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Research Article

An experimental study on performance, emissions, and combustion characteristics of a CI engine running on Citrullus Colocynthis biodiesel blends

Chitradevi V.[1], **Balu PANDIAN**[1,*]

[1]*Department of Automobile Engineering, Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, 600073, India*

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ABSTRACT

A fatty acid alkyl ester can be made from Citrullus Colocynthis oil instead of pure diesel, since it has a higher ratio of triglycerides to monoglycerides. In the current study, the aim of the experimental work was to investigate combustion, emissions, and performance using biodiesel blends derived from Citrullus Colocynthis. A comparison of the qualities of pure Citrullus Colocynthis oil (100% biodiesel), pure diesel (100% diesel), and blended Citrullus Colocynthis and biodiesel (B20, B25, B50, and B75) is presented in the study. The B20 biodiesel blends are the most efficient because of their lower emission concentrations and higher thermal efficiency. Citrullus Colocynthis oil and its blends result in lower in-cylinder pressure and heat release rates. Compared to diesel fuel, a B20 blend performs better and produces less pollution. The test results showed an 18% reduction in HC emissions, a 35% reduction in CO emissions, a 33% reduction in smoke emissions, a 20% reduction in NOx emissions, and a 10% reduction in brake thermal efficiency.

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INTRODUCTION

A pivotal role in transportation is played by internal combustion engines. Finding alternative fuels is essential because combustion emissions worsen air pollution and accelerate global warming [1]. The dependence on fossil fuels may be reduced by obtaining energy from renewable sources such as biomass, wind, and solar energy. Since it is renewable and environmentally beneficial, biodiesel made from vegetable oils and animal fats is a viable diesel alternative [2]. Experiments employing pure and modified vegetable oils in both edible and non-edible forms demonstrated that they can entirely or substantially replace diesel [3]. Despite the potential of edible oils to replace diesel fuel in a variety of ways, diversifying feedstocks for biodiesel production should be a strategic objective for governments [4]. All studies revealed that adding different amounts of palmarosa oil to diesel may significantly lower the emissions of unburned HC, CO, NOx, and exhaust smoke.

***Corresponding author.**
*E-mail address: balumitauto@gmail.com

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By marginally increasing the amount of fuel used for the brakes, castor oil biodiesel lowered HC and CO emissions by 10%. Citrullus Colocynthis seed oil typically contains between 16 and 52 percent of the total oil source and over 84 percent of unsaturated fats. This results in biodiesel and melon as a common name. Although this species is widely distributed in places like India, the Middle East, and the Mediterranean area, it is less common in Africa and is most common in Iran, tropical Asia, and Algeria. In a single-cylinder, stationary, four-stroke diesel engine [5] investigated the performance and emissions of several fuels derived from linseed, mahua, and rice bran. With LOME mixes, they have not encountered similar problems. They concluded that the 20% LOME mix increased the engine›s thermal efficiency while reducing smoke density and BSFC. Pongamia pinnata oil and its derivatives have been investigated for its potential and benefits as a diesel engine fuel by Milano et al. [6], we have looked into and compared the fuel qualities of pogamia pinnata oil to those of diesel. It has been discussed how to develop peak pressure using biodiesel, how to study heat release rates, and how to analyze engine vibrations when using the fuel. Biodiesel reduces particulate matter, carbon monoxide, and unburned hydrocarbon emissions from diesel engines, they claim. Calophyllum inophyllum oil was transformed into a hydrocarbon fuel using fly ash catalyst, according to Saravanan et al. [7]. They showed that the B25-powered engine behaved more like a diesel engine and that greater mixtures resulted in worse brake thermal efficiency. As a result, the B25›s smoke, hydrocarbon, and carbon monoxide emissions were comparable to those of diesel, while its nitrogen oxide emissions were less than those of diesel. Jatropha biodiesel affects the torque and thermal efficiency of a conventional diesel engine, according to study by Vijay Kumar et al. [8], with the decline becoming more obvious as the biodiesel concentration of the mixture increases. By blending biodiesel into blended fuels, BSFC is impacted. Mixed fuels containing a higher percentage of biodiesel have higher cylinder peak pressures and shorter ignition delay times. When compared to using pure diesel, using jatropha biodiesel produces more NOx emissions. The amount of jatropha biodiesel in the blends increases, which lowers the emissions of PM and smoke. Jatropha biodiesel increases the quantity of carbon dioxide released at the exhaust of diesel engines [9]. There has been a comprehensive and in-depth analysis of the literature. It illustrates that a standard DI diesel engine can run on both clean and mixed vegetable oil. Only lesser mixtures are advised over the long run. Fuel must undergo transesterification in order to be utilised in higher mixes, however this modification has no effect on engine efficiency or emissions [10]. However, research on biodiesel engine modifications is scarce in the literature. Citrullus Colocynthis oil biodiesel is investigated in this study in a single-cylinder 4 stroke DI engine.

