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Impact on Green Synthesised Al_2O_3 Nanoparticles on Performance and Emission Properties as Biodiesel operated diesel engine

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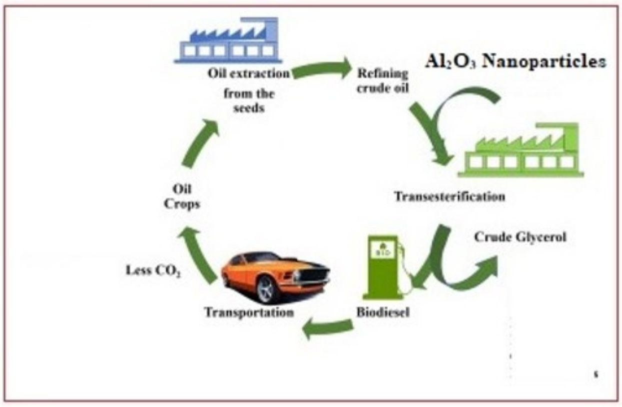
Graphical abstract



Abstract

Global warming and pollution are two of the numerous causes of environmental issues due to industrial wastes and greenhouse gases. As a result, efforts are being made to limit emissions in order to mitigate these issues and reduce pollution. Given that fuel supplies are running low, biodiesel is one of the best alternatives to diesel fuel. One of the main obstacles to biodiesel's commercialization is its higher cost than diesel. One of the more superior substitute fuels for diesel is biodiesel, which is a fuel with great potential. When combined with 20% commercial diesel (B20), the resulting biodiesel is known as Pongamia. Improving engine performance and combustion characteristics while decreasing atmospheric NOX, CO, and HC exhaust emissions are the primary goals of this research. In comparison to neat diesel, BSFC and BTE were found to have increased by 12.27% and 15.34% respectively, while NOx, CO, and HC concentrations were decreased by 15.46%, 54%, 7.30%, and 25.67% respectively. Biodiesel mixed with Al_2O_3 nano additive significantly improves the performance and combustion characteristics of diesel engines.

Keywords: Diesel engine, Biodiesel, Nano Additives, green synthesis, Performance, Emission

1. Introduction

Because it works better in compression ignition engines than diesel, biodiesel has become more and more important in recent years [Abdelrahman *et al.* 2020]. Because biodiesel is more expensive than conventional fuel, there is environmental concern about pollution from burning fossil fuels, there is a shortage owing to population growth, and transportation is used often, there is a lot of study being done on the fuel [Kanthavelkumaran *et al.* 2024]. The government also spreads knowledge about the use of fuels other than petroleum-based ones. As a result, a lot of businesses are giving alternative fuels more attention. By concentrating on alternative fuels, issues with pollution, shortages, and the environment may be resolved, and farmers will benefit from increased expansion. Biodiesel is emphasised more for its benefits and is seen to be a superior alternative to diesel fuel due to cost and environmental concerns. As part of the manufacturing process, algae, non-edible oils, and edible oils are used to make three generations of biodiesel [Fayad and Dhahad 2021]. Biodiesel is made from waste, which is an inedible source, whereas alcohol is used for more beneficial purposes [Kanthavelkumaran *et al.* 2023]. However, some nations advance to the third phase, using genetically modified agricultural plants to manufacture biodiesel from algae

Harigaran Arumugam, Balu Pandian, Ravikumar Muthaiyan, Sivashankar Arumugam, Silambarasan Rajendran and Chander Prakash (2024), Impact on Green Synthesised Al_2O_3 Nanoparticles on Performance and Emission Properties as Biodiesel operated diesel engine, *Global NEST Journal*, **26**(10), 06425.

