IMPACT OF AL_2O_3 NANOPARTICLES ON THE EMISSION AND PERFORMANCE OF DIESEL ENGINES POWERED BY BLENDS OF DIESEL AND USED TEMPLE OIL BIODIESEL

Anjappa SB[1,*], and Devarahalli Kempegowda Ramesha[2]

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Abstract

Research on the use of nanoparticles has shown impressive results in various application areas, from the treatment of environmental degradation to the use of medicine. Alumina nanoparticles are added to diesel and biodiesel mixtures in this study. Examining the effects of Al_2O_3 nanoparticle integration in diesel–biodiesel blends on the performance and emission characteristics of diesel engines was the main goal of the current investigation. A minimum of fifteen different biodiesel blends were made for trial and two concentrations of alumina nanoparticles (25 and, 50 ppm) were incorporated in the diesel. To accomplish a practical effect, no nanoparticle stabilizer was used in the dispersion. The diesel and biodiesel were blended at high-speed shearing, and the ultrasonication process was used to distribute the nanoparticles throughout the mixtures. The resulting mixes were tested at three different compression ratios and a set RPM using a single-cylinder diesel engine. Software based on LabView was used to measure the brake-specific fuel consumption (BSFC) and brake thermal efficiency (BTE) for fuel samples. An external gas analyzer connected to the engine's exhaust vent calculated CO and unburnt hydrocarbon (UBHC) emissions. The findings of the investigation indicate that with the addition of Al_2O_3 nanoparticles, enhanced engine performance was achieved together with reduced toxicity of the exhaust emitted from the engine. Additionally, the inclusion of alumina nanoparticles served to reverse the declining performance that was associated with the blending of biodiesel. Consequently, greater compression ratios achieved superior nanoparticle inclusion results over the lower ones. Accounting demonstrated that the Al_2O_3 nanoparticle is a valuable addition to fuels meant to improve the profitability of diesel engines and reduce harmful exhausts.

Keywords: Alumina Nanoparticles; BTE; BSFC; UBHC; Used Temple Oil Biodiesel

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[1] *Department of Mechanical Engineering, Viswam Engineering College, Madanapalle, Andhrapradesh-517325, India. E-mail: ani05.ga@gmail.com[*]*
[2] *Department of Mechanical Engineering, University of Visvesvaraya College of Engineering, Bengaluru-560001, India. E-mail: dkramesha@bub.ernet.in*
[*] *Corresponding author*

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Introduction

Any nation's progress cannot be ignored without considering the role that energy plays. Information on the availability and consumption of energy can be used to gauge a nation's development. In addition to GDP, annual energy consumption can be used as a gauge of the nation's wealth. The rising energy application and diminished fossil energy reserves have spurred the research effort toward exploring novel substitutes to the current energy storage pools as well as proper utilization of the existing sources at minimum expense. For researchers, the domain is the hypothetical one that embraces the power acquired at the cost of conventional fuels, efficiency, and economic loss, and the speculative huge emission of the hazardous pollutants that burned the hydrocarbon fuels (Ansari *et al*., 2023). Before the COVID-19 pandemic, the magnitude of the share of fossil fuels stood at the level of 3/4 of the global energy mix the "Global Energy and CO_2 Status Report 2018" increased by 1.7% to 33.1 Gt of CO_2 emissions about the previous year by increasing the energy consumption. As the "Global Energy Review 2021" showed, while global oil demand was over one-fifth down from pre-ovid levels, they remained 6% lower in 2021 and were expected to fall faster than others. Concerns about the environment throughout the world and the potential depletion of fossil fuels have made it more urgent than ever to innovate in the relevant field.

Researchers are constantly working hard in a bid to try and improve the results of the existing plant and equipment. These opportunity areas include reducing the mass of automotive materials, using other forms of fuzzy logic to increase comfort, changing the joining and machining procedures, etc. (Gundoshmian *et al*., 2021). As for the size diesel engines are now the cheapest source of power for rural regions, means of transportation, agricultural sector, and other related business sectors. Diesel engines are statistically the most efficient prime movers that are available for use in the market today. Additionally, since the dawn of automobile applications, the improvement of thermal efficiency for diesel engines is usually due to the better fuel economy than gasoline engines.

