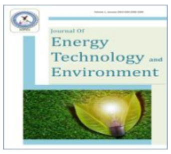
NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng



Performance Parameters of an Internal Combustion Engine Fueled by used Luffa cylindrica Biodiesel Blend with Petrol Diesel

Frederick Okhakumhe Oshomogho*[1] and Wilfred Chinedu Okologume[2]
*[1]Department of Chemical Engineering, University of Benin, Benin City, Nigeria
[2]Department of Petroleum and Gas Engineering, Federal University of Petroleum Resources Effurun, Nigeria
*Corresponding Author Email: fred.oshomogho@uniben.edu, (+2348055966268)

Article information

Article History
Received 17 June 2024
Revised 12 July 2024
Accepted 27 July 2024
Available online 31 July 2024

Keywords:
Engine-performance, Esterification, Fuel-consumption, Transesterification, Brake-power.

https://doi.org/10.5281/zenodo.13146931

https://nipes.org

Abstract

This study compares performance of biodiesel to petroleum diesel blends in an internal combustion (IC) engine. B0 to B50 were characterized and tested for performance. Engine performance and emissions were examined using specific fuel consumption (SFC), brake specific fuel consumption (BSFC), and brake thermal efficiency (BTE) from different blends. Biodiesel production from Luffa cylindrica oil yielded 92.436% fatty acid methyl ester (FAME) and 0.431 mgKOH/g acid with octadecadienoic acid, methyl ester, a linoleic acid, having the highest concentration of fatty acids at 30.29% and hexadecanoic acid, methyl ester, at 20.81%. The pure petroleum diesel had a calorific value of 43.814 MJ/kg, greater than B50 blends with calorific values of and 40.418 MJ/kg. Fuel consumption decreased steadily from about 2.6 lt/hr B20 to about 1.8 lt/hr B50. Increase in biodiesel blend from B0 to B50 was observed to result in a decrease in SO_2 *levels from 1.2ppm to 1.4ppm respectively and calorific values decreased significantly. Blending biodiesel with petroleum diesel improves the physical properties of diesel fuel. Blending biodiesel with petroleum fuel lowers the emissions from internal combustion engines. The performance of an IC engine was improved by using biodiesel blends in terms of brake thermal efficiency and brake specific fuel consumption. Blends of biodiesel are more efficient than pure petroleum diesel in terms of fuel consumption rate for a given load.*

1. Introduction

Studies has demonstrated that the fuel properties of biodiesel made from oils that are not edible are at par with—or in some cases even superior to those of diesel derived from petroleum [1]. Because it competes with the food chain, the cost of producing biodiesel from oils that are edible is still high. The production of biodiesel can only be sustained if non-edible oil-bearing seeds which have been found to be high in oil content are adequately harnessed. Energy supply, provided by fossil fuels like gasoline and diesel, is a global transportation and environmental concern. Motorization has raised transport energy consumption by 1.1 % annually worldwide [2]. From 2010 to 2040, only the transportation sector increased worldwide liquid fuel consumption by 63 % [3].

The growth of the global motorization industry has also increased pollution emissions. It's important to recall that transportation accounts for 22% of global GHG emissions [4]. According to forecasts made by the International Energy Agency (IEA), the transportation sector's greenhouse gas (GHG) emissions are expected to rise by 92% between 1990 and 2020, and between 2020 and 2035, 8.6 billion metric tons of CO_2 would be produced. Vehicle emissions of PM, HC, CO_2, CO, and NOx are a major source of air pollution. For both producers and consumers, torque, power, and fuel economy are significant factors. Frictional power separates the two of them. The brake-to-indicated value ratio measures the mechanical efficiency of an engine. Efficiency and emission levels of biodiesel engines are dependent on a number of parameters [5]; [6]. Emission levels and performance are influenced by the ratio of compression, load, speed, fuel injection parameters (pressure, timing, and duration), air swirl, and piston geometry [3].

Diesel engines are the primary means of transportation in the globe because of their reduced emissions, fuel consumption, and thermal efficiency. Fossil fuels were cheap and plentiful for years. The 1973–1974 oil crisis boosted interest in alternative energy [5]. Various studies focused on biodiesel due to strict pollution standards in various countries [6][7][8]. Due to its lower emissions, biodiesel is a diesel substitute [9]. Because biodiesel is renewable and environmentally friendly, it can be used in diesel engines with no alterations. However, operating an unmodified diesel engine with biodiesel reduces performance [10]. Additionally, biodiesel engines emit greater NOx. Chemical molecules comprising nitrogen and oxygen are called NOx. High combustion temperature and ignition delay cause NOx production. Thus, NOx reduction is a priority nowadays [5]; [11]. Biodiesel is produced by transesterifying waste fats from both animals and vegetables and edible and inedible oils. Plant cultivation, oil production, and biodiesel production could boost rural economies [12].