MATERIALS AND METHODS

Preparation of Citrullus Lanatus

The blooming plant Citrullus Lanatus, which resembles a vine, is native to southern Africa. It is a vital part of the Cucurbitaceae family from an economic perspective. Throughout Egypt, the Middle East, and Africa, it has been grown for a very long time. The fleshy interior of the water

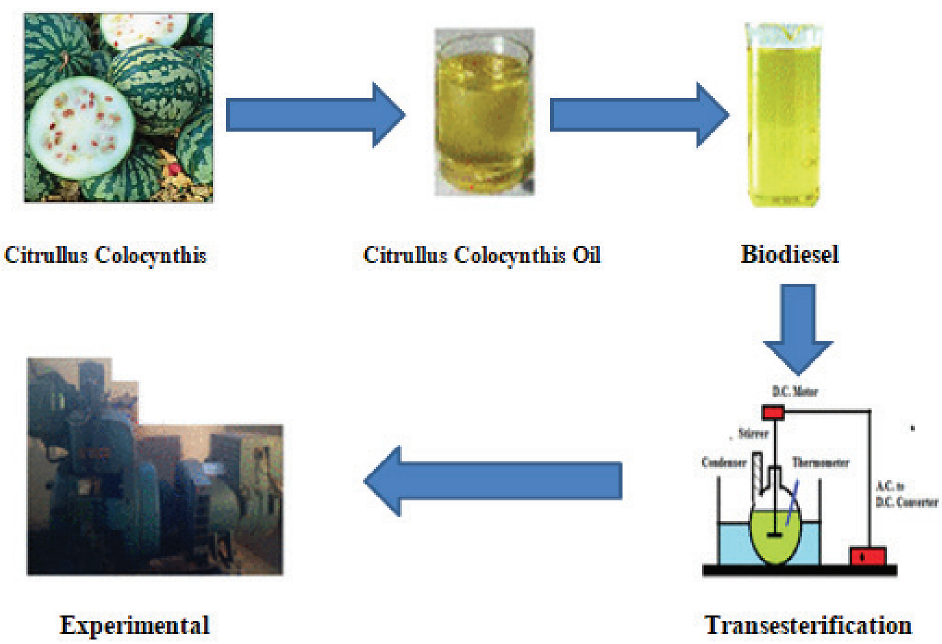

Figure 1. Preparation of Citrullus Lanatus.

Table 1. Compared to diesel, the characteristics of biodiesel mixes

Properties	Diesel	B20	B25	B50	B75
Kinematic Viscosity at 40°C (cSt)	3.45	3.87	3.91	4.12	4.46
Calorific value (MJ/kg)	41.23	40.27	40.58	38.52	37.96
Density (kg/m^3)	815	829	833	843	856
Fire point (°C)	58	84	86	92	94
Flash point (°C)	50	71	73	79	81

melon fruit (the mesocarp and endocarp) contains crimson pulp and watery juice, as well as a thick, smooth rind (the exocarp). 60% of the watermelon fruit is flesh, and 90% of it is liquid with 7–10% w/v sugars (Table 1). As a result, the fruit of the watermelon is quickly fermentable to a liquid in excess of 50% [11]. It has been proven that lycopene, a beneficial antioxidant found in Citrullus Lanatus, lowers the risk of heart attacks and cancer cells. (Figure 1).

Experimental Setup

In the experimental study, a single-cylinder, direct-injection, four-stroke, water-cooled, compression-ignition (CI) engine was used. Table 2 contains the engine›s technical specifications. The time it took to consume a known amount of gasoline (10cc) from a burette was recorded in order to calculate the fuel flow rate. A red wood viscometer was used to measure the viscosity of raw and esterified oil, a hydrometer to assess density, a bomb calorimeter to measure calorific value, and an open cup to measure flash and fire point (Table 3). HC, CO, and NOx emissions from the exhaust tailpipe were recorded using an AVL-444 DI Gas Analyzer. The engine was first made to run in perfect conditions as a warm-up phase before the experimental testing began, and then the experiments were carried out. After starting, the engine was given around 10 minutes to warm up. Five distinct part load scenarios, namely 20%, 40%, 60%, 80%, and 100%, were used to test the engine (Figure 2).

