J Ther Eng, Vol. 10, No. 4, pp. 904–910, July, 2024

Journal of Thermal Engineering
Web page info: https://jten.yildiz.edu.tr
DOI: 10.14744/thermal.0000839

Research Article

An experimental assessment of performance and emission analysis on a green microalgae biodiesel di engine with Bi_2O_3 nanoparticles

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ARTICLE INFO

Article history
Received: 30 May 2023
Revised: 25 September 2023
Accepted: 28 September 2023

Keywords:
Biodiesel; Diesel Engine; Emission; Green Microalgae; Nanoparticles; Performance

ABSTRACT

A rapid growth in vehicles and population has resulted in a rapid rise in energy demand. Since fossil fuels are rapidly depleting, researchers are focused on finding alternative fuels for diesel as a result of climate change. The country imports 79% of its oil needs at the moment and plans to reduce that to 70% by 2024. To achieve this, alternative fuel sources that are non-toxic, renewable, and inexpensive are needed. It is emerging that algae-based biodiesel could be a viable alternative to diesel fuel. It has been found that microalgae oil can be used to produce biodiesel. The present study investigates the preparation of a biodiesel fuel blend of 80-20 (80 % diesel and 20 % biodiesel) using nanoparticles of Bi_2O_3. This research tests the fuels properties in accordance with ASTM standards. It is possible for nanoparticles to enhance fuel properties and overcome certain disadvantages in general by being adding as fuel additives. In this study, Green Microalgae blends and diesel blends containing Bi_2O_3 nanoadditives were compared for performance and emission characteristics. In experiments, the use of a biodiesel blend with nano-additives resulted in better performance characteristics and lower exhaust emissions.

Cite this article as: Sekharraj K, Balu P, Ravisankar R, Saravanan AM. An experimental assessment of performance and emission analysis on a green microalgae biodiesel di engine with BI_2O_3 nanoparticles. J Ther Eng 2024;10(4):904–910.

INTRODUCTION

In the transportation, defence, power generation, agriculture, and farming sectors, diesel engines are essential sources of power. They produce high power output, are highly energy-efficient, and are simple to maintain [1]. Global warming threatens the ecological harmony of the planet. Scientists are analysing eco-friendly and economically feasible options in light of recent fuel hardships [2]. Efforts are being made to find an affordable and environmentally friendly fuel source. The use of biodiesel with CI engines is becoming more common because fossil fuels are depleting and fuel prices are high, as well as pollution from exhaust gases [3]. Microalgae are non-edible and grows in freshwater, marine water, and non-agriculture-suitable lands, so it will not affect human

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This paper was recommended for publication in revised form by Editor-in-Chief Ahmet Selim Dalkılıç

Published by Yıldız Technical University Press, İstanbul, Turkey

nutrition [4]. Biofuels made from green algae are non-toxic, contain no sulphur, and decompose quickly. The left-over material can be used as soil fertilizer or to produce ethanol after oil extraction. Thus, it can be used as a biodiesel feedstock. Moreover, green microalgae have a high growth rate due to the fact that they can double their mass within five to fifteen days, as well as a high production rate. As a result of the large amount of CO_2 required for higher production of Green Microalgae biomass, it plays a significant role in CO_2 biofixation processes. Biodiesel from microalgae outperforms petroleum on many parameters, including environmental ones. There is, however, one major drawback to biodiesel: its high cost disparity with petroleum diesel. Because of this, biodiesel is not viewed as a complete replacement for petroleum distillates, but rather as an additional fuel, such as B20, that requires no modification to the engine [5]. The physicochemical properties of algae biofuel blends as well as mixtures can, however, are improved to improve emission and combustion characteristics. The inclusion of combustible nanoparticles will likely improve the performance of CI engines powered by biodiesel. Nanomaterials also have the advantage of not clogging fuel injectors and also filters, which is possible when micron-sized particles are present. Literature review reveals that the majority of the work focuses on biodiesel blends with neat diesel of various proportions [6]. In an alternative proportion, a suitable oxide nano additive was combined with biodiesel to improve its physical and chemical properties. A micro or nano additive could be added to neat diesel according to research. The fact that biodiesel research has a significant gap based on these details supports this information [7].

