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Research Article

Influence of nano additives on performance and emissions characteristics of a diesel engine fueled with watermelon methyl ester

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ABSTRACT

Significant population and automobile expansion have resulted in a rapid rise in energy demand. Because of the high demand for energy and the rapid depletion of fossil fuels, experts are concentrating their efforts on developing a suitable alternative fuel for diesel. The performance and emission characteristics of biodiesel made from watermelon methyl ester were investigated using a lanthanum oxide (La_2O_3) nanoparticle addition. Through the transesterification meth od, biodiesel was produced from non-edible watermelon seed oil. Compared to B20, addition of 100 parts per million (ppm) of La_2O_3 nanoparticles to biodiesel emulsion fuel reduces CO and HC emissions by 4.75% and 6.67%, respectively. Compared to B20 at full load circumstances, the inclusion of La_2O_3 nanoparticles at 100 ppm enhances the brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) by 2% and 8.8%, respectively.

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INTRODUCTION

With increasing population and industrialization, the energy demand is rising steadily; also, the harmful effects caused by fossil fuels on the environment and human beings, along with the declining feedstock availability of fossil fuels, necessitate research in alternate fuels Mustafa Yilmaz et al.2012. Biodiesel has shown promising features, such as biodegradability, renewability, readiness for use, carbon neutrality, fewer toxins, increased safety, and smoother use of the IC engine, among other choices for automotive fuels Appavu and Venkata Ramanan 2018.

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However, the toxic compounds in non-edible oils make them unsuitable for consumption. The major advantages of the biodiesel obtained from non-edible feedstock are lower carbon monoxide, nitrogen oxide, particulate matter, hydrocarbon, and smoke emissions, together with higher diffusion combustion and higher compression ratio related to increased injection pressure characteristics. The main disadvantages of oil employed in diesel engines are poor atomization and vaporization, high smoke, and sticky deposits on engine elements because of its high viscosities Hasan Koten., 2018a.

These issues are often overcome by adopting appropriate ways like blending, changing to biodiesel, heating to reduce viscosity, low heat rejection of diesel engines, fuel additives, etc. Devarajan and Munuswamy 2016. Numerous studies selected metal-based nano-additives to mitigate the limitations of biodiesel. Nanotechnology has enabled nano-size molecules that increase thermal properties, therefore contributing to the combustion of the benefits of a significant volume/surface ratio Venu and Madhavan 2017. The nano additives act as a catalyst, enhancing the engine's performance and significantly improving emission characteristics Pandian et al. 2018. Nanoscale additives also enhance fuel oxidation properties, reducing hazardous pollutants Devarajan, Munuswamy and Mahalingam 2018. They found nanoparticles have become a unique and assuring additive that reduces emissions and improves diesel engine performance. In contrast to other test fuels, carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NO_x), and smoke emissions were reduced when canola biodiesel (B20) was treated with nanoparticle addition titanium oxide (TiO_2) Nithya et al. 2019. They found a reduction of CO emissions, CO_2 emissions, and hydrocarbons from the aluminium nanoparticles. They also indicate that incorporating nanoparticles of aluminium biodiesel considerably enhanced NO_x emissions Prabu 2017. As the oxygen-providing catalyst, cerium oxide nanoparticles have reduced CO and NO_x emissions due to increased oxidation, leading to complete biodiesel combustion and decreased emissions Karthikeyan et al., 2016a. The literature review shows biofuels are being investigated as a possible replacement for diesel engines. Only a few research works have utilized La_2O_3 nanoparticles in diesel engines. The ultrasonication technique is used in this study to incorporate La_2O_3 nano-additives into watermelon seed biodiesel at two concentrations (50 ppm and 100 ppm) to assess diesel engine performance and emission characteristics. This research investigates the effect of La_2O_3 additions on watermelon methyl ester. Under various loads, a diesel engine's performance characteristics and exhaust emissions were determined, including the BTE and BSFC, as well as CO, HC, and NO_x emissions.