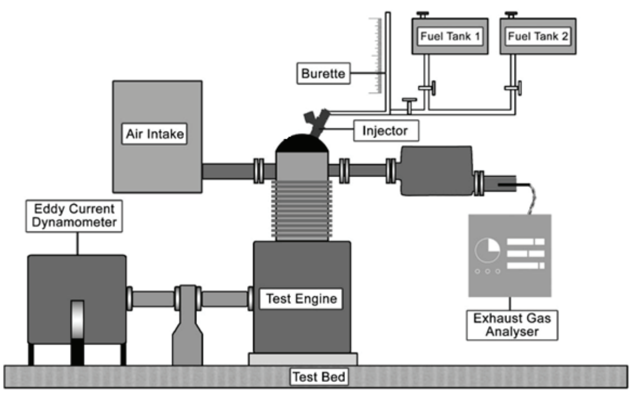

Figure 2. Experiment setup.

Table 2. Research engine specifications

Make	Kirloskar TV – I
Rated brake power	5.2 kW
Bore & Stroke	87.5 mm & 110 mm
Injection timing	23°before TDC
Compression ratio	17.5:1
Injection Pressure	220 bar
Speed	1500 rpm
Injection type	Mechanical injection system

Table 3. Uncertainty of various parameters

Parameters	Uncertainty (%)
Load	0.3
Speed	0.2
Pressure	0.4
Temperature	0.2
Crank angle	0.2
Mass flow rate for hydrogen	0.4
Brake thermal efficiency	0.6
Brake specific fuel consumption	0.7
Oxides of Nitrogen	0.9
Carbon Monoxide	0.04
Unburnt Hydrocarbon	0.13

RESULTS AND DISCUSSION

Brake Thermal Efficiency

Figure 3 depicts the fluctuation of brake thermal efficiency with brake power for various biodiesel mixes. At all power outputs, it was discovered that biodiesel blends had worse brake thermal efficiency than diesel. The calorific value of the fuel determines how much energy is used and how much braking power is applied to the diesel engine. Based on research findings, it was determined that biodiesel will have higher BTE rates than mineral diesel due to its higher oxygen content and better fuel-rich combustion. Due to larger fuel droplet size, a greater fuel density, a

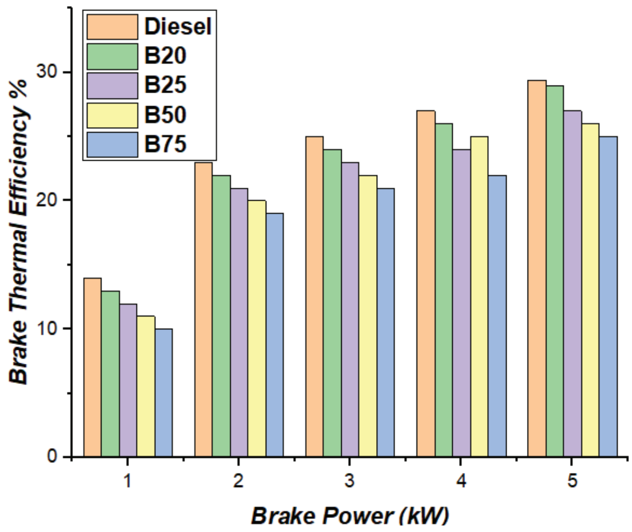

Figure 3. Illustrate the deviation of BTE and brake power.

higher fuel presence in the combustion chamber, deprived atomization, and less volatile fuel, the test fuel blends diesel (29.4%), B20 (28.6%), and B75 (26.9%) had a minimum rate of BTE at higher load compared to mineral diesel [12].

Brake Specific Fuel Consumption

Figure 4 depicts the fluctuation of brake specific fuel consumption with brake power for various biodiesel mixes. Brake specific fuel consumption falls with increasing load. When compared to diesel, it has been found that biodiesel blends have greater brake specific fuel consumption. A higher calorific value of a fuel will result in a higher rate of evaporation, thereby improving combustion. Because biodiesel blends are less calorific than diesel, they evaporate more slowly. Slower evaporation rates increase the amount of fuel required for the brakes [13].