Given the existing hydrocarbon fossil fuel supply and rising costs, biodiesel is now a more financially advantageous choice (Ramesh *et al*., 2018). In the opinion of experts speaking on the matter, the available stock of oil and natural gas is expected to last only a few more decades (Mishra *et al*., 2013). Current research employing nanoparticle dispersion and CME biodiesel-diesel mixtures on a diesel engine indicated that 25 ppm of CME added to a 20% blend enhances BTE and decreases BSFC. Further, it was found that CO emission was lowered at the same concentration as HC emission (Ansari *et al*., 2024). In a related study, alumina nanoparticles were mixed with biodiesel produced from soap and candle nuts. The experiments had shown that there were low emissions, low BSFC, and improved BTE. Though there was an increase in Nox, CeO_2 nanoparticles blended with corn oil biodiesel had proven to have low CO and UBHC (Muruganantham *et al*., 2021). A study that measured the acoustic characteristics of a CI engine and analyzed frequency effects to evaluate noise for that purpose utilized magnetized biodiesel blends. Margatum biodiesel blends were discovered to enhance performance parameters and decrease fume contaminants in an engine study (Samadi and Heidarbeigi, 2020). The use of renewable fuels like biodiesel to replace diminishing oil sources to address the approaching fuel problem has emerged as an intriguing avenue for scientific growth. A different study that used mixtures of biodiesel and carbon nanotube nanoparticles showed a significant reduction in hazardous exhausts, such as NOx (Karthikeyan *et al*., 2020). Another attempt to reduce fume pollutants resulted in a 25-75% reduction in emissions by utilizing different biodiesel-diesel blends and exhaust gas re-circulation systems (Shekofteh *et al*., 2020). Diesel can be readily replaced with biodiesel in a compression ignition engine. Biodiesel produces less pollutants during burning and has similar qualities to petroleum diesel. The main sources of biodiesel are palm, used temple oil, soybean, and rapeseed oils. Rich countries are becoming more and more inclined to use the newest technologies and conduct a lot of ongoing research on renewable energy. Biofuels are starting to outperform fossil fuels in terms of cost (Cai *et al*., 2022).

To enhance engine performance and reduce emissions from diesel engines, some researchers have added nanoparticles to blends of diesel and biodiesel.To improve performance, a study on a diesel engine that includes ZnO nanoparticles in mixtures of ethanol and biodiesel has been planned (Prabakaran and Udhoji, 2016). The initial combustion temperature is raised by the behavior of Al nanoparticles, which act as potential energy carriers. Better combustion and a decrease in ignition latency could result from this (Soudagar *et al*., 2021). Particulate matter, unburned hydrocarbons, and carbon dioxide have been significantly decreased when ceramic nanoparticles have been added to diesel emulsion fuel (Ramesh *et al*., 2018). It has been demonstrated that adding silica and alumina nanoparticles to diesel-butanol blends improves compression ignition engine performance and reduces soot emissions (Fayyazbakhsh and Pirouzfar, 2016). When aluminum nanoparticles were introduced at different volume percentages, diesel fuel consumption as well as NOx and particulate matter emissions were considerably decreased (Ghanbari *et al*., 2021). In a different investigation, diesel fuel was treated with alumina oxide and cupric oxide nanoparticles, and the improved combustion characteristics were recorded (Ağbulut *et al*., 2020). According to a study, test fuels containing dispersed nanoparticles have better thermophysical characteristics because of their larger surface-to-volume ratio. Additionally, nanoparticles act as an oxygen buffer in relation to NOx emissions (Haq *et al*., 2024). The dispersion of nano-additives based on metals has shown a notable reduction in fuel usage. Moreover, adding nano metal oxides has demonstrated a significant reduction in diesel emissions (El-Shafay *et al*., 2025). The hydroxyl radicals created by the reaction of metal with water accelerate the oxidation of soot and cause the oxidation temperature to drop, which is the cause of the emission drop (Krishnamoorthi *et al*., 2025).

In this study, fuel features and engine performance and emission as well as combustion-related parameters of a VCR diesel engine were investigated using different contents of alumina nanoparticles blended with temple oil biodiesel in various proportions. Commercial used temple oil used in the study was transesterified to produce used temple oil biodiesel. Other mixtures were prepared with different PPMs of alumina nanoparticles and ratios of diesel and used temple oil biodiesel. The biodiesel and diesel were blended 1:1 using used temple oil and then dispersed into aqueous suspensions of alumina nanoparticles by the application of a 120-watt high-energy ultrasonic probe sonicator.