MATERIALS AND METHODS

Watermelon Seeds

Watermelon fruit had numerous smooth, squashed seeds thicker at the edge and black and yellow-white. The watermelon seed oil has generated significantly greater cetane number and thermal stability than petrol diesel but has inferior cold flow characteristics. The watermelon seed oil showed substantial concentrations of unsaturated fatty acids compared to other seeds. Accordingly, excellent, affordable, and new oil sources must be provided to be used domestically and maybe industrially. It spreads mainly by seeds and is best cultivated in warm places. This tropical fruit needs enough light with a temperature above 25°C to get the best development possible. Watermelon flourishes best in very acidic drained-rich soil. Watermelon fruits with seeds are depicted in figure 1.

Figure 1. Watermelon Seeds.

Figure 2. Lanthanum oxide nanoparticles.

Production of Biodiesel

Watermelons were cut into slices, and the seeds were collected using the hands and then washed with distilled water. They were put to dry in the sun at approximated 28°C for a week. After shelling, the seeds were manually peeled by shattering them with a metal cylinder to extract the kernels. The fine kernel flour was obtained with a coffee grinder and oil extracted in hexane from the soxhlet device. Watermelon-produced oil is highly viscous and low in volatility. The conversion of these fuels to biodiesel, whose qualities, performances, and performance are comparable to petrol diesel may resolve these issues.

Lanthanum Oxide

The inorganic compound comprising rare earth elements lanthanum and oxygen is Lanthanum oxide, sometimes called lanthanum, chemical formula La_2O_3. It is employed as optical material in certain ferroelectric materials and is used as a feedstock for some catalysts. Lanthanum oxide is an odorless, white solid which is water- insoluble but diluted in acid-soluble. Various crystal forms may be formed depending on the pH of the chemical. La_2O_3 is hygroscopic; it absorbs moisture in the environment over time and becomes a lanthanum hydroxide. Figure. 2 shows a lanthanum oxide nanoparticle image.

Transesterification Process

It can be made from raw edible and non-edible oil using methyl alcohol as a substance and potassium hydroxide and sulfuric acid as substances for base component and component acid chemical reactions, respectively. The 10% methyl alcohol blended with 0.3% sulfuric acid (volume) was arranged as an acid solvent. The acid solvent was mixed with 1000 ml of neat watermelon seed oil at 55°C and stirred with a constant speed of 20-30 rpm for half an hour to remove the deposits. The ending solution may be detached by using a detaching funnel. To make the base course, 20% of methyl alcohol blended with 0.64% potassium hydroxide solvent was arranged as the base solvent. The base solvent was further to 1000 ml of non-edible oil from the acid course till 63.5°C for half an hour. The funnel could separate the resulting solution from the residue. Figure. 3 shows the transesterification of watermelon biodiesel.

Experimental Set-Up

As depicted in Figure 4, the experimental apparatus consists of a Kirloskar single-cylinder, constant-speed, direct-injection engine utilized to examine watermelon biodiesel's performance and emission characteristics with nano additives. The engine works at a constant speed of 1500 rpm under various load conditions with a single blend, and the engine specifications are shown in table1. The diesel engine was directly connected to an eddy current dynamometer that changed the load from zero to full. The engine load ranges between 0% and 100%, increasing by 25% in each phase, based on a power of 5.2 kW. The engine loads were adjusted manually using an eddy current dynamometer. The combination of air and fuel in the engine cylinder is critical for managing engine power and emissions. The exhaust emissions from the engine are often paired with smoke, which contains many pollutants that may be examined using the five-gas emission analyzer. CO, HC, and NO_x emissions were measured using a five-gas emission analyzer.

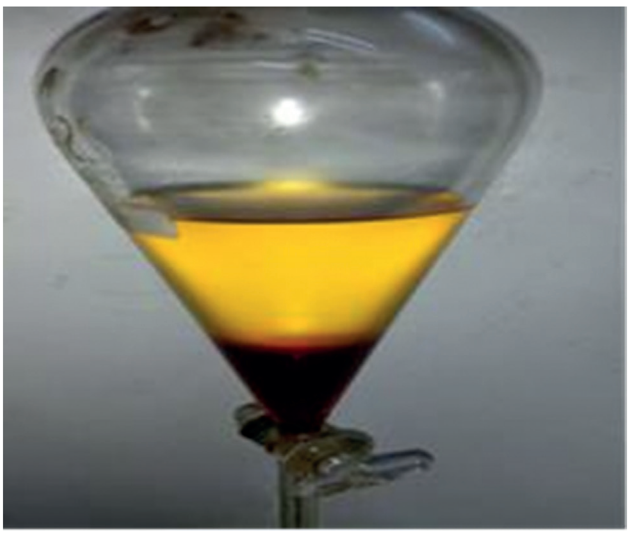

Figure 3. Transesterification of watermelon biodiesel.