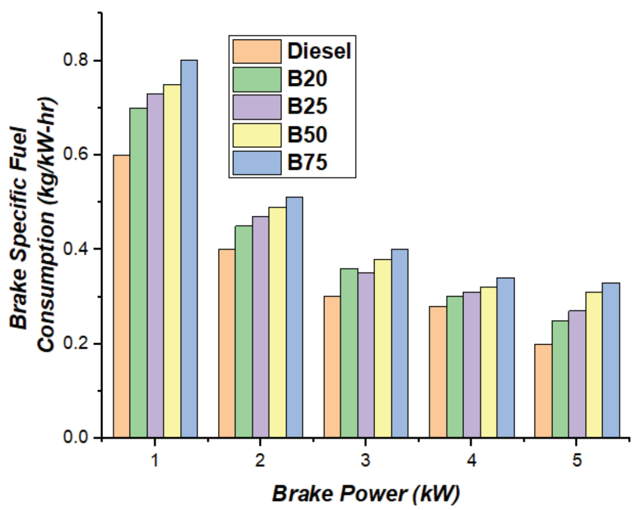

Figure 4. Variation of brake specific fuel consumption with brake Power.

Hydrocarbon (HC) Emissions

Figure 5 depicts the change of hydrocarbon emissions with brake power for various biodiesel mixes. Increases in load have been found to have a linear relationship with increases in unburned hydrocarbon emissions. This is because there is proportionately less oxygen available for the reaction when more petrol is put into the engine cylinder while the engine is operating at a high load. Due to the greater density and viscosity of Citrullus Colocynthis plain oil, mixture formation is weak and certain hydrocarbons are only partially burnt during combustion.

Carbon Monoxide (CO) Emissions

Figure 6 illustrates how carbon monoxide emissions change as a function of brake power for various biodiesel

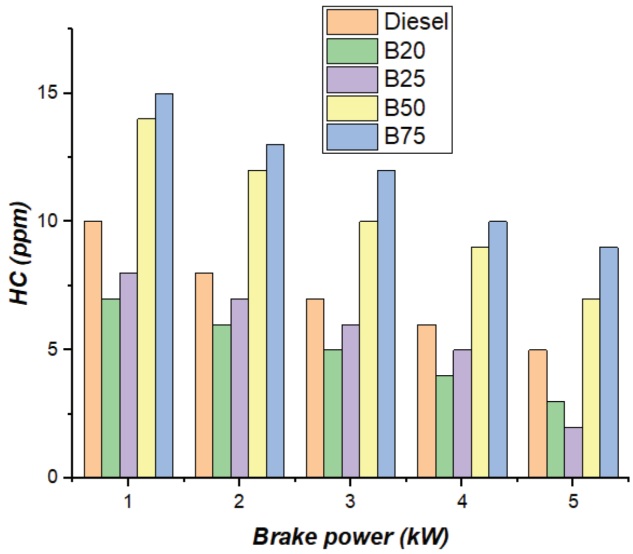

Figure 5. HC VS brake power.

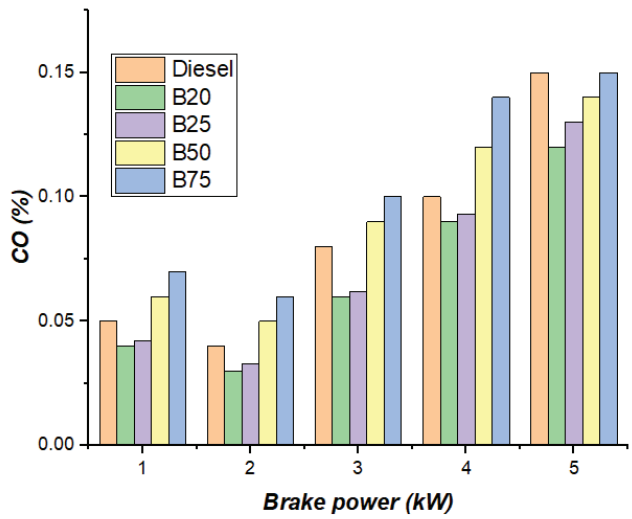

Figure 6. CO VS Brake power.

blends. Citrullus Colocynthis oil had a greater concentration of CO emissions than regular diesel fuel under all loading conditions. This was brought on by the Citrullus Colocynthis oil's poor atomization and poor combustion properties. When compared to Citrullus Colocynthis (B75) oil, the carbon monoxide emissions from the blends are significantly lower. With the B10 blend, the combustion rate has improved, resulting in better fuel and spray distribution inside the combustion chamber and a decrease in CO emissions. Mohammed et al. [12] found similar carbon monoxide emission outputs.