Many factors influence how well and how polluting biodiesel-powered vehicles function. Performance and emissions are influenced by a number of important elements, including compression ratio, load and speed, fuel injection parameters (such as injection pressure, timing, and duration), air swirl, and piston design [11]. Fuel injection parameters, including as injection rate, nozzle design (including number of holes), injection timing, and injection pressure, have a major role in emissions mitigation. It is unrealistic to expect the same performance as an engine powered by diesel as biodiesel is usually used in an existing diesel engine without any modifications [12].
This is due in part to the low energy content, higher viscosity, and poor atomization properties of biodiesel. Raising the injection pressure into the biodiesel fuel engines improved performance and reduced emissions [11]; [13] have out constant-speed performance tests on a direct-injection diesel engine using methyl esters from linseed oil at three different injection pressures: 200 bar, 220 bar, and 240 bar. Their research indicates that 240 bar of injection pressure is ideal. The thermal efficiency was similar to that of a diesel engine at this optimal injection pressure, however the emissions of NOx were greater and CO was lower. According to Crookes [8], for higher % biodiesel-diesel blends (like B20, B50, and B100), raising the injection pressure led to greater emissions of carbon dioxide and NOx and reduced the amount of smoke capacity, unburned hydrocarbon, CO, and NOx. When evaluating a single-cylinder direct injection engine at various pressures (205 bar, 220 bar, 240 bar, 260 bar, and 280 bar) with blend of fatty acid methyl ester (B20), it was discovered that an injection pressure of 220 bar worked well. Maximum torque of 191 Nm for diesel, 185 Nm for rapeseed, and 179 Nm for soybean biodiesel was noted at injection pressure of 250 bar [14]. Similar tendencies in the use of certain fuel types were reported. Boosting the injection pressure from 250 bar to 350 bar greatly reduced smoke and CO emissions. At high injection pressure, however, NOx levels rose by 20 %. For the single-cylinder constant-speed diesel engine using methyl esters of the seed oil, the optimal injection pressure and injection timing were observed to be 225 bar and 271 BTDC, respectively [13].

The fuel and engine properties of B20 to B80 diesel made from Luffa cylindrica seed oils are assessed in this study. A promising renewable fuel with the potential to lower greenhouse gas emissions and enhance air quality is luffa cylindrica biodiesel. However, its impacts on the nature of exhaust emissions and internal combustion engine performance are not fully understood. This study aims to investigate the effects of various Luffa cylindrica biodiesel blends on the characteristics and performance of emission levels in internal combustion engines running under different engine operating conditions.

Using an experimental methodology, this study examines the effects of Luffa cylindrica biodiesel blends on internal combustion engine performance and exhaust emission characteristics. A range of Luffa cylindrica biodiesel blends, from B20 (20% Luffa cylindrica biodiesel, 80% petrol diesel) to B100 (100% Luffa cylindrica biodiesel), were used to test the engine. The engine was run across a wide range of engine speeds and loads in order to measure a number of engine parameters, including brake power, specific fuel consumption, thermal efficiency, exhaust gas temperature, emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and smoke opacity. The results of the study will provide valuable insight into how Luffa cylindrica biodiesel mixes impact internal combustion engine efficiency and exhaust emission characteristics. Techniques to maximize the use of Luffa cylindrica biodiesel in internal combustion engines can be developed with the use of this data.

2.0 Materials and Methods

A 2000 ml capacity Thermo Scientific Cimarec 2 Basic Magnetic Stirrer, was used to facilitate the transesterification process in the flask. To cool any vapors released during the reaction, the flask was attached to an Ace Glassware Braham Condenser. A Thermo Scientific Cimarec 2 Basic Magnetic Stirrer, which has a continuous temperature setting of 65°C, was used to heat the flask. After being put into the flask, the liquid reaction mixture was continuously swirled at 380 rpm. After a series of studies with varying stirring speeds, the ideal stirring speed was identified. The reaction was allowed to proceed for 1 hour, and the yield of the transesterification reaction was measured using a gas chromatograph (Agilent Technologies 7890A GC System). After an hour of reaction time, the transesterification reaction's yield was assessed using a gas chromatograph (Agilent Technologies 7890A GC System).

2.1 Esterification Reaction

Exactly 1000 g of Luffa cylindrica oil in a round bottom flask glass reactor was esterified with 25 wt.% of methanol using 1.0 wt.% H_2SO_4 as catalyst to reduce the free fatty acids to about 1 % FFA according to Lim et al. [16]**.** The mixtures were placed on a constant temperature magnetic stirrer set to heat at a constant temperature 60°C for 1.5hour transesterification reaction. The procedure was repeated until % FFA was about 1%. The esterified Luffa cylindrica seed oil is much clearer and lighter in color than the original Luffa cylindrica oil. This is because the esterification reaction has removed the free fatty acids from the Luffa cylindrica oil.

2.2 Transesterification Reaction

This work effectively produced biodiesel from Luffa cylindrica seed oil and methanol utilizing a transesterification process in a 2000 ml round bottom flask reactor, following the methodology by Putra et al. [15]. The reactor was brought up to temperature, 1000 g of esterified oil was weighed in, and a catalyst and methanol mixture was added while the reactor was being agitated at 300 rpm. The reaction byproduct was added to a separating funnel, which allowed the glycerol and biodiesel to separate into layers of transparency. A chemical process called transesterification transforms triglycerides into glycerol and biodiesel. A strong base, like potassium hydroxide (KOH) or sodium hydroxide (NaOH), catalyzes the process. After dissolving the catalyst in methanol, it was combined with the esterified oil. For one to two hours, the reaction was conducted at a temperature between 60 and 70 °C. The reaction byproduct was moved to a separating funnel once the reaction was finished. Due to their disparate densities, glycerol and biodiesel split into two layers. After being removed from the separating funnel, the biodiesel layer was cleaned with water to get rid of any last traces of contaminants or catalysts. The glycerol layer is at the bottom and the biodiesel layer is at the top. The glycerol layer is thick and dark, but the biodiesel layer is transparent and yellow. There is a different interface between the two layers. This process yields biodiesel that is compatible with diesel engines straight out of the bottle. As a sustainable and renewable fuel, biodiesel can aid in lowering greenhouse gas emissions and enhancing air quality.