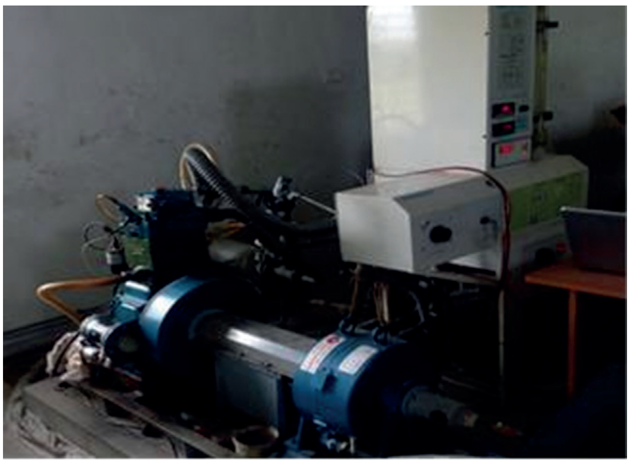

Figure 4. Experimental set-up.

Table 1. Technical specification CI engine

No of cylinders	Single cylinder
Bore mm	87.5
Stroke mm	110
Rated output kW	5.2
Rated speed rpm	1500
Cooling system	Water cooling
Cubic capacity cm^3	0.661
Operating pressure bar	210
Compression ratio	17.5:1

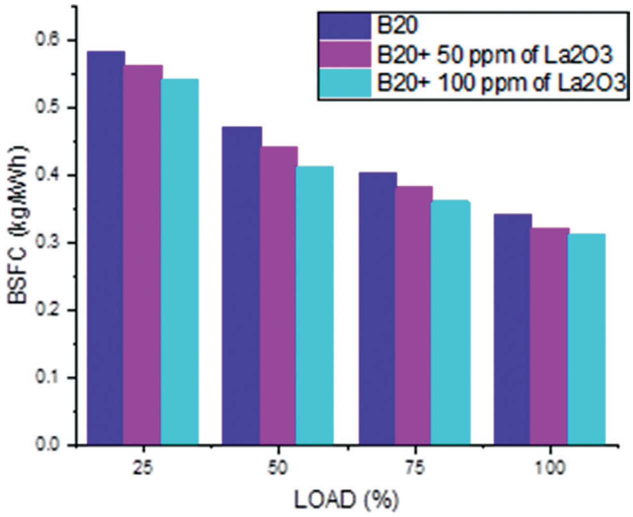

Figure 5. Variation of BSFC with load.

RESULTS AND DISCUSSION

Brake Specific Fuel Consumption

It is seen that La_2O_3 additives improve brake-specific energy consumption. Lower viscosity and higher oxygen content of additives facilitate better atomization and complete combustion leading to a marginal decrease in BSFC. The variations of BSFC with load for WME 20 and WME 20 blends with different proportions of lanthanum oxide nano additives are shown in figure 5. The maximum decrease of 5.8% and 8.8% is obtained for the WME 20 blend with 50 and 100 ppm of lanthanum oxide nano additives, respectively, at full load compared with WME 20. A maximum decrease in BSFC is observed for the WME 20+100 ppm of La_2O_3 blend. It is caused by the inclusion of La_2O_3 blended fuel enhanced the surface area/volume ratio and shortened the ignition delay, resulting in improved combustion and lower BSFC Köten H 2018b,

Brake Thermal Efficiency

The variations of BTE with load for WME 20 and WME 20 blends with different proportions of additives are shown in figure 6. graph indicated that BTE decreases for the WME 20 blend compared to lanthanum oxide blends. It suggests that the fuel mixture of the WME 20+100ppm La_2O_3 is 2% more efficient than the WME 20 at full load. At all loads, the excess oxygen in the additives enhances the combustion and improves the BTE. Because lanthanum oxide nano additives act as an oxygen source for the fuel blend and improve the combustion chamber heat level, proper atomization takes place, which is done by the thermal properties of the additive. It will assist in preventing carbon deposits in the combustion chamber Balamurugan et al., 2013.