Nano additives should not have a particle size greater than 100 nanometers according to the survey. In a diesel engine, longer blends of Bi_2O_3 cause various problems, such as incomplete combustion, viscosity, and atomization. The current study evaluated the Performance and emission characteristics of a DI engine based on nano blends.

MATERIAL AND METHODS

Green Microalgaeoil Extraction

It is possible to produce biofuels from microalgae. There are a variety of biofuels that can be produced using algal biomass as a feedstock. Many organic solvents and combinations of organic solvents have been suggested for selectively separating lipids from a complex mixture of organic compounds. It is usually chloroform that is used in these methods of solvent extraction, though it is not feasible to extract lipids at a large scale due to environmental and health concerns. There have been many studies carried out to investigate less-toxic, but less effective, solvents for microalgae lipid extraction, including ethanol, isopropanol, butanol, MTBE, acetic acid ester, hexane, and combination thereof. The extraction of lipids from microalgae is also accomplished mechanically, both at pilot scale and at scales commercially. In contrast to chemical methods, mechanical methods are more effective since the type of microalgae is less dependent on it. It is also less likely that the extracted lipid product will be contaminated by them. Energy inputs required by the above methods are usually higher than those required by chemical or enzymatic methods, however [8].

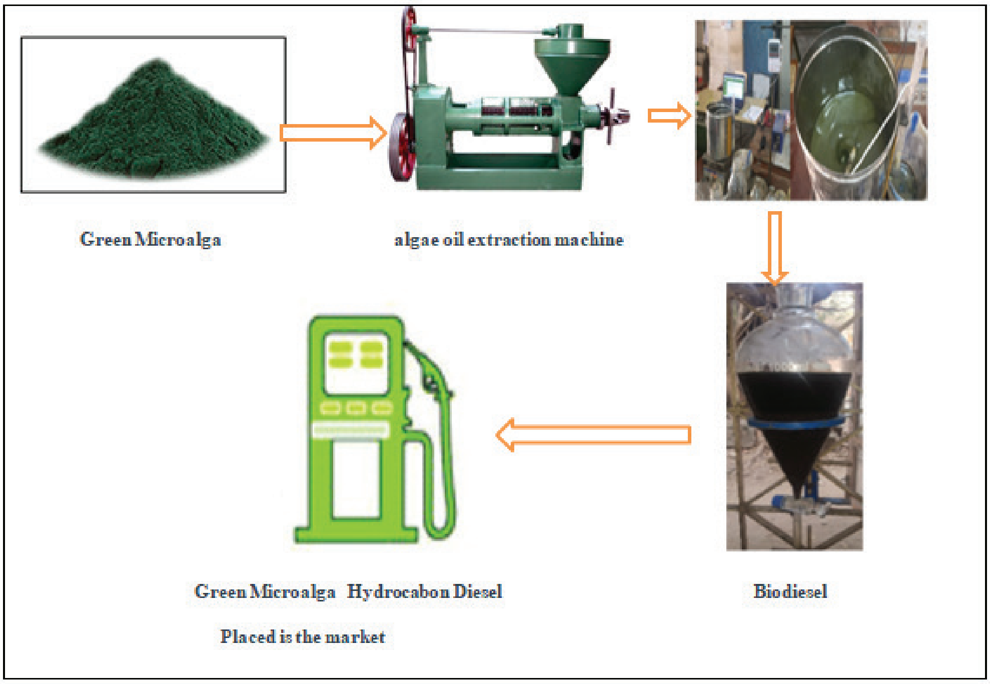

Figure 1. Preparation of green microalgaeoil extraction.