2.3 Crude Biodiesel Purification

Warm water was used to wash the crude biodiesel after a separating funnel was used to achieve the highest level of separation. To stop an emulsion from forming and water droplets from slowly percolating through the ester, the crude biodiesel was combined with water and gently agitated. Until clean wash water was generated, indicating that all impurities had been removed, the process was repeated.

2.4 Diesel Engine Test

A single-cylinder, 10.0 horsepower diesel engine with a single-phase, 220V, 15kW alternator was used to test the performance of biodiesel blends. This particular engine is commonly used in medium-sized power generation applications. An exhaust gas detector/analyzer, a digital tachometer, and a digital rotameter were instantly connected to the test engine. In order to aid engine warm-up, the engine was first run for a short while using petrol-diesel fuel before testing with biodiesel-blended fuels were conducted. Diesel fuel was also used before the engine was shut down. For each fuel, the same procedure was constantly used.

Engine performance testing was first conducted with the engine running at maximum load and the throttle maintained at 100% aperture. The engine speed will be adjusted with the throttle by 200 rpm increments between 1000 and 2000 rpm. The exhaust emission gases which include CO, H_2S, HC, and NOx/NO were measured using a BOSCH exhaust gas analyzer model BEA-350. For the purpose of the emissions tests, engines will only run at speeds of up to 2000 revolutions per minute (rpm). To measure the fuel flow, an electronic rotameter flow meter was employed. The temperatures of the engine oil, cooling water, exhaust gas, and intake air were measured using a K-type thermocouple. Equations (1) to (5), which indicate the brake torque, brake power (BP), brake-specific fuel consumption (BSFC), and brake thermal efficiency (BTE), were calculated utilizing the approach outlined by Sai et al. [6].

$$Break\ Power\ (BP) = \frac{2\pi N\{WR_e(9.81)\}}{60000} \tag{1}$$

$$Break\ Mean\ Effective\ Pressure\ (BMEP) = \frac{BP60}{SVN} \tag{2}$$

$$Total\ Fuel\ Consumption\ (TFC) = \frac{5.SG.3600}{1000t}\,(kg/h) \tag{3}$$

$$Brake\ Specific\ Fuel\ Consumption\ (BSFC) = \frac{TFC}{BP}\,(kg/kWh) \tag{4}$$

$$Brake\ Thermal\ Efficiency\ (BTE) = \left[\frac{BP.3600}{TFC.C_v}\right].100 \tag{5}$$

Where; N is engine speed (rpm), W is electrical load applied on the engine (watt), Re is the effective radius of brake drum, SV is the stroke volume, C_v is calorific value and N is engine speed (rpm)

The test fuels were petroleum diesel and Luffa cylindrica biodiesel blends. The fuels were blended with an overhead mixer/homogenizer device at a speed of 1500 rpm for 10 min.

2.5 Study of Engine Performance and Emissions

The performance and emission characteristics of an engine operating on various blends of petroleum diesel and biodiesel are examined in the current study. The examination primarily focuses on two key characteristics: brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC). An experimental analysis was conducted to assess the performance and emission characteristics of several blends of petroleum diesel and biodiesel starting with pure petroleum diesel (B0), to 50% biodiesel (B50). In an engine with compression ignition (IC) and a set load, the mixes were assessed. The pollutants that the engine produced, namely carbon monoxide (CO), nitrogen oxide (NOx), carbon dioxide (CO_2), and hydrocarbon (HC), were examined using an exhaust gas detector and analyzer. Using a variety of gasoline mixes, the inquiry will measure the rate of fuel consumption under various load levels.

3.0 Results and Discussion

3.1 Results of Physical and Chemical Analysis of Luffa Cylindrica Seed Oil

The findings of the analysis conducted on Luffa cylindrica oil are presented in Table 1. The concentration of FFA in the oil sample was determined to be 2.6575 %. Numerous studies have demonstrated that an elevated concentration of free fatty acids (FFA) has a detrimental impact on the efficiency of catalysts and leads to a decline in production yield. Consequently, it is advised that the quantity of FFA should not surpass 2 wt.% based on the findings of Kawentar & Budiman, [16] as well as Sarno and Iuliano, [17]. The moisture content of Luffa cylindrica oil, as determined to be 0.32wt%, was found to be lower than the minimum threshold (≥0.5 wt.%) suggested in the literature by Okullo et al. [18] for optimizing biodiesel yield. The iodine value of Luffa cylindrica oil was found to be 98.51 I2g/100g, indicating a somewhat higher value. This can be attributed to the composition of fatty acids present in the oil, which has an impact on the iodine value [19].

