INTRODUCTION

The first biodiesel test was in 1938. This feat was achieved when vegetable oils were discovered as potential fuel for diesel engines. The basic observation in the first biodiesel test was the presence of methyl esters in vegetable oils and animal fats, which raised issues on the sustenance of biodiesel viscosity in diesel engines. Another challenge of biodiesel production was the use of biomass feed from valuable agricultural crops. This may lead to food scarcity in communities that have inadequate agricultural schemes. Biodiesel has been largely produced using edible vegetable oils. Edible plants like rapeseed, soybean, sunflower, palm, and moringa have been used for biodiesel productions in larger scale. The intense use of edible plants for biodiesel production is due to the fact that they are largely produced in some parts of the world. For example, the European Union and some other countries like the United States, Indonesia, and Brazil are the largest producer of biodiesel using edible plant oils.
Soya is a good biomass for biodiesel production. It has high viscosity, heating value, and lubricity properties which makes it suitable for diesel engines. Its shortcoming is its high acid value. So far, the basic test on the derived soya-biodiesels that is certain number, cold flow, oxidative stability, lubricity, and viscosity show that it may be a good substitute for diesel fuel. Olive oil is produced on a large scale in some parts of the world. Spain, Italy, Greece, Turkey, Tunisia, Portugal, Syria, Morocco, Algeria, Lebanon, France, Libya, Jordan, and Israel are the largest producer of olive oil. The cultivation of olive tree is currently high in United States, India, Pakistan, Afghanistan and other Asian, African, and Middle Eastern countries. The choice of olive and soya biomass in this project is to seek new market perspective for biodiesel production. Olive oil has high boiling point and low vapor pressure. Methyl ester present in olive oil has a flash point of 150°C which makes it noninflammable. Also it has the advantage of high kinematic viscosity which is attributed to its chain length, position number, and double bonds nature.

Advancement on biodiesel research has shown that mixing biodiesel with petro-diesel would most likely solve technical challenges like fluid-viscosity and other operational issues. Also, the use of additives (e.g. rapeseed oil methyl ester) can reduce the anthropogenic emissions from biodiesel engines. In recent time, the challenge of cyclic breaking in biodiesel production and usage was discovered in laboratory scale by Emetere et al. The rate of cyclic breaking in ethyl, methyl, and butyl biodiesels were investigated under the same laboratory conditions. The ethyl-biodiesel had less cyclic breaking among the three products. It was proposed that cyclic breaking may be the major causative agent that triggers melting points and flash point issues that was reported by Rashid et al. It is generally accepted that abnormality in biodiesel is caused by the presence of fatty acids in the biodiesel products. However, there are no clear-cut indices on how to detect biodiesel quality since scientists now adopt the use of rapeseed oil methyl ester (and other additives) to curb anthropogenic pollution from engine emissions. The cyclic breaking concept has been proven to be accurate in understanding the quality of biodiesel. Hence it can be used as complimentary experiment in-place of already known techniques as cetane number of biodiesel, advance injection timing, combustion, oxygen contents, engine speed, density, and viscosity. The main focus of this paper is to advance the concept of cyclic breaking in running diesel engine. The study was carried-out using the TQ TD200 diesel engine to understand the parametric analysis of selected biodiesel products. The diesel engine has two strokes and one cylinder. It has a maximum torque of 15 NM, maximum speed of 7000 revolutions per minute and maximum power absorption of 7.5 KW at 7000 revolutions per minute.

**2 | MATERIALS AND METHODOLOGY**

The mode of laboratory preparation of the olive and soya biodiesel is discussed in our recent publication. The equipment and apparatus used in this experiment were sound meter, stop watch, measuring cylinders, density bottles, viscometer tube, viscometer bath, density scale, UV spectrophotometer (2R1R235201), TQ data display unit, and TQ TD200 biodiesel test set and CO meter.