Table 1. As measured by ASTM standard for B20 and Bi_2O_3

Properties	ASTM	Diesel	Green Algae oil	B20
Calorific value (kJ/kg)	D-240	45400	10954	43,540
Kinematic viscosity at 40 °C (mm ^{2}/s)	D-445	2.5	4.13	4.73
Pour point (°C)	D-97	-21	-4	-4
Cetane number	D-613	45	52	58
Flashpoint (min °C)	D-92	55	164	176
Water and sediment (% vol.)	D-2709	0.03	0.05	0.05
Density (g/cm^3)	D-4052	0.743	0.8802	0.830

Experimental Setup

Research was conducted on a water-cooled, four-stroke single-cylinder DI diesel engine. Based on engine brake load testing of 3.1 kW (part load) and 5.2 kW (maximum load) using biodiesel blends, engine brake powers of 3.1 kW and 5.2 kW respectively were measured at 1500 rpm. A piezoelectric pressure transducer measured the in-cylinder pressure on the cylinder head. The first law of thermodynamics was used to calculate heat release rates for 100 cycles using AVL Indicom software. As part of the measurement, CO, HC, and NO emissions were measured with a digasanalyzer from AVL. By timing the amount of time the engine took to consume 10 cc of fuel available in the burette, fuel consumption was calculated. The engine was operated for 25 minutes before taking the readings to ensure stable operation and reach 75°C cooling water temperature. As shown in Figure 2, there are various measuring setups on the research engine. Table 2 provides detailed engine specifications. The uncertainty of the various measurements is shown in Table 3.

Table 2. Specifications of a research engine

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

Characterization of Bi_2O_3 Nanoparticles

A SEM and EDS analysis was performed on Bi_2O_3 nanoparticles. Nanoparticle morphology and average particle size were measured using SEM. As shown in Figure 3, an image of Bi_2O_3 nanoparticles at 49000X magnification. From SEM images, Bi_2O_3 nanoparticles range between 50.24 and 110.87 nm in size. Bi_2O_3 nanoparticles were shown in Figure 3 to show their Energy Dispersive Spectrum (EDS).

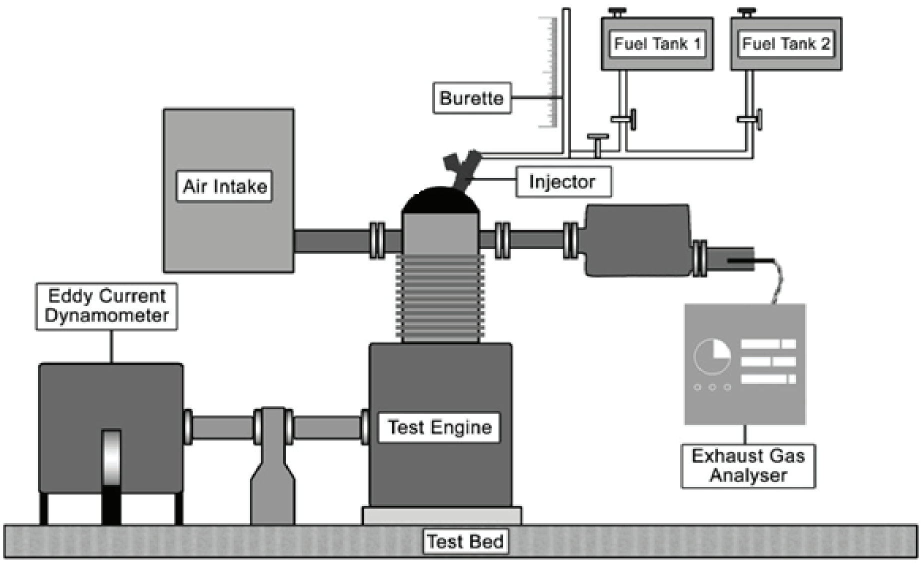

Figure 2. Experiment setup.

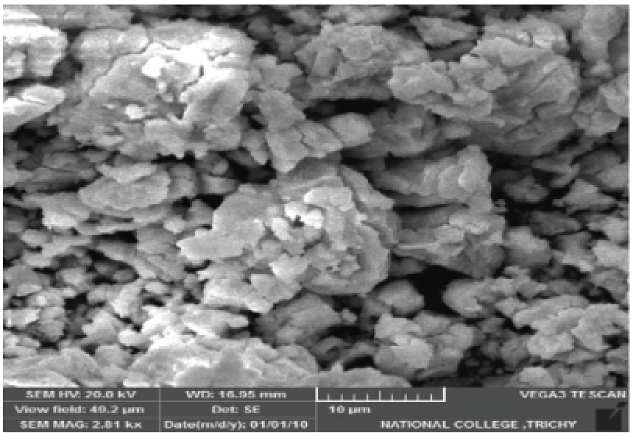

Figure 3. Bi_2O_3 nanoparticles.