Table 1: Physical and Chemical Properties of Luffa cylindrica Seed Oil

Properties (Unit)	**Value**
Density (g/cm^3)	0.8798
Moisture content (wt%)	0.32
Flash point (^oC)	179
Acid value (mgKOH/g)	5.315
FFA content (%)	2.6575
Saponification value (mgKOH/g)	178.763
Iodine content ($I_2g/100g$)	98.51
Peroxide value (mg*Eq*/kg)	125.58

3.2 Physical and Chemical Properties of Luffa cylindrica Biodiesel

The biodiesel quality was evaluated using standard methods after water washing. The requirements that pure biodiesel (B100) needs to meet in order to be utilized as fuel either alone or in blend with petroleum diesel fuel have been outlined by ASTM [20]. the chemical and physical properties of biodiesel were examined such as viscosity ASTM D93, oxidation stability EN 14112, and acid value

ASTM D664. All measured values of the luffa cylindrica biodiesel fell within the designated test limit range, as indicated by the data displayed in Table 2.

Table 2 Physical and chemical properties of Luffa cylindrica biodiesel

Properties Measured (Unit)	Luffa cylindrica Biodiesel	Standard ASTM
Yield (%)	92.436	NA
Density @ 30^{o}C (g/ml)	0.8537	NA
Sp. Gravity	0.8474	0.88
Dyn. Viscosity (mPa.s)	4.53	1.9 – 6.0
Kin. viscosity @ 30^{o}C (mm^2/s)	5.7159	NA
Flash Point (^{o}C)	129	100 – 170
Moisture Content (%)	0.113	NA
Acid value (mgKOH/g)	0.431	<0.5
FFA (%)	0.215	NA
Peroxide value (m*Eq*/kg)	68.94	NA
Oxidative Stability	4 hr 32min	>3 hrs

The transesterification reaction which was conducted using the esterified Luffa cylindrica oil yielded optimum biodiesel with an acid value and water content 0.431 mgKOH/g and 0.113 %. Flash point was within the standard range at 129℃. The viscosities and other properties (Table 2) of the biodiesel quality assessment revealed that the values were within range.

3.2.1 Results of Gas Chromatograph Mass Spectrometry (GCMS) Analysis of Luffa cylindrica Biodiesel

The concentration of the components as obtained from the library was estimated using the peak areas on the chromatogram that resulted from the GC-MS study of the biodiesel samples synthesized under optimal conditions for Luffa cylindrica biodiesel. The FAME compositions and quantities found in Luffa cylindrica biodiesel are reported in Table 3.

Table 3: Fatty acid methyl ester concentration of Luffa cylindrica biodiesel

Retention Time (min)	Common Name	IUPAC Name	Concentration (%)
16.81	*Palmitic acid*	Hexadecanoic acid, methyl ester	1.20
20.243	*α-Linoleic acid*	10,13-Octadecadienoic acid, methyl ester	21.34
20.73	*Ricinoleic acid*	trans-13-Octadecenoic acid, methyl ester	6.78
21.04	*Margarinic acid*	Heptadecanoic acid, 14-methyl-, methyl ester	4.27
23.95	*Stearic acid*	Octadecenoic acid, methyl ester,	56.44
26.941	*Octadecanoic* acid	Oxiraneoctanoic acid, 3-octyl-, methyl ester	9.97

As shown in Table 3 shows the major fatty acids methyl ester present in Luffa cylindrica biodiesel were Octadecenoic acid, methyl ester which is stearic acid with a concentration of 56.44 % followed by Octadecadienoic acid, methyl ester which is an alpha-Linoleic acid with a concentration of 21.34 %.

3.3 Effects of Blend on Fuel Properties

Results of tests conducted on fuel properties revealed that the physical properties of petroleum diesel were greatly influenced by the blending with biodiesel. Petroleum diesel had a lesser density and specific gravity compared to biodiesel (Table 4). According to international standards and criteria most frequently supplied for use in the retail diesel fuel marketplace, pure petroleum diesel

B0 and different blends with biodiesel were analyzed [21]. The "B" factor denotes the percentage of biodiesel in any fuel blend; 100% biodiesel is referred to as B100, while pure petroleum biodiesel (B0) contains no biodiesel at all. Therefore, B10, B20, B30 and B40 stands for petroleum diesel containing 10 %, 20 %, 30 % and 40 % biodiesel, respectively.

Table 4 Properties of Petroleum Diesel and Luffa cylindrica Biodiesel Blends

Property	B0	B10	B20	B30	B40	B50
Density @ 30°C (g/cm^3)	0.8362	0.8548	0.8815	0.8829	0.8953	0.8976
Flash point (°C)	71	80	87	91	98	103
Viscosity (mPa.s)	0.71	0.79	0.84	1.06	1.27	1.34
Calorific value (MJ/kg)	43.814	43.013	42.050	41.543	40.418	40.013

The calorific value is a very important property of fuels to be used in an engine for combustion because the power output is pretty much dependent on calorific value. Because it mostly determines the amount of power produced, the calorific value of fuels is a crucial characteristic to consider when using them in an engine for combustion [22]. Table 4 show that different blends have different calorific value. There was a notable decrease in the calorific values from B0 to B50 for biodiesel blends. The study discovered that blends with a calorific value of 40.013 MJ/kg for B50 of Luffa cylindrica biodiesel blends had a higher calorific value (43.814 MJ/kg) than petroleum diesel, even though biodiesel has less energy than petroleum diesel. Reports from a variety of sources indicate that diesel fuel has a higher calorific value than biodiesel fuel [23]; [1]. Pure petroleum diesel fuel has an increased calorific value (43.814 MJ/kg) than blends of biodiesel, which range from 39 to 41 MJ/kg. Engine efficiency is improved when the calorific value increases because it causes a larger release of heat during combustion.