[Chhabra *et al.* 2017]. According to research by Rolvin D'Silva [Dharmaraja *et al.* 2019], adding nano additions causes the fuel's density and viscosity to rise. CuO nano additions to biodiesel increased its brake thermal efficiency (BTE). When compared to B20 mix, B20+10 ppm CuO yields the greatest BTE at the maximum load. It is observed that, in comparison to other blends, B20+50 ppm CuO has the lowest BSFC out of all the samples collected. By adding more CuO nano additions to the B20 mix, CO emissions can be reduced. In comparison to other mixes, B20+50 ppm CuO emits less smoke. Increasing the amount of CuO nano additions in the B20 mix can reduce smoke. It is discovered that adding CuO nanoparticles to the B20 mix improves both performance and emission characteristics.The use of aluminium oxide nanoparticles (ZnO NPs) as catalysts for the esterification of free fatty acids (FFAs) and the transesterification of triglycerides has recently begun to gain momentum among researchers among other metal oxides. Zinc oxide, or ZnO, is an amphoteric transition-metal oxide that has been employed as a heterogeneous catalyst for a number of catalytic conversions, such as the production of biodiesel from rapeseed, palm, and soybean oils, among other edible feedstocks [Soudagar *et al.* 2020].Researchers have combined fuel with ZnO nanoadditives in several studies. Several nanoparticles, including ZnO, Al2O3, Fe2O3, NiO, MgO, SiO2, TIO2, NiFe2O4, and Zn0.5Ni0.5Fe2O4, were introduced by Ozgur *et al.* [El-Seesy *et al.* 2018] to examine the impact of exhaust emission of NOx alone. According to the author's study, at 2800 rpm engine speed, NOx emission was decreased by 3.2%, 10.2% with 25 ppm concentration of ZnO, NiO, 7%, 6.4% with 50 ppm concentration of SiO2, Al2O3, 18.9%, 16.2%, 12.6%, and 22.1% with 100 ppm concentration of Fe2O3, TiO2, Zn0.5Ni0.5Fe2O4, and NiFe2O4.Researchers have combined fuel with ZnO nanoadditives in several studies. Several nanoparticles, including ZnO, Al2O3, Fe2O3, NiO, MgO, SiO2, TIO2, NiFe2O4, and Zn0.5Ni0.5Fe2O4, were introduced by Ozgur *et al.* [El-Seesy *et al.* 2018] to examine the impact of exhaust emission of NOx alone. According to the author's study, at 2800 rpm engine speed, NOx emission was decreased by 3.2%, 10.2% with 25 ppm concentration of ZnO, NiO, 7%, 6.4% with 50 ppm concentration of SiO2, Al2O3, 18.9%, 16.2%, 12.6%, and 22.1% with 100 ppm concentration of Fe2O3, TiO2, Zn0.5Ni0.5Fe2O4, and NiFe2O4.Nano additives were introduced and tested in an effort to enhance the performance of biodiesel in diesel engines. This study compared the performance, emissions, and combustion properties of pongamia biodiesel combined with additives in a diesel engine to that of diesel.

2. Materials and Methods

2.1. Preparation of biodiesel

Making biodiesel Transesterification—which occurs between an oil and an alcohol in the presence of a catalyst—is one of the most often used techniques in the biodiesel industry to lower oil viscosity. Essentially, transesterification is a reaction to time. Diglycerides are produced by first reducing triglycerides. Then, the diglycerides are broken down into monoglycerides. Ultimately, carboxylic acid esters are produced from the reduction of the monoglycerides. A thermometer, a beaker, and a magnetic stirrer are needed pieces of equipment for the transesterification reaction. Pongamia oil, methanol, and potassium hydroxide are used as raw ingredients. The main beaker was filled with 1000 ml of pogo dai oil after it was metered out. The oil was then heated to 60°C after being agitated at 1000 rpm. Furthermore, 250 millilitres of methanol were used to dissolve 5 grammes of potassium hydroxide, which was then vigorously stirred. After adding this alcohol combination to the pongamia oil, it was aggressively agitated at 1000 rpm for 60 minutes at 60 degrees Celsius. The heavier liquid, crude glycerin, separated at the bottom and the methyl ester at the top. Following completion, a double volume of methyl ester is added, and the mixture is agitated for 15 minutes at 80°C. Once more, the glycerin was allowed to settle. Until the ester layer turned clear, the procedure was repeated (**Figure 1**).

