Physiochemical Characterization of B20 Biodiesel from Arachis Hypogaea Oil as Alternative Fuel for Marine Diesel Engines

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Abstract: For decades, research has scaled up in the production of an eco-friendly and efficient alternative fuel, that can be used in place of regular fossil fuel in marine diesel engines. This research work deals with the production of biodiesel B20 from Arachis Hypogaea oil, through transesterification process; a mixture of 20% Biodiesel and 80% Petroleum Diesel, for use in marine diesel engines. The results indicated a better performance characteristics, when the physical and chemical properties of the produced B100 and B20 blend was compared with B100 standard and Petroleum Diesel. From the research, it was concluded that B20 biodiesel blend can be used as an alternative fuel for marine diesel engines without any form of engine modification.

Keywords: Transesterification, Biodiesel, Engines, Arachis Hypogaea Oil, Characteristics, Marine

I. INTRODUCTION

Due to depleting fossil fuel deposits [1] the world over, growing environmental concern [2][3] has made renewable energy a very attractive energy source for the future. According to [4] the interest in biodiesel as a renewable energy source in the long-term has increased in recent years. Biodiesel is an environmentally friendly substitute liquid fuel that can be used in any diesel engine devoid of modification [5].

Biodiesel is a fatty acid ethyl ester or methyl prepared from used or virgin vegetable oils and animal fat [6]. According to [7] biodiesel are non-toxic biofuel, biodegradable, which possesses inherent lubricity and also reduces exhaust emission. A great number of studies have shown that biodiesel is one of the most encouraging renewable, alternative and environmentally friendly biofuels which could be used in diesel engines with little or no requirement for engine alteration [3].

Due to stringent engine emission regulations [8] by the International Maritime Organization (IMO) and other regulatory agencies [9], marine diesel engine operators have resulted to the use of multi-injection strategies, exhaust gas after treatment and clean alternative fuels like biodiesel [8]. [10] Submitted that biodiesel is the most promising renewable energy source with a high potential for replacing petroleum-derived diesel fuel because of their similarity in chemical properties.

Advantages of Biodiesel:

The choice of the researchers to produce blends of biodiesel as replacement for petroleum-diesel in the running of marine diesel engines is due to its advantages. [11] In their research posited that the higher oxygenated state of biodiesel compared to conventional diesel leads to lower carbon monoxide (CO) production and abridged emission of particulate matter. According to [12] a major advantage of biodiesel over petroleum-diesel is its renewability.

Petroleum is absent from biodiesel, but could be blended at any level with petroleum diesel to create a biodiesel blend that can be stored just like petroleum diesel fuel and hence requires no separate
infrastructure for storage purposes [6]. Biodiesel is a biofuel that has reduced exhaust emission, with relatively high flash point in comparison to petroleum diesel [7]. According to [13] biodiesel production and usage reduces a countries reliance on crude oil imports, creates job and increases farmers income.

**Arachis Hypogaea (Groundnut):**
Groundnut is one of the major economically important legumes [14] found in Nigeria. Groundnut provides an inexpensive source of high quality oil of about 50% and dietary protein [15], it is also the fifth most produced oil crop the world over [16-17]. According to [17] groundnut is the fifth most important oilseed crop in the world after soybean, cotton seed, rape seed, and sunflower seed. The Arachis Hypogaea was chosen for the production of the biodiesel due to its high prevalence in Nigeria.

**Problem Statement:**
Nigeria is one of the nations affected by the global fuel crisis, as petroleum is her major source of revenue [18]. This effect is felt in all regions in Nigeria. With the consistent exploration of natural gas and petroleum, it is predicted that petroleum fuel will ultimately get exhausted [19] at some point in Nigeria. Coupled with the stringent engine emission regulations as attributed to in their researches [7-9]. Hence the urgent need to scale up the production of an alternative fuel like biodiesel.

**Aim of Study:**
The aim of this study is the production of B20 Biodiesel blend from Arachis Hypogaea for use in marine diesel engines and to carryout chemical characterization on the biodiesel produced.