3.3.1 Effects of Blending on Fuel Consumption

The performance of biodiesel blends was evaluated with fuel consumption at a fixed electrical load of 6000 Watts. From Figure 1, it was observed that there was a reduction in fuel consumption from 3.5 lt/hr of B0 to about 2.65 lt/hr for B20 for both Luffa cylindrica biodiesel. There was a consistent decrease in fuel consumption from about 2.6 lt/hr B20 to about 1.8lt/hr B50.

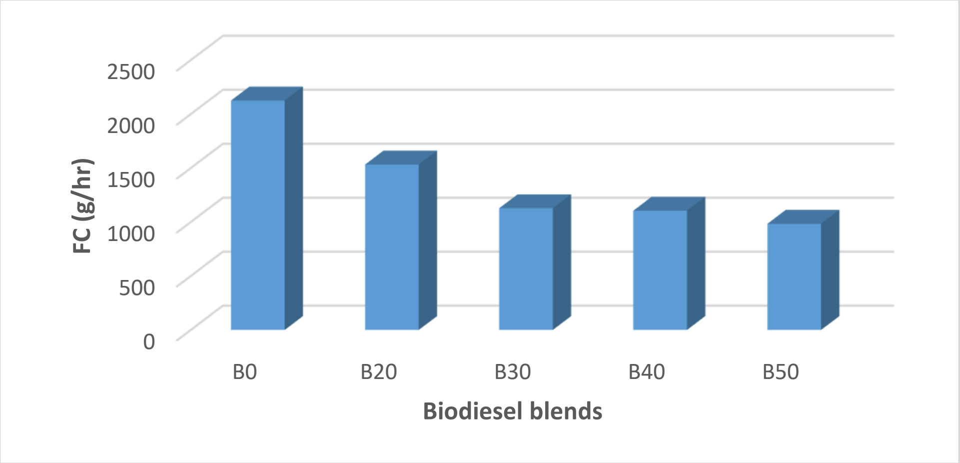


Fig. 1: Effect of blends on rate of fuel consumption at 6000W of load

3.3.2 Effects of Blends on Engine Exhaust Gas

Nitrogen dioxide (NO_2) is considered a hazardous pollutant produced by diesel engines, in contrast to nitrogen monoxide (NO). The toxicity of nitrogen dioxide (NO_2) is attributed to its capacity to react with water in the eye, lung, mucous membrane, and skin, resulting in the formation of nitric acid (HNO_3) [24]. The results shown in Table 5 indicate that when biodiesel blending is used in an internal combustion (IC) engine's exhaust gas, the amount of nitrogen oxide (NOx) emissions is reduced. For Luffa cylindrica biodiesel, the concentration of NOx emissions was decreased from 134 ppm to 53 ppm for B0 and to 55 ppm for B50. Compared to gasoline engines, diesel engines operate at higher temperatures and pressures. The high pressure and temperature that are created inside the cylinder during compression lead to the production of NOx emissions. The volume and length of the flame's most intense portion determine how much of a substance there is [25]**.** It is acknowledged that one of the two primary causes of acid rain is nitrogen dioxide. Acid rain is a phenomenon that arises from the atmospheric release of sulfur dioxide (SO_2) and nitrogen oxides (NO_X), which are then carried by air currents and wind. As the biodiesel mix was increased in the study, SO_2 levels decreased. For example, concentrations of Luffa cylindrica biodiesel blended at B40 blends dropped from 12 ppm to 1.4 ppm.

Table 5 Effects of Blends on Exhaust Emissions

Property	B0	B20	B30	B40	B50
CO (ppm)	0.00	0.00	0.00	0.00	0.00
CO_2 (ppm)	915	849	747	678	625
Sound (dBA)	99.5	100.4	106.7	108.6	110.2
TVOC (mg/m^2)	0.058	0.097	0.238	0.388	0.397
HCHO (mg/m^2)	0.016	0.014	0.011	0.006	0.002
SO_2 (ppm)	12	9.4	6.3	4.2	1.3
NO_x (ppm)	134	103	68	67	53
H_2S (ppm)	0.00	0.00	0.00	0.00	0.00
LEL (%)	0.00	0.00	0.00	0.00	0.00

Hydrogen sulphide (H_2S), Low Emission Limit (LEL) of exhaust gas in the form of methane (CH_4) and carbon monoxide (CO) where not present in a detectable limit. CO_2 was decreased with increase in blends from 915 ppm to about 635 ppm for B40 of Luffa cylindrica biodiesel blends.

3.4 Results of Engine Performance Test

In an Internal Combustion (IC) engine, the effectiveness of blends of biodiesel was assessed based on changes in Brake Mean Effective Pressure (BMEP), Brake Specific Fuel Consumption (BSFC), and Brake Thermal Efficiency (BTE) [13].

3.4.1 Break power

The torque and speed of an engine are directly related to its braking power. Figure 2 shows how the break power output changes with engine speed for different biodiesel blends. For each tested gasoline mixture, break power increased progressively as mixtures were increased. The maximum break power output values for diesel, B50, for Luffa cylindrica biodiesel blends were 20886.7(W) from 19492.5(W) at B0. Consequently, the average brake power outputs of the blends with Luffa cylindrica biodiesel were 7.15% higher than those of pure petroleum diesel fuel. Blends of biodiesel have a higher power output than diesel fuel because they have a greater amount of energy and flash point per unit of volume. Furthermore, the high density and viscosity of biofuels lead to good atomization and even combustion, which increases high power.