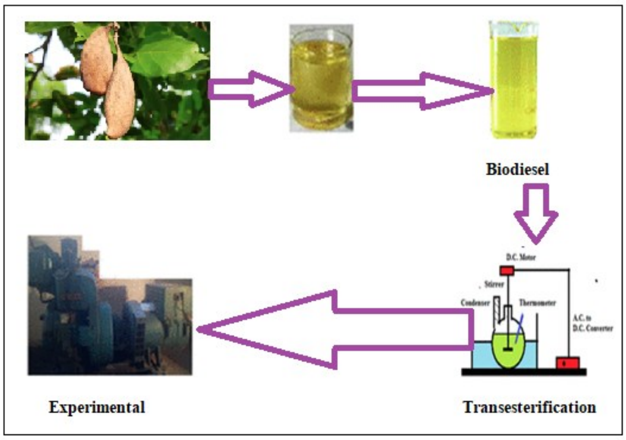


Figure 1. Preparation of Citrullus Lanatus

2.2. Characterization of the Al_2O_3 Nanoparticles

Figure 2 shows the SEM pictures at different magnifications. The as-synthesised Al2O3's photos show a porous surface with an uneven shape. Using EDX spectroscopy, the elemental composition of the produced Al2O3 nanoparticles is determined; the percentage data obtained are shown in **Figure 3**. According to the EDX study, Al2O3 is extremely stoichiometric, with an atomic percentage of 42.55 for Al and 57.45 for O.

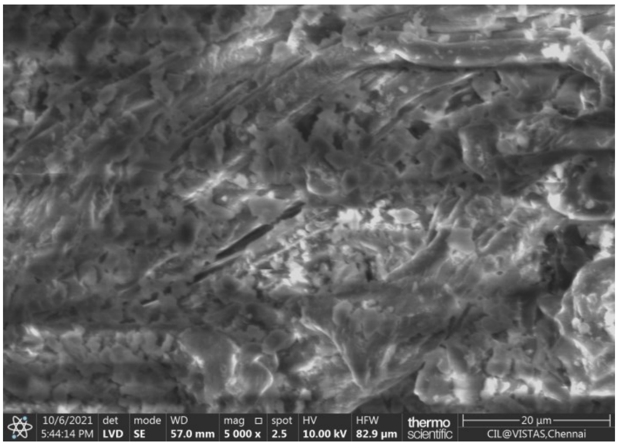


Figure 2. SEM images of the as-synthesized Al$_2$O$_3$.

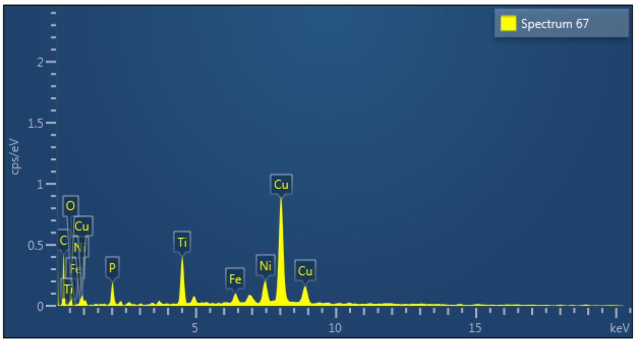


Figure 3. EDAX spectrum ofAl$_2$O$_3$.