Materials and Methods

Fuel Preparation

The four-stroke, water-cooled, single-cylinder VCR engine utilized in this study ran on biodiesel made from old temple oil, which was transesterified twice and then mixed with diesel and Al_2O_3 nanoparticles as additives (Kayed *et al*., 2024). The fuel derived from used temple oil using transesterification to obtain the biodiesel in Figure 1. The chemical reaction of methanol with triglycerides i.e., the fats of oils, in the presence of a catalyst is called the transesterification reaction. The endothermic reaction leads to the formation of easter and glycerol. For analytical purposes only, biodiesel-used temple oil was isolated from dewaxed used temple oil employing an acid-catalyzed transesterification method as well as a base-catalyzed transesterification method. Sulfuric acid was utilized as the acid catalyst and sodium hydroxide, which serves as the aspiration process's base catalyst. The Table 1 shows the fatty acid composition present in the used temple oil. Five samples of diesel/biodiesel blends containing 10% to 50% biodiesel were prepared and subjected to an experimental investigation using a high-speed shearer set to 2,000 RPM. To produce new

Table 1. Composition of fatty acids in used temple oil

Fatty acid	Amount in %
Myristic acid	0.03
Arachidic acid	1.6
Linoleic acid	14.7
Oleic acid	51.3
Palmitic acid	17.8
Stearic acid	14.4

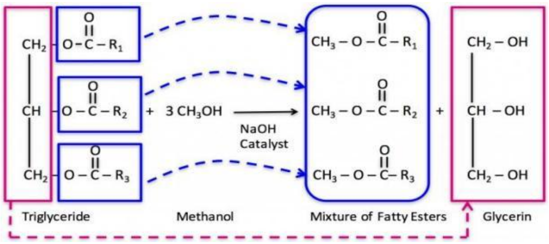

Figure 1. Transesterification process

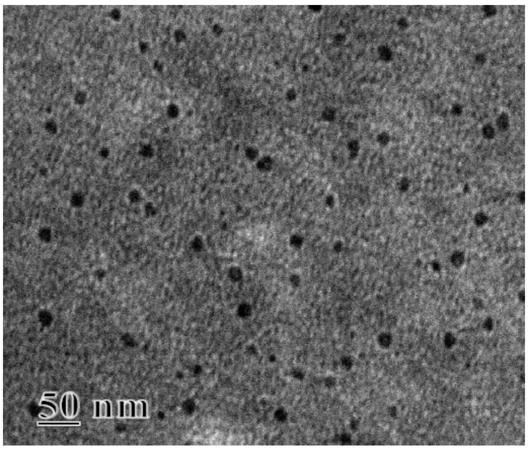

Figure 2. TEM image of diesel with scattered nanoparticles

compositions, these mixes were also dosed with nanoparticles at 25 and 50 parts per million. A 120 W probe sonicator with a cycle of 15 s OFF and ON for 30 min was used to disperse the nanoparticles in the mixes. The result is depicted in Figure 1 below. As they dissolve in equal parts, Figure 1 shows that Al_2O_3 nanoparticles are uniformly and randomly distributed throughout the diesel and biodiesel blends. Figure 2, the TEM image confirms the successful dispersion of the nanoparticles within the diesel base fluid. The nanoparticles appear as dark, distinct, and roughly spherical spots scattered across the lighter background of the diesel fuel. After the engine testing, the characteristics of the Al_2O_3 nanoparticles listed in Table 2 mixes were compared with the characteristics of diesel in terms of engine performance and emission factors. The exhaust gas analyzer used in the study, the AIRVISOR -5 Gas Analyser AVG 500, is described in detail about specifications in Table 3.

Performance Evaluation

All mixes were assessed in compliance with the IS 1448 P-32 and P-6 standards for density and calorific value, respectively, and the ASTM D-15 standard for kinematic viscosity evaluation.

Table 2. Al_2O_3 nanoparticle properties

Size range	27-43 nm
Density	3.7 g/cm^3
Flammability	Non flammable

Figure 3 shows the variations in diesel density (a), calorific value (b), and kinematic viscosity (c) with nanoparticle dispersion. The fuel-consumption calculating unit, pressure manometer, airbox, transmitter for airflow and fuel estimation, process and engine indicators, and two gasoline tanks for the dyad fuel test are coupling elements. In this particular design, the flow of cooling water was computed from a rotameter. Brake power (BP), brake-specific fuel consumption (BSFC), brake thermal efficiency (BTE), heat balance, and air-to-fuel ratio (A/F) were all used to assess the VCR engine's performance based on the experimental design (Zheng and Cho, 2024). Furthermore, the LabView-based Engine Performance Analysis software package "Enginesoft LV" was adopted to conduct a direct digital performance analysis. The paper explains how the physiochemical characteristics of different mixes are affected by the introduction of nanoparticles (Anjappa *et al*., 2025). Al_2O_3 nanoparticles added to pure diesel showed very little change in density and kinematic viscosity, although there was a slight increase in calorific value, as shown in Figure 3(a-c).