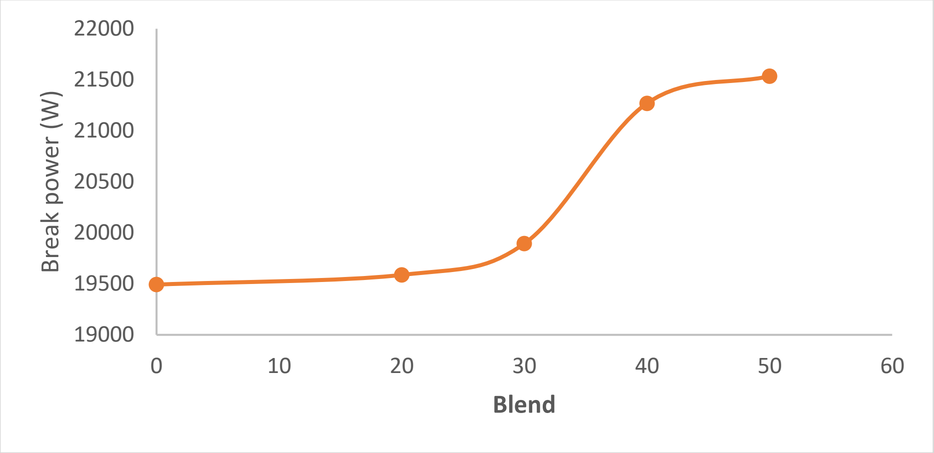


Fig. 2: Biodiesel blends' effects on engine break power

3.4.2 Rate of fuel Consumption

The rate of fuel consumption in the internal combustion engine was observed to have a decline with an increase in blends from B0 to B50 at a constant load of 6kW. Figure 3 showed a decline in FC from B0 at 3049.2g/hr and 1316.5g/hr for Luffa cylindrica biodiesel blend.

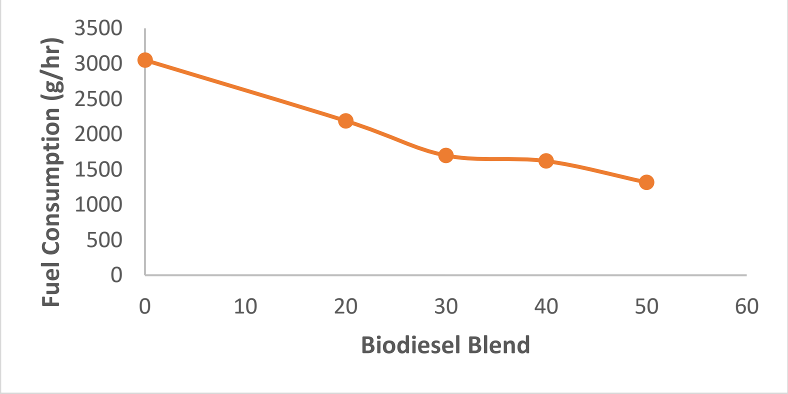


Fig. 3: Effects of biodiesel blends on rate of fuel consumption

3.4.3 Brake Specific Fuel Consumption

Figure 4 displays the variation in brake-specific fuel consumption (BSFC) for all fuels tested to different blends. Braking specific fuel consumption (BSFC) is the ratio of fuel mass consumption to braking power. The inverse relationship between a fuel's BSFC and thermal efficiency describes this relationship. Typically, biodiesel has a decreased calorific value due to the fuel-borne oxygen it contains. The higher viscosity of biodiesel blends coupled with the volumetric effect of constant fuel injection rate is what causes an upsurge in gasoline consumption. Brake Specific Fuel Consumption (BSFC) shows a consistent decrease as the fuel composition varies from pure petroleum diesel B0 (0.156 kg/kWh) to blend B50 (0.067 kg/kWh). For Luffa cylindrica biodiesel blends, BSFC then reduces to 0.061 kg/kWh.

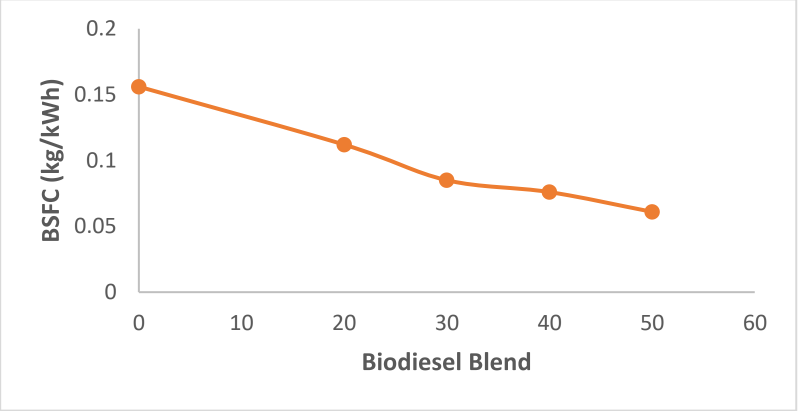


Fig. 4: Effects of biodiesel blend on brake specific fuel consumption

3.4.4 Break Thermal Efficiency

The break power of a heat engine is a function of the fuel's thermal input. Figure 5 shows that the break thermal efficiency is affected by petrol diesel blended by biodiesel. the engine's transformation of biodiesel and petrol-diesel blends into mechanical energy increases as biodiesel blending increases. Brake thermal efficiency is crucial in determining the overall performance and effectiveness of an engine. A higher break thermal efficiency over 180,000% was obtained with B50 and lower blends of B20 and B30 were 147,000% and 154,000% respectively. A higher brake thermal efficiency indicates that the engine is able to convert a greater percentage of the fuel's energy into useful work. By measuring brake thermal efficiency, engineers can make improvements to engine design and operation to increase energy efficiency and reduce fuel consumption. Ultimately, understanding and optimizing brake thermal efficiency is essential for developing more sustainable and cost-effective engine systems.