3. Experimental Setup

The test is conducted using a computerised, single-cylinder, four-stroke, Direct Injection (D.I), water-cooled, variable compression ratio diesel engine test rig with a 3.5 kW rated power. For each mix, the trials are run at constant speeds of 1500 rpm with varied weights. B20, B20+50 ppm ZnO, B20+100 ppm ZnO, and B20+150 ppm ZnO are the fuel samples that were utilised. The diesel engine's compression ratio may be adjusted between 12:1 and 18:1. An eddy current dynamometer is directly attached to it. An independent panel box with an air box, fuel tank, manometer, fuel measuring unit, transmitters for monitoring fuel and air flow, a process indicator, an engine indicator, and an engine is part of the diesel engine setup. The NOx (ppm), CO (%), CO2 (%), and HC (ppm) emissions in the exhaust are measured using an AVL digas 444 five gas exhaust gas analyzer. The opacity of smoke is expressed as a percentage of volume using a smoke metre. The injection pressure is set at 200 bar and the speed is preset at 1500 rpm. In five phases, the load is changed from 0% to 25% to 50% to 75% to 100%, and the tabulated fuel consumption and emission data are recorded (**Table 1, Figure 4**).

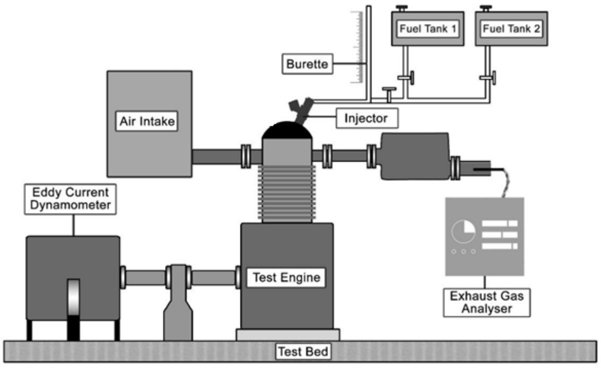


Figure 4. Experiment set up

Table 1. 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

3.1. *Uncertainty Analysis*

Table 2 displays the accuracy and uncertainty of data measurement by an instrument.

Table 2. 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

4. Results and Discussion

4.1. *Brake Thermal Efficiency*

Figure 5 makes this evident: at maximum load, the brake thermal efficiency of B20+100 (ppm) alumina oxide nanoparticle blends is the most efficient when compared to B20 and other blends, and BTE increases by 3.14% when compared to B20 biodiesel. The adequate oxygen level in the nano fluid is what causes the rise in brake thermal efficiency. The blend generates a homogeneous mixture because of the large surface area per volume of the nanoparticles. So that the gasoline burns through completely [Devarajan *et al.* 2019].

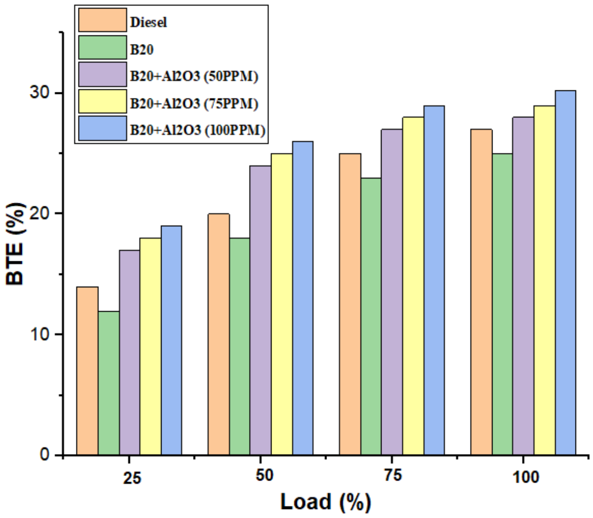


Figure 5. Brake Thermal Efficiency Vs Load

4.2. *Brake specific fuel consumption*

Figure 6 makes it evident that, when compared to the other blends, the B20+100 of Al2O3 nanoparticle mix exhibits the least amount of BSFC at maximum load, with an 8.52% drop in BSFC when compared to B20 biodiesel. The incorporation of nanoparticles into biodiesel is the cause of the decline in BSFC. The amount of nanoparticles in the biodiesel increases with an increase in its calorific value. The BSFC value falls as the calorific value of biodiesel rises [Elumalai *et al.* 2021].