Nitrogen Oxide (NOx) Emissions

Figure 7 depicts how Nitrogen Oxide emissions change as a function of brake power for various biodiesel mixes. Only a some of the factors that influence NOx formation include premixed combustion, in-cylinder pressure, in-cylinder temperature, oxygen concentration, and residence time. Oxides of nitrogen are created when an airborne nitrogen molecule combines with an oxygen molecule at a higher temperature. As load increases, NOx emissions rise as a result of the elevated temperature inside the combustion chamber. Based on a certain NOx value, the B75 and its combinations produce more pollutants than diesel. This demonstrates that B20 has fewer NOx emissions when compared to diesel. Due to the decreased premixed burning rate after the delay interval, the NOx emissions have decreased. There was a slight rise in NOx levels as a result of the increased mix of diesel and Citrullus Colocynthis oil [8].

Smoke

Figure 8 depicts the fluctuation of smoke opacity with brake power for several biodiesel mixes. The results showed that the amount of smoke rises as engine output power increases. The main cause of the rise in smoke emissions

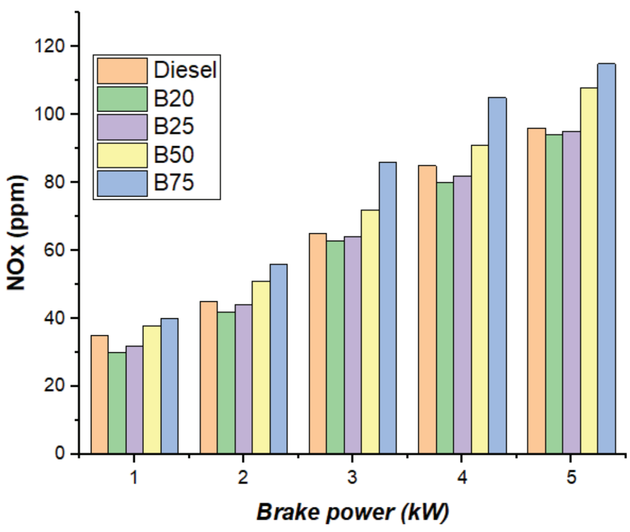

Figure 7. NOx VS brake power.

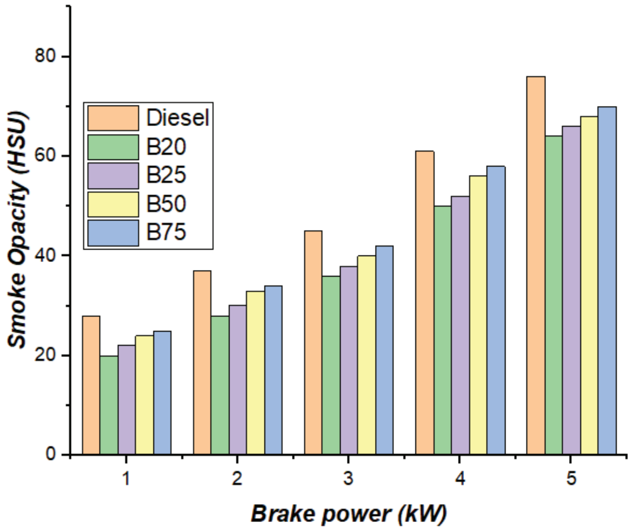

Figure 8. Smoke vs brake power.

is the greater fuel consumption necessary to deliver a constant-speed engine with the same amount of power as diesel fuel. The high viscosity and low volatility of the Citrullus Colocynthis oil, however, resulted in subpar atomization and slow burning. For diesel, the equivalent smoke emissions for B20, B25, B50, and B75 mixtures at full load are 64HSU, 66HSU, 68HSU, 70HSU, and 76HSU. More Citrullus Colocynthis oil in the mixes improves the fuel's ability to burn as the amount of oxygen in the fuel increases [14].