Table 3. Uncertainty of various parameters

Parameters	Uncertainty (%)
Pressure	0.4
Load	0.3
Speed	0.2
Crank angle	0.2
Temperature	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

In the Bi_2O_3 nanoparticles, Bi_2 and O_3 are confirmed by EDS analysis [9].

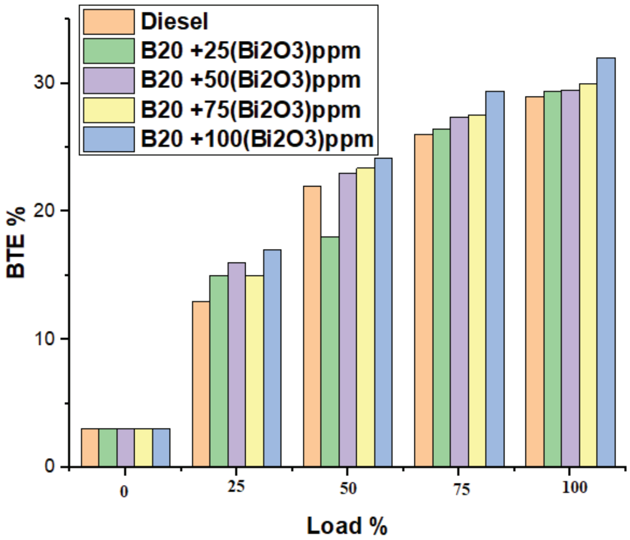

Figure 4. Brake thermal efficiency vs load.

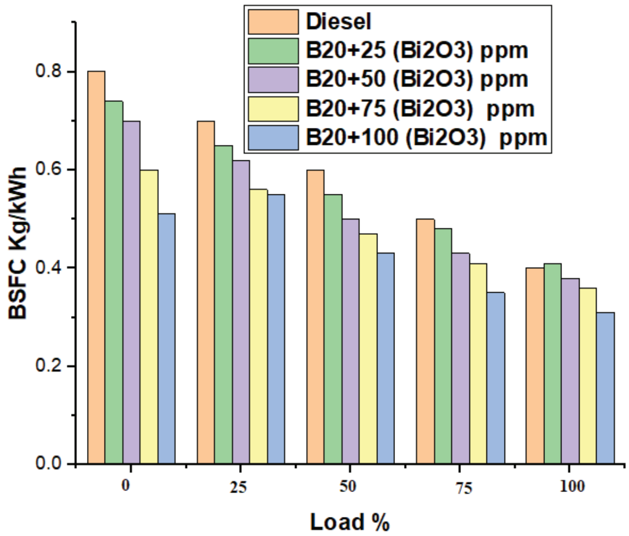

Figure 5. Brake specific fuel consumption vs load.

RESULTS AND DISCUSSION

Brake Thermal Efficiency

The variation of BTE with load is shown in Figure 4. In contrast to diesel fuel with the full load condition, B20 fuel with 25 ppm, 50 ppm, 75 ppm and 100 ppm fuel samples exhibit better BTEs. The thermal efficiency of engines with green microalgae blends increased significantly with the addition of Bi_2O_3 nanoparticle. The thermal performance of the engine is significantly improved B20 with Bi_2O_3 nanoparticle is added to blends. In comparison to the other blend, the amount of heat released when the fuel ignited was increased, resulting in a higher BTE [10].

Brake Specific Fuel Consumption

The results are shown in Figure 5 for diesel, B20P25ppm, B20P50ppm, B20P75ppm, and B20P100ppm loads. In fuel blends with Bi_2O_3 nano additives, the BSFC is lowest, whereas in fuel blends with diesel the BSFC is highest. This is due to the fact that B20 with Bi_2O_3 improves fuel properties and reduces ignition delay time, which results in full combustion.