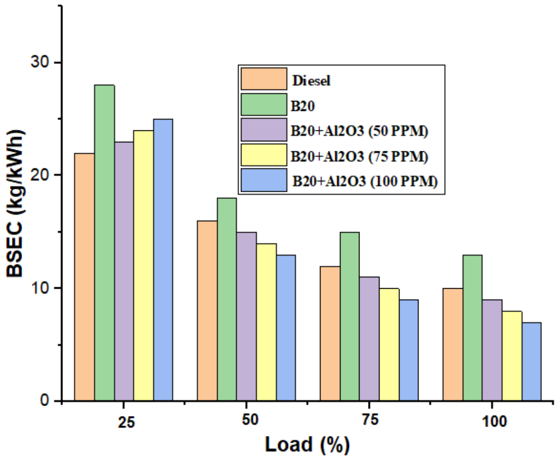


Figure 6. Brake specific fuel consumption Vs Load

4.3. *Carbon Monoxide (CO) emission*

When compared to other blends of B20 Bio diesel, the CO emission of B20+100 (ppm) of alumina oxide at full load is quite low, as seen in **Figure 7**. When compared to B20 neat mix, the CO emission of B20+100 (ppm) of alumina oxide is 15% lower at full load. Since Al2O3 is an oxidation catalyst and improves the mixed fuel's combustion properties, its inclusion is responsible for the reduction in CO emissions.Existing CO is transformed into CO2 [Balu *et al.* 2023; Ponnusamy Sudeshkumar *et al.* 2022].

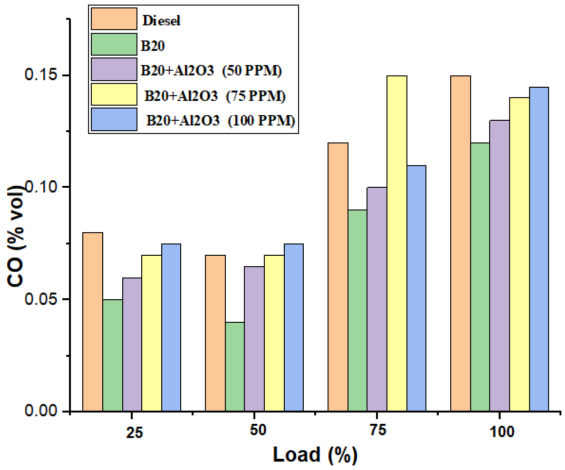


Figure 7. Carbon Monoxide Vs Load

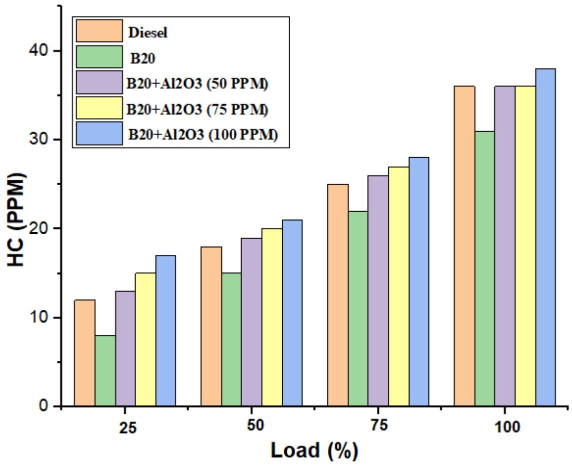


Figure 8. Hydrocarbon Vs Load

4.4. *Hydrocarbon (HC) emission*

Figure 8 makes it evident that, when compared to other B20 biodiesel blends and other nano additive blends of alumina oxide at all other loads, the HC emission of B20+100 (ppm) of alumina oxide exhibits lower HC emissions. Because the nano fuel mixes burn well, the introduction of nanoparticles to the biodiesel reduces the ignition delay [Kanthavelkumaran *et al.* 2021].

4.5. *NO$_X$ emission*

Figure 9 makes it evident that, at all load levels, the NOX emissions of B20+100 ppm of alumina oxide are lower than those of other blends of B20 biodiesel and other nano additive blends of alumina oxide [Ramanujam Soundararaj *et al.* 2021].