The diesel engine used to perform this experiment is a two stroke engine. A two stroke diesel engine has the same mode of operation as an internal combustion engine, which makes it better than other gasoline engines. A two stroke diesel engine does not have valves that take in air. Rather,
it uses a system called scavenging. Scavenging allows air to enter and leave the engine and this operation is performed by the piston at the center where the intake valve is opened in the cylinder wall. The TD 200 test bed experiment was based on the following speeds which are 2000, 2150, 2169, 2172, 2193, 2200, 2500 revolutions per minute. The description of the diesel engine is shown in Table 1a and the properties of the biodiesels are shown in Table 1b. The preparation of the biodiesels sample has been discussed by Emetere et al.\textsuperscript{9,11}

Mixing of each biodiesel was limited to B10 and B20. In B10, 10\% of each biodiesel product was mixed with 90\% pure diesel. For B20, 20\% of biodiesel was mixed with 80\% of pure diesel. This process was carried out for soya and olive biodiesels. Pure diesel was used as control to understand the efficiency of the biodiesel product. Also, pure diesel was used to normalize the inner mechanism of the diesel after each round of experiment.

The following general observations were made when operating the diesel engine using the biodiesel products:

1. Engine performance (torque and engine power generation) was observed to be reduced.
2. There was also a decrease in torque of the engine.
3. Engine sound was also observed to be higher than when the engine was running on pure diesel.
4. The engine appeared to be overloaded when no load was put on it, that is the power output of the engine running on olive and soya B10 was lower compared to that of pure diesel.
5. Fuel consumption rate was very low.

The quality of the soya and olive biodiesel was tested using the UV Spectrometer. The densities of each biodiesel mixture and the pure diesel were obtained via the use of different density bottles. The viscosity experiment was also carried using a viscometer and a viscometer bath tube. Each test fuels were put in a viscometer and are heated up to a constant temperature of 40°C. The C value for the viscometer used was 7.870 mm\(^2\)/sec.

Aside the parameters gotten from the TD 200 diesel engine, some other vital parameters were calculated using existing formulas. The nominal compression ratio of the engine can be estimated using the following relationship:

\[ P = p_0 \times CR \]

where \( p_0 \) is the cylinder pressure at the bottom dead center which is usually at 1 atm, CR is the compression ratio, and \( \gamma \) is the specific heat ratio for the working fluid, which is about 1.4 for air, and 1.3 for methane-air mixture.

\[ \text{Horsepower} = \frac{\text{Torque}(T_1) \times \text{RPM}}{5252} \]  

The brake mean effect pressure was calculated using

\[ \text{BMEP} = \frac{4\pi T_1}{V_d} \]  

The engine efficiency can be calculated\textsuperscript{13} as:

\[ T_2 = T_1 \left[ 1 + \left( \frac{p_2}{p_1} \right) - 1 \right] \eta_e \]  

The thermal efficiency can be calculated\textsuperscript{13} as:

\[ \eta_t = 1 - \frac{T_1}{T_2} \]  

The derived parameter for the UV spectrometry is also given. Zawadzki et al\textsuperscript{14} quantified the absorption spectroscopy in form of absorbance index that originally measures the shape of the absorbance in the UV absorbance spectra.

\[ \text{AI} = 10\left( \frac{A_{500} - A_{420}}{A_{280} - A_{220}} \right) \]  

where \( \text{AI} = \text{absorbance index}, A_{xxx} = \text{absorbance at the xxx nm wavelength} \). The error due to noise (\%) of the UV absorbance spectra is given by Owen\textsuperscript{15} as

\[ \text{AE} = \frac{(A_i - A_m)}{(A_i \times 100)} \]  

3 \ | RESULTS AND DISCUSSION

The 500 nm wavelength was used as the control to understand the changes in the cyclic nature of the biodiesel. Details on why the 500 nm wavelength was chosen are highlighted by Emetere et al\textsuperscript{9,11} The absorbance of the 500 nm wavelength of soya biodiesel showed no clear peak (Figure 1) while the absorbance of olive biodiesel had four clear peaks. It shows that the cyclic structure in olive biodiesel was more pronounced. Hence, it will be easy to observe how the cyclic structure is preserved as the wavelength is increased. At 600 nm wavelength, the absorbance showed fewer presence of cyclic structure that is judging by the number of peaks (Figure 1A,B). The peaks were more significant at 700 nm (Figure 1C,D). Both biodiesel products had two peaks which signify that the unclear peaks that were noticed in Figure 1A may signify an additional chemical component that is attached to the cyclic structure of the biodiesel. At 800 nm wavelength, soya biodiesel had more peaks than olive biodiesel.

