable, and safe for handling and storage. These values fall within the ASTM D6751 flash point specifications for diesel and biodiesel which is in the range of 60 – 80°C and ≥ 120°C.

The fire point of the SGB was found to be 255.33° which is an indication that the SGB is free from fire hazards. Oladeji (2015) reported a lower value (123°C) for watermelon oil biodiesel.

The SGB has a cloud and pour points of – 1.67°C and 0.33°C respectively. The cloud and pour points of the SGB were found to be lower than the 5°C and 2°C reported by Hadiza *et al.*, (2020) for watermelon seed oil. The cloud point of the SGB was within the range of – 3 to 15°C recommended by EN 14214. The pour point of the SGB of 0.33°C fall within the range recommended by ASTM D6751 which is −15 - 10°C. The low cloud and pour points are indication that the SGB can flow at room temperature.

The cetane number of the SGB was found to be 84.60 which is higher than the 44.47 and 76.8 reported by Oladeji (2015) and Hadiza *et al.* (2015) for watermelon biodiesel. The cetane number obtained was in agreement with the range specified by ASTM D6751 and EN 14214 as ≥ 47 and ≥ 51 respectively. Higher cetane number (>50) shortens ignition delay period resulting to incomplete combustion and increase amount of exhaust emissions (Hasan and Rahman 2017).

IV. CONCLUSION

Biodiesel was produced through transesterification of snake gourd oil with methanol (alcohol) and using potassium hydroxide (KOH) as the catalyst. The properties of the SGB were investigated to determine its suitability for use as a fuel in diesel engines. The SGB has a flash point and cetane number higher than those of diesel fuel. The high flash point of the SGB makes it safer for handling and storage whereas the high cetane number is an indication of better combustion properties. Therefore, snake gourd biodiesel is suitable for use as a substitute for conventional diesel fuel.

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