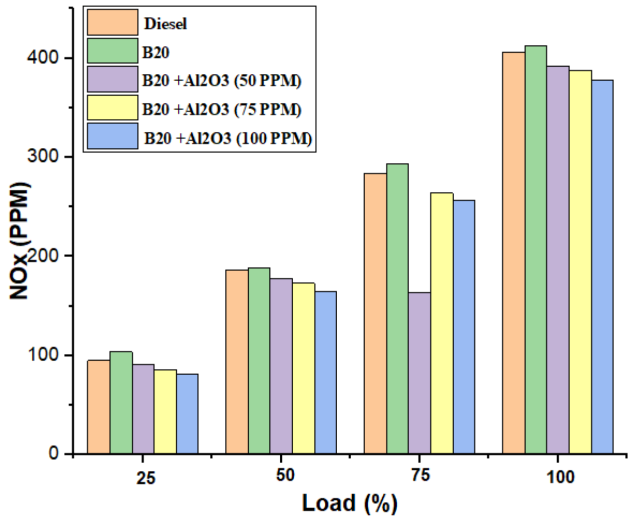


Figure 9. NO$_X$ Vs Load

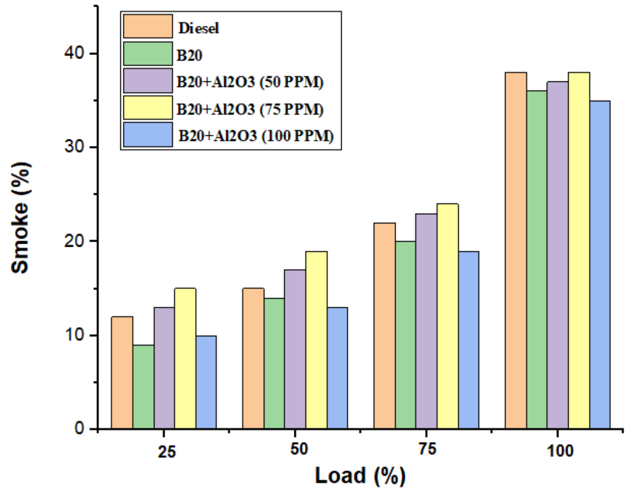


Figure 10. Smoke Vs Load

4.6. Smoke emission

Figure 10 Changes in smoke in relation to brake power **Figure 9** makes it evident that, for all other loads, the smoke emissions of B20+100 (ppm) of alumina oxide are lower than those of other blends of B20 biodiesel and other nano additive blends of alumina oxide. The low concentration of HC, CO, and CO2 emissions of the fuel are a result of the nano fuel's strong thermal stability, which also leads to good combustion and reduced smoke emissions [Harigaran and Pandian Balu 2023].

5. Conclusion

Based on an analysis of diesel engine performance and emissions utilising B20 biodiesel and other nano-blended fuels, the following conclusions were drawn.

1. At maximum load, the brake thermal efficiency of the B20+100 ppm alumina oxide nanoparticle blend is the highest when compared to the other B20 blends. A rise of 2.62% in BTE is observed over the B20 biodiesel blend, while a decrease of 8.52% is observed in the B20+100 ppm alumina oxide blend's BSFC.
2. At all load levels, the B20+50 (ppm) alumina oxide blend exhibits lower HC emissions than other B20 biodiesel blends and other nano additive alumina oxide blends.
3. The B20+100 (ppm) of alumina oxide emits 5.20% less carbon dioxide than the B20 neat blend, and at maximum load, the B20+100 (ppm) of alumina oxide emits 15% less carbon dioxide than the B20 neat blend.
4. At all load levels, the NOx emissions of B20+100 (ppm) alumina oxide are lower than those of other B20 biodiesel blends and other nano additive blends of alumina oxide.
5. The experiment's total analysis revealed that, in comparison to other blends, the B20+100 (ppm) Al2O3blends was more advantageous.

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