Unlike the absorbance result, the absorbance index showed clear peaks for soya biodiesel at 500 nm wavelength (Figure 2). The soya and olive biodiesel had same number
FIGURE 1 UV spectrometry results for absorbance (A) Soya (500/600) (B) Olive (500/600) (C) Soya (500/700) (D) Olive (500/700) (E) Soya (500/800) (F) Olive (500/800)
FIGURE 2  UV spectrometry results for absorbance index (A) Soya (500/600), (B) Olive (500/600), (C) Soya (500/700), (D) Olive (500/700), (E) Soya (500/800), (F) Olive (500/800)
of peaks at 500 nm and 600 nm wavelengths (Figure 2A,B). Also, both products had the same number of peaks for 700 nm (Figure 2C,D) and 800 nm (Figure 2E,F). Generally, the absorbance index for the olive biodiesel was higher than the soya biodiesel. As stated earlier, the absorbance index displayed the peaks in soya which was hidden under the absorbance. The reason for these anomalies may be adduced to the error due to noise which was considered in Figure 3 below.

More peaks may signify the presence of the frequency of error due to noise of the investigative tool. The peaks for the
soya and olive were distinct (i.e., considering the error due to noise). Hence, aside the earlier hypothesis given, it could be inferred that the noise may also come from the investigative instrument. From recent studies, soya and olive were distinct (i.e., considering the error due to noise). Hence, aside the earlier hypothesis given, it could be inferred that the noise may also come from the investigative instrument. From recent studies, it can be inferred that the concept of cyclic breaking will be more pronounced in the Olive biodiesel than the Soya biodiesel.

The biodiesel was mixed with petro-diesel to obtain soya B10, soya B20, olive B20, and olive B10. The densities of the mixtures are given below (Table 2). The experiment did not go beyond B20 blends because of the capacity of the TD 200 diesel engine. The results of the diesel engine parameters were discussed with respect to time in order to parameterize the processes. The viscosity of the biodiesel blends was measured as shown in Table 3.

The carbon deposition was obtained from the soot deposited on the surface of the foam that was placed at the exit outlet of the exhaust pipe. The soot was weighed using the digital weight balance. Olive biodiesel had the highest carbon deposition. This may be due to incomplete combustion. This can be affirmed from the carbon monoxide emission from

| Test fuels | Weight of density bottles | Weight of the test fuels with the density bottle | Actual weight of test fuels | Actual weight/volume of bottle (50 ml) = actual density |
|------------|---------------------------|-----------------------------------------------|-----------------------------|-------------------------------------------------------|
| Diesel     | 28.0                      | 71.4                                          | 43.4                        | 868                                                   |
| Soya B10   | 33.0                      | 74.9                                          | 41.9                        | 838                                                   |
| Soya B20   | 34.0                      | 76.7                                          | 42.7                        | 854                                                   |
| Olive B10  | 32.0                      | 73.6                                          | 41.6                        | 832                                                   |
| Olive B20  | 28.6                      | 71.7                                          | 43.1                        | 862                                                   |

| Test fuels | Temperature (°C) | Time (sec) | Viscosity (Pa sec) | Estimated carbon deposition (% w/w) | Estimated calorific value (MJ/Kg) |
|------------|-----------------|------------|-------------------|-----------------------------------|-----------------------------------|
| Soya B20   | 40              | 1.44       | 5.6664            | 2.0                               | 39.05                             |
| Olive B10  | 40              | 1.06       | 4.1711            | 3.0                               | 39.64                             |
| Olive B20  | 40              | 1.50       | 5.9025            | 3.5                               | 39.53                             |
| Soya B10   | 40              | 1.42       | 5.5875            | 3.0                               | 39.21                             |
| Pure diesel| 40              | 0.90       | 3.5415            | 1.5                               | 49.6                              |

**FIGURE 4** Operational temperature for pure diesel and biodiesel blend of olive B10 and Soya B10
the exhaust pipe. The carbon monoxide emission of the pure diesel, Olive B10, Olive B20, Soya B10, and Soya B20 is given as 200 g/kWh, 174 g/kWh, 169 g/kWh, 171 g/kWh, and 163 g/kWh respectively. The calorific value for the diesel was the highest. Olive biodiesel had the higher calorific value than soya biodiesel.

The first parameter that was considered was the operational temperature (Figure 4). The operation temperature of olive B10 was the highest (340°C). The maximum temperature for soya B10 was 310°C. The pure petro-diesel had a maximum temperature of 241°C. Hence the temperature of the engine would increase by 41% and 29% for olive B10 and soya B10, respectively. This result shows that the heating rate would be higher for the biodiesel than the petro-diesel. Though the operational temperature of biodiesel blends is within the limit of the engine, it may not be appropriate...
at the long-run because it may lead to overheating of the engine.