**Objective of Study:**
The objective of this research includes;
- The production of B20 Biodiesel blend.
- To carryout physical and chemical characterization on the biodiesel produced.
- To compare the physical and chemical properties of the produced blend

**II. MATERIALS AND METHODS**
Groundnut seeds bought from Opolo market, Yenagoa, Bayelsa state, Nigeria were used for this research work. The seeds were processed using mechanical extraction method. The extracted oil was trans-esterified to produce alcohol esters using a multiple batch process, wherein small quantities are esterified in batches at different times. Also, petroleum diesel fuel used for blending was bought from a local filling station in Wilberforce Island, Bayelsa State, Nigeria. Methanol was used as the preferred alcohol to trans-esterify the extracted groundnut oil.

**Trans-Esterification Reaction:**
The main components used in the manufacturing of biodiesel are fats and oils derived from plants or animal fats, with slightly different properties [20]. Animal fats and oils contain triglycerides, which are esters that contain three fatty acids and a glycerol molecule [19]. Through transesterification, these esters, in the presence of methanol or ethanol, react to form mono-alkyl esters, also known as biodiesel [18]. However, this reaction is rather slow, so a base catalyst of either NaOH, KOH, NaOCH₃, or KOCH₃ is added. This normally yields up to 98% conversion in a relatively short period of time [20]. Glycerol is a byproduct of this reaction and since biodiesel and glycerol form two distinct phases, they can be easily separated [21-22].
Batch Processing:
The simplest method for producing alcohol esters is to use a batch, stirred tank reactor. Alcohol to triglyceride ratios from 4:1 to 20:1 (mole: mole) have been reported with a 6:1 ratio most common [20]. The reactor may be sealed or equipped with a reflux condenser. The operating temperature is usually about 65°C, although temperatures from 25°C to 85°C have been reported [20][22]. The most commonly used catalyst is sodium hydroxide and potassium hydroxide with loading ranges from 0.3% to about 1.5% [20].

Thorough mixing is necessary at the beginning of the reaction to bring the oil, catalyst and alcohol into intimate contact. Towards the end of the reaction, less mixing can help increase the extent of reaction by allowing the inhibitory product, glycerol, to phase separate from the ester-oil phase. Completions of 85% to 94% are reported [20][23].

Some groups use a two-step reaction, with glycerol removal between steps, to increase the final reaction extent to 95+% [20]. Higher temperature and higher alcohol: oil ratios can enhance the percent completion and typical reaction times range from 20 minutes to more than one hour [23]. In batch processing, the trans-esterification is done in one stage only, with the advantage that it saves time.

Materials Used for Each Batch:
- 1 liter of Arachis Hypogaea oil
- 200 ml of Methanol (99% pure)
- 5.3 grams of Potassium hydroxide (KOH)
- Weighing scale
- Beakers
- Translucent HDPE containers
- Funnel
- Duct tape

![Figure 1: Materials used for the batch processing of bio diesel](image)

Phase Separation:
Phase separation of the products of transesterification was achieved easily. After settling, glycerin (the heavier liquid layer) settled to the bottom, while the product of esterification floated on top. The ester (Biodiesel) layer was drained off by decanting while the glycerin in the bottle remained. Figure 2 below shows the phase separation showing the produced Biodiesel and glycerol by-product.
Preheating of Arachis Hypogaea Oil:
The Arachis Hypogaea oil was preheated to a temperature of about 55°C before been used for the esterification process. The percentage losses are recorded in table 1 below. The free fatty acids and phospholipids were responsible for the losses recorded after preheating. The oil extracted depicted moderate acid value, which may have been responsible for its small percentage loss.

Table 1: Shows percentage loss of Arachis Hypogaea oil in the different batch test after preheating

| TEST BATCH | WEIGHT OF OIL (g) | WEIGHT OF OIL AFTER PREHEAT (g) | PERCENTAGE LOSS (%) |
|------------|------------------|---------------------------------|---------------------|
| Batch A    | 1000             | 974                             | 2.6                 |
| Batch B    | 1000             | 968                             | 3.2                 |
| Batch C    | 1000             | 981                             | 1.9                 |

Production of Biodiesel and B20 Blend:
The result of the production of biodiesel and B20 blend is studied, where data as regarding the experimental conditions of the esterification processes for each of the test batches are examined. Table 2 shows the test result in batches in relation with the experimental conditions.