The characteristics of diesel were also affected by the addition of used temple oil biodiesel (Kumar, *et al*., 2020). Figure 3(a-c) displays the attributes of the various blends in comparison to diesel. The comprehensive analysis of these critical fuel properties is presented in Figure 4(a-c), which illustrates the effects of the biodiesel blend ratio on density, calorific value, and kinematic viscosity. As depicted, a clear trend is observed: with

Table 3. The emission analyzers technical specifications

Sl.N	Measurement range	Measurement Data	Resolution
1	0-10% Vol.	CO	0.01% Vol.
2	0-20% Vol.	CO_2	0.1% Vol.
3	0-25% Vol.	O_2	0.01% Vol.
4	0-20,000 ppm	HC	1 ppm

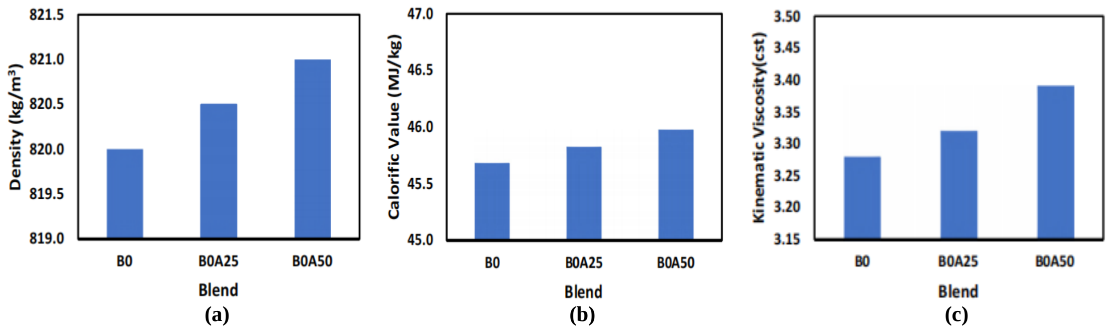

Figure 3. Change in the physiochemical characteristics of diesel due to the dispersion of nanoparticles: (a) density, (b) calorific value, and (c) kinematic viscosity

an increasing percentage of biodiesel, both the density and kinematic viscosity of the fuel blend increase. Results showed that adding used temple oil biodiesel to diesel significantly increased its density and kinematic viscosity. However, because used temple oil biodiesel has a relatively low calorific value, there was a noticeable decrease in calorific value.

Exhaust Emission Analysis

The exhaust of a motor consists of several elements and each of them is contained in the exhaust in variable amounts. The exhaust's UBHC, CO, and CO_2 emissions were obtained using AVL 4000 Light Di-gas analyzer. The species of emissions being analyzed by this analyzer include hydrocarbons (HCs), carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2). The requisite characteristics for measuring the above-mentioned pollutants were recorded by connecting the exhaust valve of the engine to the input manifold of the analyzer.

Results and Discussions

This study examined the emission characteristics and engine performance of a single-cylinder

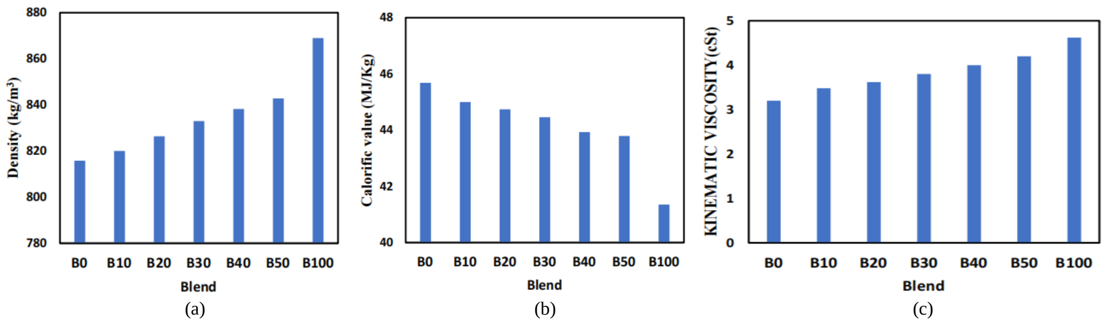

Figure 4. Effects of density, calorific value, and kinematic viscosity on diesel with the biodiesel blend ratio