The second parameter that was considered was the differential pressure in the engine for the biodiesel and petro-diesel products (Figure 5). The results were negative. In an engine, the negative differential pressure is caused by depression that is created by the energy transferred from the expansion of gases during combustion to the crankshaft via the piston. The seal that is formed between the piston ring and the cylinder wall releases depression on the piston as it travels downward at a high velocity. Hence, soya B10 had the highest depression. The petro-diesel had a lower depression with the highest differential pressure. The olive B10 blend had the longest range of differential pressure. It is proposed that the cyclic breaking in the olive create unimaginable stress on the engine as shown between 20 and 25 minutes. Aside the abnormal depression that will be experienced, it may also infer that both compression and expansion of gases occur during combustion.
The third parameter that was considered was the torque in the engine for the biodiesel and petro-diesel products (Figure 6). Petro-diesel had the highest torque. This means that if the engine were to be an automobile engine, the vehicle would accelerate faster using the petrol-diesel than the blends of biodiesel. Invariably, soya B10 will perform better than olive B10 though they appear to be closely related within a close range of 0.7-1.3 Nm. The power generated by the engine further supports the results of the torque produced (Figure 7). However, the closeness of the maximum and minimum power values for soya and petro-diesel is significant as it depicts the loss in torque, as well as total work done by the piston (Figure 8). The reason for the loss is more related to the outcome of the UV spectrometry experiment which affirms the concept of cyclic breaking. The unclear peaks of the absorbance at 500 nm wavelength are finally explained. The loss in torque produced by the engine was also as a result of cyclic breaking Emetere et al.9,11. If the engine experience high losses, it may lead to the damage of
TABLE 4   Thermal and engine efficiency

| Speed (rev/min) | Thermal efficiency | Engine efficiency ($\gamma = 1.2$) | Engine efficiency ($\gamma = 1.3$) | Engine efficiency ($\gamma = 1.4$) | Engine efficiency ($\gamma = 1.5$) | Engine efficiency ($\gamma = 1.6$) | Engine efficiency ($\gamma = 1.7$) |
|----------------|--------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
|                |                    |                                      |                                      |                                      |                                      |                                      |                                      |
| Soya B10       |                    |                                      |                                      |                                      |                                      |                                      |                                      |
| 2000           | 0.427              | 0.028                                | 0.039                                | 0.049                                | 0.057                                | 0.064                                | 0.071                                |
| 2150           | 0.458              | 0.026                                | 0.037                                | 0.046                                | 0.053                                | 0.060                                | 0.066                                |
| 2169           | 0.435              | 0.030                                | 0.041                                | 0.052                                | 0.060                                | 0.068                                | 0.075                                |
| 2172           | 0.394              | 0.036                                | 0.050                                | 0.063                                | 0.073                                | 0.083                                | 0.091                                |
| 2193           | 0.424              | 0.035                                | 0.048                                | 0.060                                | 0.070                                | 0.079                                | 0.088                                |
| 2200           | 0.453              | 0.035                                | 0.049                                | 0.061                                | 0.071                                | 0.080                                | 0.089                                |
| 2500           | 0.500              | 0.030                                | 0.042                                | 0.052                                | 0.061                                | 0.069                                | 0.076                                |
| Olive B10      |                    |                                      |                                      |                                      |                                      |                                      |                                      |
| 2000           | 0.465347           | 0.023                                | 0.032                                | 0.040                                | 0.047                                | 0.053                                | 0.058                                |
| 2150           | 0.447917           | 0.026                                | 0.036                                | 0.044                                | 0.052                                | 0.059                                | 0.065                                |
| 2169           | 0.467391           | 0.027                                | 0.038                                | 0.047                                | 0.055                                | 0.062                                | 0.069                                |
| 2172           | 0.453488           | 0.034                                | 0.047                                | 0.058                                | 0.060                                | 0.077                                | 0.085                                |
| 2193           | 0.447059           | 0.036                                | 0.050                                | 0.062                                | 0.072                                | 0.082                                | 0.090                                |
| 2200           | 0.475              | 0.042                                | 0.059                                | 0.074                                | 0.086                                | 0.097                                | 0.107                                |
| 2500           | 0.465753           | 0.046                                | 0.064                                | 0.079                                | 0.093                                | 0.105                                | 0.116                                |
| Pure diesel    |                    |                                      |                                      |                                      |                                      |                                      |                                      |
| 2200           | 0.545455           | 0.025                                | 0.034                                | 0.043                                | 0.050                                | 0.056                                | 0.062                                |
| 2500           | 0.68               | 0.015                                | 0.021                                | 0.026                                | 0.030                                | 0.034                                | 0.038                                |
the piston. This stance is supported by Fontaras et al\textsuperscript{20} who reported that the wear of some vital parts of the diesel engine by B50 and B100 biodiesel was because of its iron and copper content. Hence, this observation affirm that the cyclic breaking causes either power or torque losses in engine. It is therefore recommended that the preservation of the cyclic structure of biodiesel blends or pure biodiesel should be taken further than what is reported in this research.