In-Cylinder Pressure

In-cylinder pressure refers to the pressure created at the engine's cylinder during the power stroke, which produces the output work from the thermal energy of the fuel burning rate that was evaluated. The incorrect atomization of the fuel mixes, low calorific value, increased fuel density and cetane number, short ignition delay time, and low rate of fuel burning in the combustion chamber would all contribute to this. However, compared to mineral diesel, the B20 had a faster rate of in-cylinder pressure rise than the B75 due to the fuel blend's lower cetane number, better combustion, and longer ignition delay (Figure 9) [14].

Heat Release Rate

Figure 10 shows the various HRR curves for diesel engines and their crank angles for all fuel mixes. The figure gave the impression that diesel fuel had a greater peak HRR range than the other fuel blends because diesel had a higher crank angle than B50, B75, and B20 (108.5 kJ/deg), 89.54 kJ/deg, and 60.27 kJ/deg, respectively. A greater rate of cetane number, less ignition delay, and calorific value with a lower rate of oxygen delivery might cause this [15].

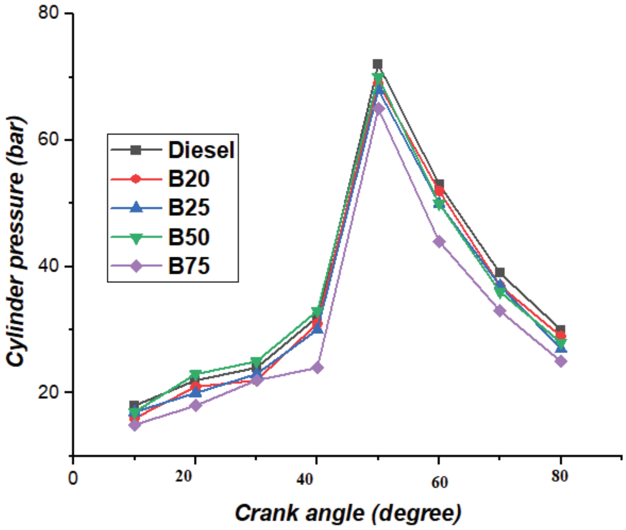

Figure 9. Exhibit the varied range of in-cylinder pressure curve and brake power.

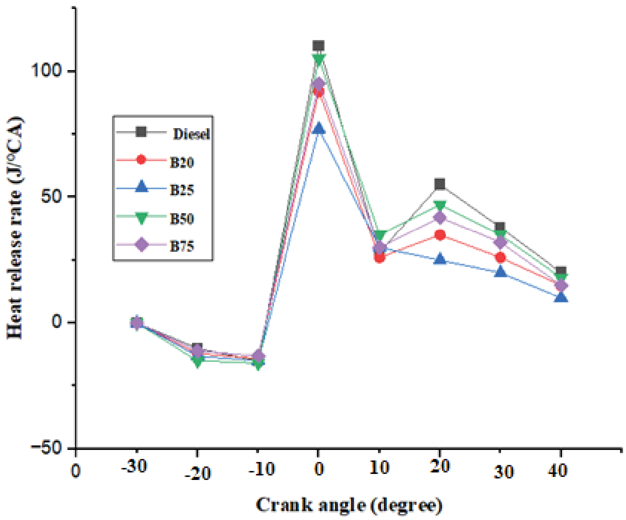

Figure 10. Display the deviations of HRR to crank angle.

CONCLUSION

The following conclusions were reached based on the experimental results:

1. At all power levels, diesel was shown to be more effective at braking than biodiesel blends. Biodiesel blends (14.6%) have a higher brake-specific fuel consumption than diesel fuel.
2. When compared to diesel fuel and biodiesel blends, B20 emits fewer hydrocarbon emissions. In comparison to diesel, B20 produces less carbon monoxide emissions. Regular diesel produces more nitrogen oxide emissions than biodiesel blends do. Plain diesel has less opacity in the smoke than biodiesel blends. B20 demonstrated the best performance with the fewest emissions out of all the evaluated biodiesel blends.
3. The inflation, ignition delay, and combustion duration would be longer as compared to biodiesel blends (10.5%).

In future studies will be required to examine the effects of different compression ratios and to discriminate between the combustion analysis of diesel and biodiesel blends with different EGR rates. However, in terms of economy and emissions, the B10 blend performs more similarly to diesel fuel.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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