Table 2: Result of Arachis Hypogaea oil trans-esterification to produce biodiesel B100

| S/N | EXPERIMENTAL CONDITIONS | 1ST BATCH | 2ND BATCH | 3RD BATCH | AVERAGE |
|-----|-------------------------|-----------|-----------|-----------|---------|
| 1   | Reaction temperature   0°C | 55        | 55        | 55        | 55      |
| 2   | Reaction time (mins)    | 120       | 120       | 120       | 120     |
| 3   | Groundnut Oil quantity (g) | 974       | 968       | 981       | 974.33  |
| 4   | Methanol quantity (g)   | 200       | 200       | 200       | 200     |
| 5   | KOH concentration (g)   | 5.3       | 5.3       | 5.3       | 5.3     |
| 6   | Biodiesel obtained (g)  | 915.20    | 914.40    | 916.03    | 915.21  |
| 7   | Glycerol obtained (g)   | 86.8      | 87.6      | 85.97     | 86.79   |
| 8   | Losses (g)              | 177.3     | 171.3     | 171.3     | 171.3   |
| 9   | Biodiesel yield (%)     | 93.96     | 94.46     | 93.38     | 93.93   |

From table 2, an average percentage yield of 93.93% was obtained, through the multiple batch processing technique.

\[ Y = \frac{W_e}{W_r} \times 100\% \]

Where,

\( Y = \) Yield of the ethyl esters in %
\[ W_e = \text{Weight of ethyl esters produced in grams} \]

\[ W_r = \text{Weight of raw oil used in grams} \]

For 1\textsuperscript{st} batch; \[ Y = \frac{915.20}{974} \times 100 = 93.96\% \]

For 2\textsuperscript{nd} batch; \[ Y = \frac{914.40}{968} \times 100 = 94.46\% \]

For 3\textsuperscript{rd} batch; \[ Y = \frac{916.03}{981} \times 100 = 93.38\% \]

The Loss was calculated by subtracting the summation of Groundnut oil, Methanol and Potassium hydroxide from the summation of the produced biodiesel and glycerol by-product, as shown in the table 2.

### III. PHYSICAL AND CHEMICAL CHARACTERIZATION OF PRODUCED BIODIESEL

Physical and chemical characterization was carried out on the produced biodiesel. The following properties were studied; specific gravity, kinematic viscosity, moisture content, flashpoint, cloud point, pour point, Sulphur content, carbon content, hydrogen content, oxygen content, saponification value, and cetane number. The data from the produced biodiesel, is shown in table 3.

**Table 3: Comparisons between the physical and chemical properties of produced biodiesel blends with ASTM standard recommendations**

| S/N | PROPERTIES                  | BIODIESEL PRODUCED | ASTM STANDARD (D7467-18) |
|-----|-----------------------------|--------------------|---------------------------|
| 1   | Specific gravity \( \frac{kg}{l} \) | 0.89               | 0.88                      |
| 2   | Kinematic viscosity \( mm^2/s \) | 3.29               | 1.9 - 6.0                 |
| 3   | Density \( kg/m^3 \)         | 892                | 860 - 900                 |
| 4   | Pour point \( {^\circ}C \)   | -3                 | -15 - 10                  |
| 5   | Moisture content, % volume   | 0.032              | 0.02                      |
| 6   | Cloud point \( {^\circ}C \)  | 10                 | -3 - 12                   |
| 7   | Flash point                  | 152                | 130                       |
| 8   | Cetane number                | 54                 | 52 - 56                   |
| 9   | Saponification value         | 194                | 192                       |
| 10  | Calorific value              | 39,820             | 37,250                    |
| 11  | Carbon (wt. %)               | 77                 | 100                       |
| 12  | Hydrogen                     | 12                 | 10                        |
| 13  | Oxygen                       | 11                 | 8                         |
| 14  | Sulphur Content (ppm)        | 1                  | <10                       |

From table 3, it is observed that some properties such as specific gravity, kinematic viscosity, density, pour point, moisture content, cloud point, and cetane number fell within the ASTM recommended range. The flash point of the biodiesel was 152, which is slightly higher than the 130 standard value. The Calorific value of the produced biodiesel was slightly higher than the standard value. Hydrogen and Oxygen values were close to the standard value, while the Carbon and Sulphur contents of the produced biodiesel was lower than the ASTM standard recommendation.