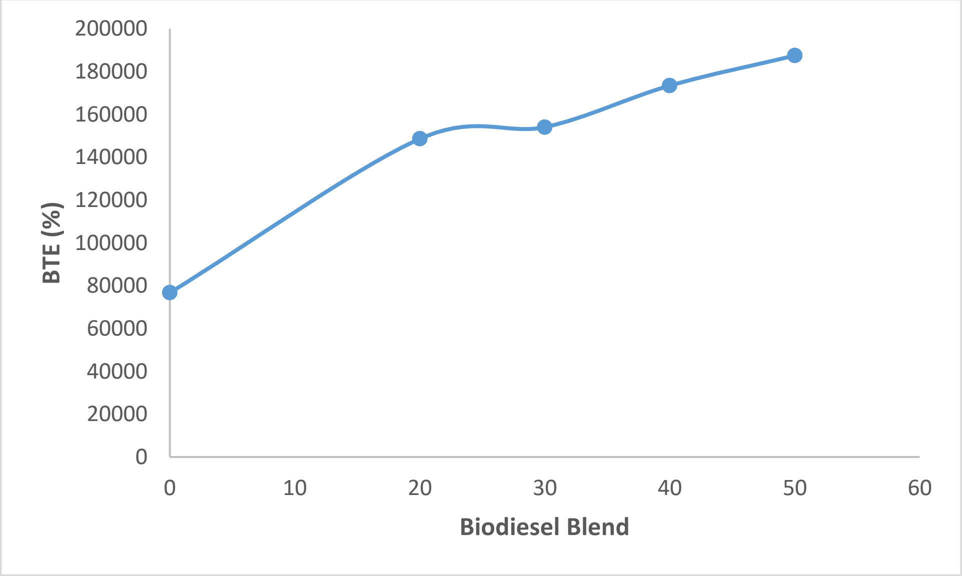


Fig. 5 Break thermal efficiency of biodiesel blends

4.0 Conclusion

The transesterification of Luffa cylindrica oil under ideal reaction conditions can result in biodiesel with a very high FAME yield of almost 94wt%. Blending of petroleum diesel with biodiesel has positive effect on the physical properties on diesel fuel. Blending of petroleum diesel with biodiesel leads to decrease in the amount of NOx, SO_2 and CO emissions in an IC engine. TVOC emissions is increased by blending because of the organic component content of FAME. The performance of an internal combustion engine was improved by the use of biodiesel blends in terms of brake thermal efficiency and brake specific fuel consumption. Blends of biodiesel and pure petroleum diesel use fuel more efficiently at the same rate for a given load. The study's findings can be applied to a variety of internal combustion engines, such as diesel engines used in automobiles, generators, and commercial settings. It is crucial to remember that the ideal ratio of Luffa cylindrica biodiesel to petrol diesel fuel might change based on the particular engine and its operating circumstances. The study's overall findings indicate that Luffa cylindrica biodiesel is a viable substitute for petro-diesel fuel. To maximize the usage of Luffa cylindrica biodiesel blends in internal combustion engines and evaluate the long-term impacts on engine durability, more research is necessary.

Acknowledgements

Authors hereby acknowledged the management of Luco Chemical Laboratory Limited, Benin City, Nigeria, for their assistance during the course of the research.

References

[1] Sahoo BB, (2020) Determination of optimum diesel: jatropha blend for compression ignition diesel engines through fuel properties analysis, *SN Appl. Sci.*, vol. 2, no. 12, pp. 1–6, doi: 10.1007/s42452-020-03807-7.

[2] Cansino JM, Pablo-Romero MDP, Román R, and Yñiguez R, (2012) Promotion of biofuel consumption in the transport sector: An EU-27 perspective, *Renew. Sustain. Energy Rev.*, vol. 16, no. 8, pp. 6013–6021, doi: 10.1016/j.rser.2012.06.011.

[3] Sai Varun V, Pramod BVN, and Shetty D, (2018) Performance and Emission Characteristics of Commercial Kerosene Stoves using Waste Cooking Oil-Kerosene Blends, *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 377, no. 1, doi: 10.1088/1757-899X/377/1/012213.

[4] Mustak R, (2018) Effect of Blending Various Biodiesels with Diesel on Performance and Emissions of Diesel Engine : A Review, *World Sci. News*, vol. 94, no. 2, pp. 287–297.

[5] Sai SB, Subramaniapillai N, Khadhar Mohamed MSB, and Narayanan A, (2021) Effect of rubber seed oil biodiesel on engine performance and emission analysis, *Fuel*, vol. 296, no. March, p. 120708, doi: 10.1016/j.fuel.2021.120708.

[6] Ali MH, Mashud M, Rubel MR, and Ahmad RH, (2013) Biodiesel from Neem oil as an alternative fuel for diesel engine, *Procedia Eng.*, vol. 56, pp. 625–630, doi: 10.1016/j.proeng.2013.03.169.