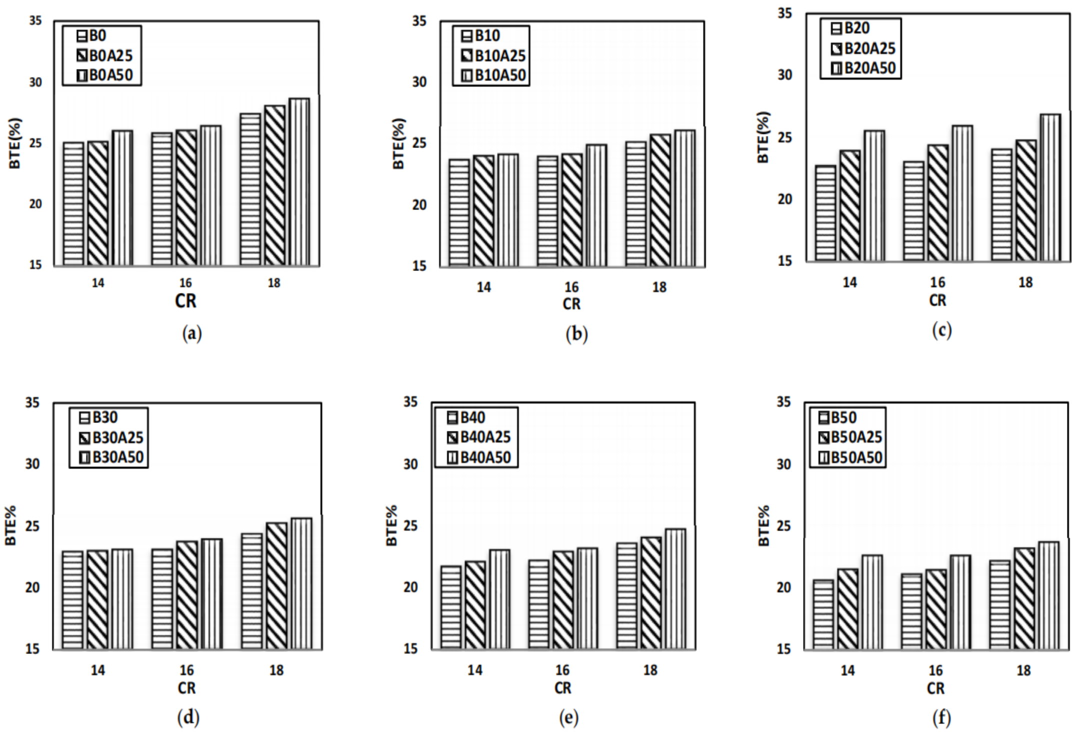

Figure 5. Brake thermal efficiency (BTE) variation versus compression ratio (CR) for the following blends at a constant load of 8 kg: (a) B0, (b) B10, (c) B20, (d) B30, (e) B40, and (f) B50

variable compression ratio (VCR) engine at varying compression ratio (CRs). Numerical investigations were conducted on volume fractions of used temple oil biodiesel, ranging from 10% to 50%, which were premixed with diesel. Test solutions containing 25 ppm and 50 ppm of anionic Al_2O_3 nanoparticles were also utilized. These blends served as test fuels for the diesel engine to evaluate its performance in terms of emissions and other than combustion characteristics.

Performance and Emission Characteristics

Several attributes of fuel, such as calorific value, kinematic viscosity, flash point, fire point, and the like directly influence the performance of an engine. Performance variations can be attributed to a variety of processes occurring within the combustion chamber. Performance and combustion characteristics are greatly impacted by several phenomena occurring inside the combustion chamber, including pressure fluctuation, valve timing, injection time, injection pressure, fuel inlet timing, and delay period. Changes in performance characteristics are closely related to fuel attributes (Lobo *et al.*, 2019). In this work, engine performance parameters like BTE, BSFC, and emissions are compared based on how the engine performs at a sustained speed of 1500 RPM and with an 8 kg load, different compression ratios, as well as different biodiesel and nanoparticle additive quantities.