**Comparison of the Physical and Chemical Properties:**

Table 4: Comparisons between physical and chemical properties of produced biodiesel B20 blends with ASTM Standard recommendations for and biodiesel petroleum diesel
| S/N | PROPERTIES             | Biodiesel Produced | B20 Blend | ASTM Petroleum Diesel (D975-18) | ASTM Biodiesel (D7467-18) |
|-----|------------------------|--------------------|-----------|---------------------------------|--------------------------|
| 1   | Specific gravity (kg/l)| 0.89               | 0.65      | 0.85                            | 0.87 – 0.90              |
| 2   | Kinematic viscosity (mm²/s) | 3.29             | 3.11      | 3.10                            | 1.9 – 6.0                |
| 3   | Density (kg/m³)        | 892                | 842       | 830                             | 875 – 900               |
| 4   | Pour point (°C)        | -3                 | -8        | -35 to -15                      | -15 – 16                 |
| 5   | Moisture content, %    | 0.032              | 0.04      | 0.05 max                        | 0.02                     |
| 6   | Cloud point (°C)       | 10                 | 2         | -15 to 5                        | -3 to 12                 |
| 7   | Flash point            | 152                | 80.5      | 60 – 80                         | 100 - 170               |
| 8   | Cetane number          | 54                 | 51.6      | 40 – 55                         | 48 - 65                  |
| 9   | Saponification value   | 194                | 124       | -                               | -                        |
| 10  | Calorific value (J/Kg) | 39,820             | 42,730    | 45,520                          | 4,2120                   |
| 11  | Carbon (wt. %)         | 77                 | 85        | 87                              | 100                      |
| 12  | Hydrogen               | 12                 | 19        | 13                              | 10                       |
| 13  | Oxygen                 | 11                 | 5.1       | -                               | 8                        |
| 14  | Sulphur Content (ppm)  | 30                 | 40        | 50                              | <10                      |

**SPECIFIC GRAVITY**

The specific gravity recorded for the produced biodiesel is higher than the value obtained for petroleum diesel. The specific gravity according to ASTM D6751 for petroleum diesel is 0.85, while for biodiesel 0.88. This is similar to the findings of this research. Also the B20 blend had a lower specific gravity value. Figure 3 shows a chart of produced biodiesel, B20 blend, ASTM Standard for biodiesel and petroleum diesel against their various recorded specific gravities.

![Figure 3 Shows specific gravity for produced biodiesel, petroleum diesel, blended biodiesel and ASTM standard biodiesel](image-url)
KINEMATIC VISCOSITY

From figure 4, it is seen that the produced biodiesel has a higher kinematic viscosity than petroleum diesel. The B20 blend also has a higher viscosity compared to petroleum diesel.

![Kinematic Viscosity Comparison Chart]

Figure 4 Shows Kinematic Viscosity for produced biodiesel, petroleum diesel, blended biodiesel and ASTM standard biodiesel

MOISTURE CONTENT

The moisture content of the produced biodiesel as shown in table 5, is the quantity of free water contained in petroleum diesel. The implication of this is that there will be more smoke, hard starting and less power, if not removed totally.

![Moisture Content Chart]

Figure 5 B100, B20, P100 ASTM and B100 ASTM against moisture content

CARBON CONTENT

It can be seen from figure 6 that petroleum diesel had reflected the most carbon content when compared to the produced B100 and B20 blends. The B20 blend had a higher carbon content than the produced B100, but significantly lower than petroleum diesel. The implication of a lower carbon content, is the reduction of residues which clog the fuel injectors and injection pumps of marine diesel engines.
Figure 6 Carbon content of B100 and B20 blends and comparisons with ASTM standard levels

CLOUD POINT
From table 7, petroleum diesel depicted a cloud point of 4°C, the produced B100 has a cloud point of 10°C, while the B20 blend recorded a moderate cloud point 2°C.