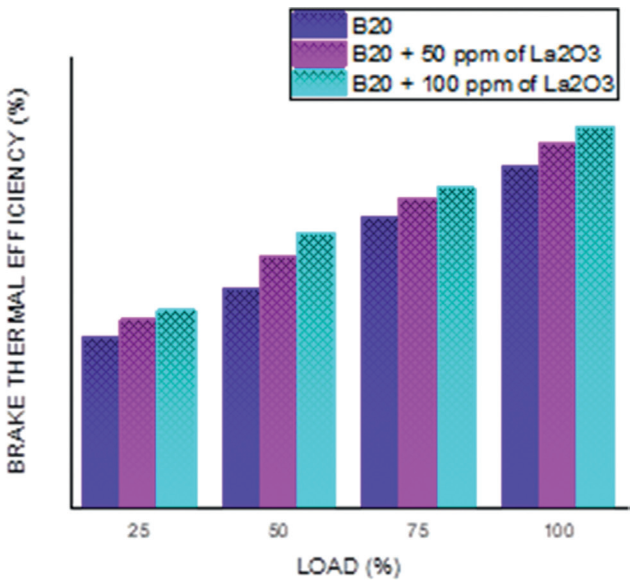

Figure 6. Variation of brake thermal efficiency with load.

Carbon Monoxide

Vehicle exhaust releases carbon monoxide into the atmosphere. Other sources of CO include incomplete fuel combustion. It was noted from the figure CO emissions of biodiesel with La_2O_3 blends are reduced. Figure 7 shows the variation of CO with respect to load for all test fuels, that is, WME 20, WME 20+50 ppm of La_2O_3, and WME 20+100 ppm of La_2O_3. At full load, WME 20+100 ppm of La_2O_3 reduces CO emissions by 4.75% compared to WME 20. Nano additives have lower density and viscosity, improving spray characteristics, atomization, fuel mixture, and combustion, leading to lower CO emissions. The fuel-rich region is removed because additives with higher oxygen concentration enhance combustion. With a higher cetane number of La_2O_3, the ignition delay is reduced, and the start of injection is improved, which leads to fewer emissions. Karthikeyan and Prathima 2016b.

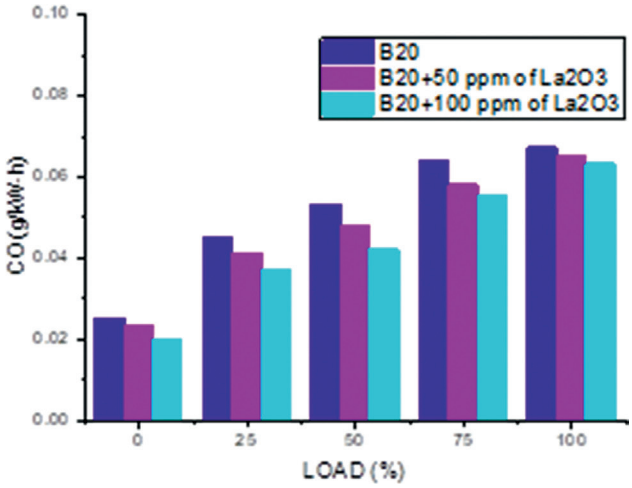

Figure 7. Variation of carbon monoxide with load.

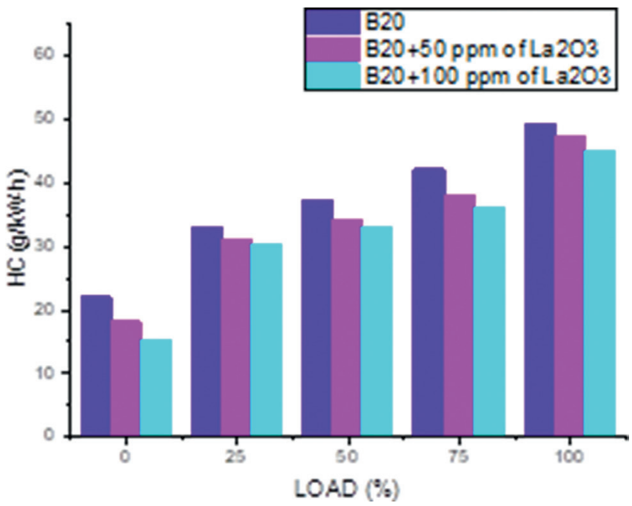

Figure 8. Variation of hydrocarbon with load.