The sound of the engine was analyzed to understand the stress on the piston as well as the pollution to the immediate environment. There are other factors that affect the sound of a diesel engine for example, bore size, stroke length, and crankshaft angles etc. This research considers the stress of the piston as it related to the input fuel. The sound of the engine drops significantly as the biodiesel blends are fed into the fuel tank. Hence, total work done by the engine is significantly reduced when the engine is working on olive B10.

The power lost to the body of the passive area (instrumentation unit) of the engine was calculated using the volume of instrumentation dimension (Figure 9). Unlike the power generated by the engine, the power loss to the passive area is more distinct. The petro-diesel had the highest loss of 10.3%, which is slightly higher than the observation (6.7%) of Murillo et al\textsuperscript{21} This may be related to the sound produced by the engine. The brake mean effect pressure (BMEP) in engine was calculated (Figure 10). The pattern of the three samples (soya, olive, and petrol diesel) considered is synonymous to the pattern of the power loss by the passive area of the engine. Though the biodiesel samples were lower, its difference with the pure petro-diesel was <10%. Muralidharan et al\textsuperscript{21} affirmed that the decreased engine brake power was as a result of uneven combustion characteristics of biodiesel fuel.

Therefore, the general performances of the biodiesel samples via the seven parameters can be considered to be above average. There are evidences of sudden changes in the biodiesel trends. This occurrence is obviously suggestive that the cyclic breaking concept in biodiesel may be the next scientific hurdle.

The thermal and engine efficiency are calculated in Table 4. The engine efficiency was calculated based on a varying specific heat ratios of 1.2, 1.3, 1.4, 1.5, 1.6, and 1.7. The recommended specific heat ratio was 1.2. A moderate scenario can be observed at $\gamma = 1.7$. When $\gamma = 1.7$, the engine may have the worst case scenario. The pure petro-diesel sample produced the highest thermal efficiency and lowest engine efficiency. Soya B10 had the lowest thermal efficiency and the highest engine efficiency that is at any of the specific ratio. Olive B10 was moderate compared to the petro-diesel and soya B10.

4 | CONCLUSION

Biodiesel has been successfully produced from different oils which are olive oil and soya oil. The results obtained in the laboratory, as well as the engine test show that the mixed biodiesel sample performed above average. Seven out of eight parameters scored the biodiesel sample high except for the operational temperature. The connection between the laboratory and engine test further corroborate the modified UV spectrometry results as a good research tool for testing the quality of biodiesel. The concept of cyclic breaking was more evident in the mixed olive biodiesel than the soya biodiesel. It was generally observed that the effect of cyclic breaking is more pronounced when the engine operates beyond 20 minutes. Based on the research, it can be inferred that cyclic breaking is dependent on the biodiesel candidate than the mode of biodiesel preparation. The shortcomings of the biodiesel samples were discussed to guide further work on the design of a biodiesel engine.

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CONFLICTS OF INTEREST

None declared.

AUTHORS CONTRIBUTION

M.E. Emetere designed the project and collated the write-up. S. Jack-Quincy did the biodiesel production in the laboratory. A.D. Adejumo, O.A. Dauda, and O.I Osunlola tested the biodiesel using the TD 200 diesel engine. S.A. Adelekan assisted in the technicality of testing the biodiesel on the diesel engine. O.I Omodara assisted with the technicality of acquiring the best biodiesel quality. A.O. Adeyemi guided the UV tested result.

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