Figure 7 shows comparison between cloud points of B100 and B20 blends against ASTM standard values

FLASH POINT
From figure 8, the produced biodiesel had the highest flash point which was followed by the B20 blend, and lastly the petroleum diesel.

Figure 8 shows comparison between flash points of B100 and B20 blends against ASTM standard values
CETANE NUMBER
From figure 9, the produced Biodiesel has the highest cetane number which is followed by the B20 blend, and lastly the petroleum diesel. The implication of a higher cetane number, is better engine performance.

![CETANE NUMBER](image)

*Figure 9 shows B100, B20, P100 ASTM and B100 ASTM*

SAPONIFICATION VALUE
From the figure 10, it is seen that the produced B100 has a greater saponification value of 194, compared to the B20 blend of 124. There is no saponification value for petroleum diesel.

![SAPONIFICATION VALUE](image)

*Figure 10 shows comparison between saponification values of B100 and B20 blends against ASTM standard values*

SULPHUR CONTENT
From figure 11, it can be seen that petroleum diesel revealed the highest Sulphur content, compared to the produced B100 and B20 blends. The B20 blend revealed a higher Sulphur value when compared to the produced B100 blend.
Figure 11 shows comparison between sulphur contents of B100 and B20 blends against ASTM standard values

CALORIFIC VALUE
Petroleum diesel presented a higher calorific value at 42,500kJ/kg, which was far higher than the B100 blend produced. However, the B20 blend revealed a slightly greater calorific value when compared to petroleum diesel, indicating a better performance in terms of the rate of heat released during combustion in marine diesel engines. The chart below shows a relationship between the calorific values of the produced B100, B20 blends and petroleum diesel.

Figure 12 shows comparison between calorific values of B100 and B20 blends against ASTM standard values

IV. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION
In Nigeria, there is an ever increasing use of fuels for transportation (land, air and Sea) rising prices of fossil fuel, climate change and environmental pollution from combustion of fossil fuels, as well as the need for a green environment. This demands the use of renewable energy sources for a more sustainable energy solution. The following conclusions could be drawn from the present study:

i. Biodiesels can be produced with multiple batch transesterification technique.
ii. The B20 blend produced revealed better fuel properties when to the produced B100.
iii. The B20 blend produced depicted better emission properties than petroleum diesel, hence mass production should be encouraged.
iv. The B20 blend can be used on marine diesel engines without modification.
Lastly, relying on fossil fuel alone is no longer realistic due to global depletion of the non-renewable energy resources, its attendant negative environmental impact. The race for energy security in the face of imminent oil shortage is already gathering momentum. Countries in Asia, Europe, South American and many US state governments are not waiting for their fossil fuel to dry up completely before searching for alternative, and only countries that don’t value their own energy security and that of their citizens would stand aloof.

5.2 RECOMMENDATION

In future, a lot of work can be done to reduce the cost of production of B20 biodiesel blend for marine diesel engines, if we consider non-edible oils or waste frying oils instead of edible oils. Non edible oils such as Neem, Karanja, Jatropha etc., are easily available in Nigeria and very cheap compared to edible oils. With the proliferation of fast food centres and restaurants in Nigeria, it is expected that considerable amount of waste frying oils will be discarded. This can be used for making biodiesel and B20 blends. Also potential feedstock for biodiesel production are in abundance in the country (Nigeria).

Nigeria, with her expansive arable land mass, can be one of the world’s leading producers and exporters of B20 biodiesel blend for marine diesel engines and other industrial applications, if the government and shipping authorities puts a premium on energy security like many countries (including United States of America and some European countries). However, there are fears that since biodiesel relies on primary agricultural products, a substantial growth in the biodiesel industry could make the prices of vegetable oil unaffordable to the common man. Hence, our approach to renewable energy sources should be gradual.

Lastly, government should provide funding, enabling environment and an enticing incentives. This involves providing comprehensive policy support and funding for research in the area of renewable energy source.

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