Carbon Monoxide (CO)

As seen in Figure 6, the load affects carbon monoxide levels. In diesel, due to low oxygen levels and incomplete combustion, there are more CO pollutants than in blends of B20 with Bi_2O_3. Nanoparticles also improve combustion and reduce ignition delay in biodiesel blends. A high engine temperature results in a lack of oxygen and a long oxidation period, which results in incomplete combustion for B100 and B50 fuels [11].

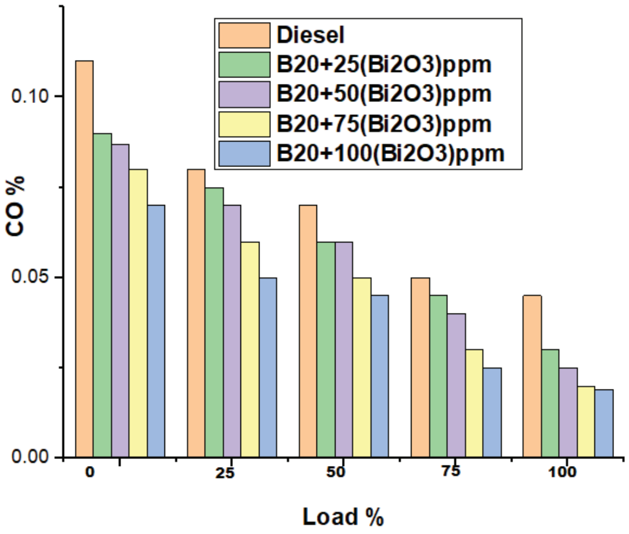

Figure 6. Carbon monoxide vs load.

Hydrocarbons (HC)

Figure 7 shows HC pollutants' variation. As a result of a better combustion process and a higher cetane number, blends of B20 with Bi2O3 nanoparticles have been observed to produce fewer HC emissions than diesel. By using a relative air-fuel mixture of B20 and a higher cetane number, the ignition delay is reduced, which reduces the amount of HC emissions [12].

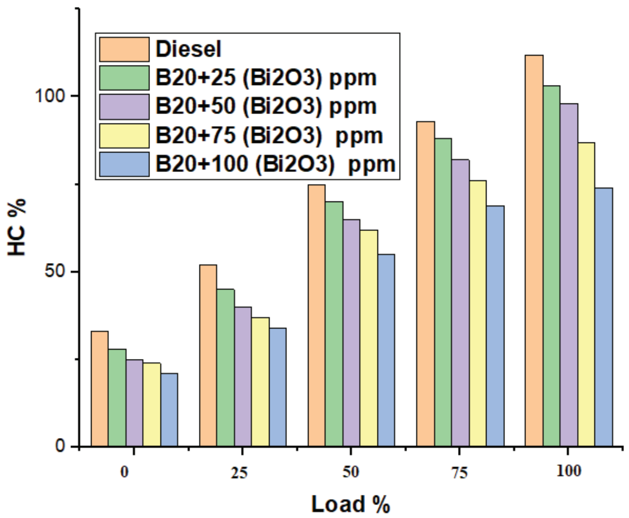

Figure 7. Hydrocarbons vs load.

The Nitrogen Oxides (NOX)

It shows Figure 8 the deviations of NOx at several loads. During high loads, the combustion temperature increases and more NOx is released. In contrast to diesel, blends of B20 with Bi_2O_3 emit more NOx. Biodiesel blends with