[7] Rizwanul Fattah IM, Ong HC, Mahlia TMI, Mofijur M, Silitonga AS, Ashrafur Rahman SM and Arslan A, (2020) State of the Art of Catalysts for Biodiesel Production, *Front. Energy Res.*, vol. 8, no. June, pp. 1–17, doi: 10.3389/fenrg.2020.00101.

[8] Ohile SO, Aboje AA, Uthman H, Usman RA, and Ighodaro OO, (2023) Optimization and Characterization of Biodiesel Production from Mango Seed Oil (Magnifera indica) via Transesterification Reaction, *J. Energy Technol. Environ.*, vol. 5, no. 3, pp. 2023–67,. Available: https://doi.org/10.5281/zenodo.8321396https://nipes.org

[9] Vilas Bôas RN and Mendes MF, (2022) Review of Biodiesel Production From Non-Edible Raw Materials Using the Transesterification Process With a Focus on Influence of Feedstock Composition and Free Fatty Acids, *J. Chil. Chem. Soc.*, vol. 67, no. 1, pp. 5433–5444, doi: 10.4067/S0717-97072022000105433.

[10] Crookes RJÃ, (2006) Comparative bio-fuel performance in internal combustion engines," *Biomass and Bioenergy*, vol. 30, pp. 461–468, doi: 10.1016/j.biombioe.2005.11.022.

[11] Singla MK, Nijhawan P, and Oberoi AS, (2021) Hydrogen fuel and fuel cell technology for cleaner future: a review, *Environ. Sci. Pollut. Res.*, vol. 28, no. 13, pp. 15607–15626, doi: 10.1007/s11356-020-12231-8.

[12] Bhupendra HMC, Singh C, and Kumar N, (2012) A study on the performance and emission of a diesel engine fueled with Jatropha biodiesel oil and its blends, *Energy*, vol. 37, pp. 616–622, doi: 10.1016/j.energy.2011.10.043.

[13] Khan ZA, Saeed A, Gregory O, and Ghafoor A, (2016) Biodiesel performance within internal combustion engine fuel system - A review, *Tribol. Ind.*, vol. 38, no. 2, pp. 197–213.

[14] Lim S, Yap CY, Pang YL, and Wong KH, (2020) Biodiesel synthesis from oil palm empty fruit bunch biochar derived heterogeneous solid catalyst using 4-benzenediazonium sulfonate, *J. Hazard. Mater.*, vol. 390, p. 121532, doi: 10.1016/j.jhazmat.2019.121532.

[15] Putra TW, Hardiansyah R, Lubis MR, and Supardan MD, (2020) Intensification of biolubricant synthesis from waste cooking oil using tetrahydrofuran as co-solvent, *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 845, no. 1, doi: 10.1088/1757-899X/845/1/012009.

[16] Kawentar WA and Budiman A, (2013) Synthesis of biodiesel from second-used cooking oil, *Energy Procedia*, vol. 32, no. 5, pp. 190–199, doi: 10.1016/j.egypro.2013.05.025.

[17] Sarno M and Iuliano M, (2019) Biodiesel production from waste cooking oil, *Green Process. Synth.*, vol. 8, no. 1, pp. 828–836, doi: 10.1515/gps-2019-0053.

[18] Okullo A, Temu AK, Ogwok P, and Ntalikwa JW, (2012) Physico-chemical properties of biodiesel from jatropha and castor oils, *Int. J. Renew. Energy Res.*, vol. 2, no. 1, pp. 47–52, doi: 10.20508/ijrer.95750.

[19] Zamberi MM and Ani FN, (2016) Biodiesel production from high FFA rubber seed oil using waste cockles, *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 12, pp. 7782–7787.

[20] Silitonga AS, Masjuki HH, Mahlia TMI, Ong HC, Chong WT, and Boosroh MH, (2013) Overview properties of biodiesel diesel blends from edible and non-edible feedstock, *Renew. Sustain. Energy Rev.*, vol. 22, pp. 346–360, doi: 10.1016/j.rser.2013.01.055.

[21] Bukkarapu KR, (2017) Comparative Study of Different Biodiesel-Diesel Blends Comparative study of different biodiesel – diesel blends Kiran Raj Bukkarapu, no. 11, doi: 10.1080/01430750.2017.1393775.

[22] Sivaramakrishnan K and Ravikumar P, (2012) Determination of cetane number of biodiesel and it’s influence on physical properties, *ARPN J. Eng. Appl. Sci.*, vol. 7, no. 2, pp. 205–211.

[23] Oliveira LE and Da Silva ML, (2013) Comparative study of calorific value of rapeseed, soybean, jatropha curcas and crambe biodiesel, *Renew. Energy Power Qual. J.*, vol. 1, no. 11, pp. 679–682, doi: 10.24084/repqj11.411.

[24] Liaquat AM, Masjuki HH, Kalam MA, and Rizwanul Fattah IM, (2014) Impact of biodiesel blend on injector deposit formation, *Energy*, vol. 72, pp. 813–823, doi: 10.1016/j.energy.2014.06.006.

[25] Zaher F, Gad MS, Aly SM, Hamed SF, Abo-Elwafa GA, and Zahran HA, (2017) Catalytic cracking of vegetable oils for producing biofuel, *Egypt. J. Chem.*, vol. 60, no. 2, pp. 291–300, doi: 10.21608/ejchem.2017.2967.