Hydrocarbon Emission

The variations in hydrocarbon emissions by using a WME20 fuel blend with various concentrations of La_2O_3 nanoparticles are shown in figure 8. The accumulation of different concentrations of La_2O_3 nanoparticles with the WME 20 fuel blend drastically mitigates the hydrocarbon emissions compared with the WME20 fuel blend. The oxygen in the nanoparticles acts as oxidation catalysts, improving the unburned hydrocarbon oxidation process and ensuring better combustion of the WME 20 fuel blend. The results show that hydrocarbon emissions decrease with the increasing concentration of La_2O_3 nanoparticles. Experimental results indicated that 100 ppm is optimal for La_2O_3 metal oxide nanoparticles. At maximum load, WME 20+ La_2O_3 100 ppm of fuel blend had 6.67% lower than WME 20 fuel.

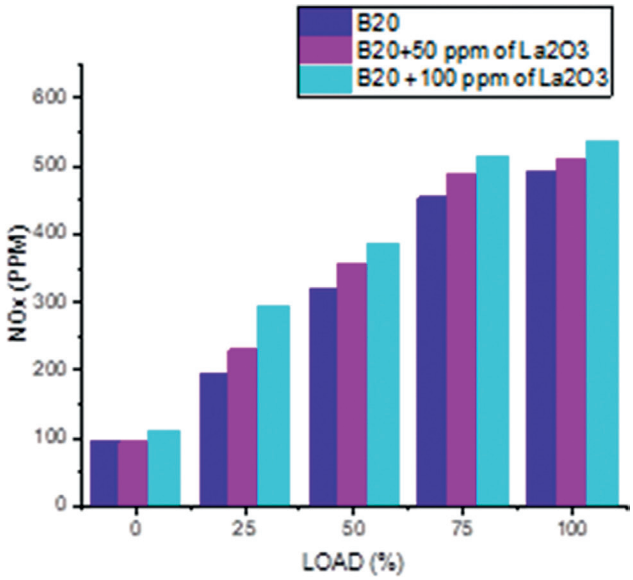

Figure 9. Variation of nitrogen oxide with load.

Nitrogen Oxide

The variations in NO_x load emissions for B20 and B20 mixtures with different additive quantities are shown in figure 9. Results indicate that adding nano additives blends increases NO_x emission more than B20. However, NO_x emissions increase with the increase in the percentages of additives. At maximum load, the addition of 100 ppm of La_2O_3 nanoparticles to B20 increases NO_x emissions by 1.6% compared to B20. The increase in NO_x is due to better combustion, leading to better combustion temperatures of biodiesel blends with additives. A comparable result is produced by Sivalakshmi & Balusamy 2013.

CONCLUSION

This study examined the impact of adding La_2O_3 nanoparticles on the performance and emission characteristics of a diesel engine operating on C. Vulgaris biodiesel. In fuel blends, La_2O_3 concentrations of 50 ppm and 100 ppm were utilized. The experimental results indicated that compared to biodiesel without nano additive, the WME 20 + 50 ppm La_2O_3 and WME 20 + 100 ppm La_2O_3 fuel blends increased BTE and decreased SFC. Because La_2O_3 acts as an oxygen buffer, nano additions promote longer and more complete burning than base fuel. Due to this increased engine performance. La_2O_3 fuel blends produce lower CO and HC emissions than the base fuel. In addition, NO_x emissions increased marginally in comparison to the base fuel. Based on the test results, the WME 20 + 100 ppm La_2O_3 mixture shows improved performance and decreased emissions.

NOMENCLATURE

BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
B20	20% Watermelon Methyl Ester + 80% Diesel
B20+50 ppm	20% Watermelon Methyl Ester + 80% Diesel+ 50 ppm of Lanthanum oxide
B20+100 ppm	20% Watermelon Methyl Ester + 80% Diesel + 100 ppm of Lanthanum oxide
CI	Compression Ignition
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydro carbon
kw	kilowatt
La_2O_3	Lanthanum oxide
mm	millimetre
mL	millilitre
NO_X	Nitrogen oxide
ppm	parts per million
rpm	revolution per minute

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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