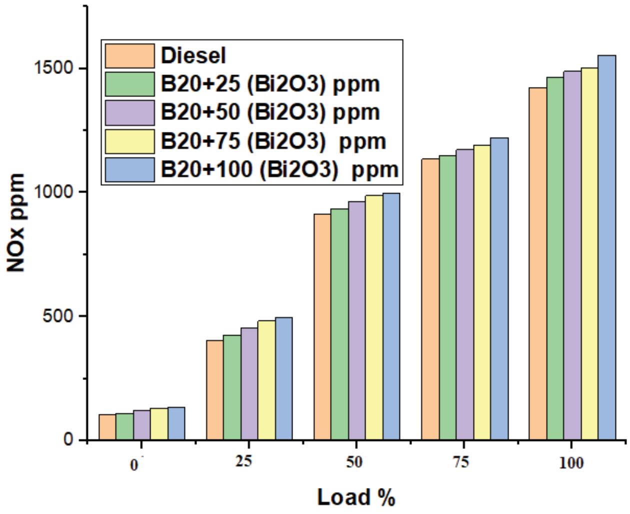

Figure 8. Oxides of nitrogen vs load.

higher oxygen content lead to higher NOx emissions due to increased adiabatic flame temperature. Reducing the temperature of the exhaust gases reduces NOx emissions for B20 blends [13].

Smoke Opacity

In Figure 9, we show the variation of smoke opacity with fuel loading for all fuel samples. In comparison with diesel, blends of B20 with Bi2O3 have a lower smoke opacity. With a higher cetane index and more oxygen, blends of B20 with Bi2O3 burn more efficiently, which results in less smoke opacity. Nanoparticles also improve combustion efficiency by reducing smoke opacity and shortening ignition delays [14].

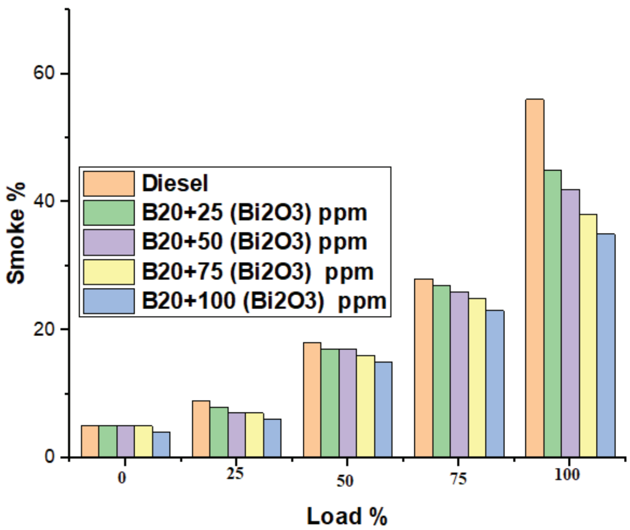

Figure 9. Smoke opacity vs load.

CONCLUSION

A four-stroke direct injection diesel engine is used to study the performance and emission characteristics of biodiesel, such as green microalgae biodiesel blended with Bi2O nano additive. The following conclusions were drawn from the results

- In nanoparticle combustion, the lighter surface area-to-volume ratio allows more fuel to react with the air, improving combustion characteristics. BTE (5%) is enhanced as a result.
- As nanoparticles improve the physical properties of fuel and reduce the ignition delay time, BSFC (10%) decreases.
- It is observed that Bi_2O_3 blend fuels produce the least CO (12%), HC (12%), and smoke (15%) emissions when compared to diesel , while Bi_2O_3 blend fuels produce the most NOx (10%) emissions.

Furthermore, the green microalgae oil biodiesel and its diesel blends can be used to substitute diesel fuel without any engine modifications. In an evaluation of the engine test results, it was determined that microalgae oil biodiesel is much more economical than the current fossil fuel. In future studies, different nano-additives and proportions of nano-additives will be tested for their impact on engine characteristics.

NOMENCLATURE

Bi_2O_3	Bismuth oxide
CO_2	Carbon dioxide
EDS	Energy Dispersive Spectrum
SEM	Scanning electron microscope
BTE	Brake thermal efficiency
BSFC	Brake Specific Fuel Consumption
CO	Carbon monoxide,
HC	Hydrocarbon
NOx	Oxides of Nitrogen
MTBE	Methyl tert-butyl ether

AUTHORSHIP CONTRIBUTIONS

K. Sekharraj: Investigation, Writing - original draft. Visualization. **Dr.P.Balu**: Supervision. **A M Saravanan**: Writing review, editing &Validation. **R.Ravisankar:** Conceptualization, Methodology

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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