BTE

Figure 5(a) shows the variation of the engine's BTE at different compression ratios when running on pure diesel and when adding nanoparticles. It seems that the distribution of nanoparticles in pure diesel has a positive effect on BTE. The increase in BTE is more pronounced at more compression ratios because of more heat is released at these ratios, and higher temperatures cause the fuel's suspended nanoparticles to absorb heat and help maintain a stable temperature during and after combustion. Figure 5(b) illustrates the combined impact of adding alumina nanoparticles (at concentrations of 25 ppm and 50 ppm) and blending 10% used temple oil biodiesel. The use of nanoparticles improves combustion even though pure diesel has a greater BTE than blended biodiesel because metal oxides help the fuel vaporize quickly, which improves commixing. This, in turn, gives fuel more surface area to react with oxygen molecules, improving combustion once more (Gan and Qiao, 2010). Figure 5(c-f) shows additional findings for increasing the biodiesel component to 50% while maintaining a steady nanoparticle dispersion percentage. Because biodiesel has a less calorific value than diesel, blends using it have lower BTE. However, the addition of Al_2O_3 nanoparticles balances out this drawback. At 50 ppm of alumina nanoparticle concentration, the BTE was observed to be maximum and increased up to ~4.5% concerning pure diesel at CR of 18. The BTE of the temple oil biodiesel further increased after being doped with alumina nanoparticles. The addition of these particles specifically in the B20 blend at CR 18 resulted in a decrease of approximately (7%) compared to unblended diesel, while when adding nanoparticles using 50 ppm and the same compression ratio Bahtzevanuunia concluded that the loss was only redistributed up to (2%).

BSFC

Figure 7(a) makes it clear that the engine uses less gasoline at greater CR. Because of the enhanced fuel combustion properties, the inclusion of nanoparticles further lowers the BSFC. This is owing to the fact that when the compression ratio

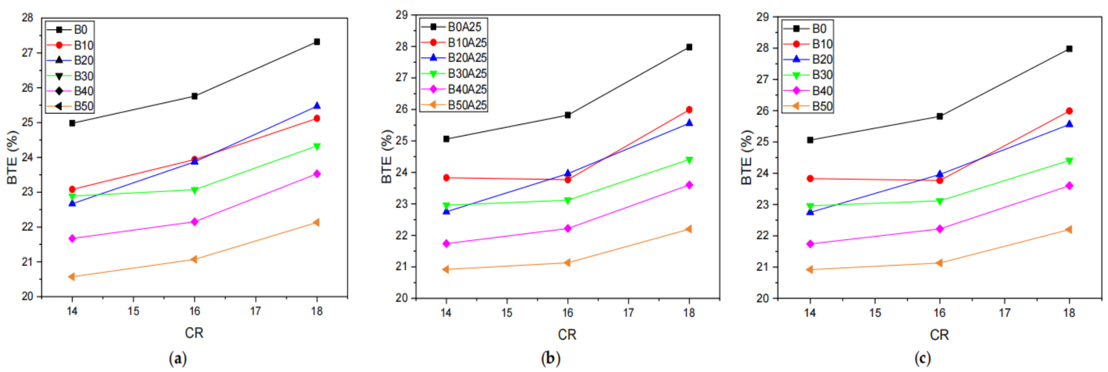

Figure 6. **Brake thermal efficiency variation with blends of biodiesel in three different conditions: (a) without nanoparticles; (b) with 25 ppm Al_2O_3; and (c) with 50 ppm Al_2O_3**

rises, the temperature rises as well. As a result, the fuel's viscosity decreases and its other properties improve, bringing forth the proper atomization of fuel. Therefore, the BSFC drops with greater compression ratios (Zhang *et al*., 2024). Figure 6(b-c) illustrates the combined impact of adding alumina nanoparticles at concentrations of 25 ppm and 50 ppm and blending biodiesel (10% and 20%, respectively). There was an increase in BSFC when biodiesel was added, which could be explained by the fuel's marginal heating value. However, adding nanoparticles resulted in a decrease in BSFC, which could be explained by the fact that the nanoparticles improved fuel atomization and combustion, which in turn released more heat (Ren *et al*., 2022). The performance of B30, B40, and B50 with nanoparticle mixing is given in Figure 6(d-f) after particle tows are added. From this, it is obvious that the alumina nanoparticle mixing causes the BSFC of the biodiesel blend to decrease compared with no Al_2O_3 introduced. In comparison with pure diesel (CR 18), the addition of alumina nanoparticles at a concentration level of 50 ppm resulted in up to a maximum reduction smaller than 1% for BSFC.

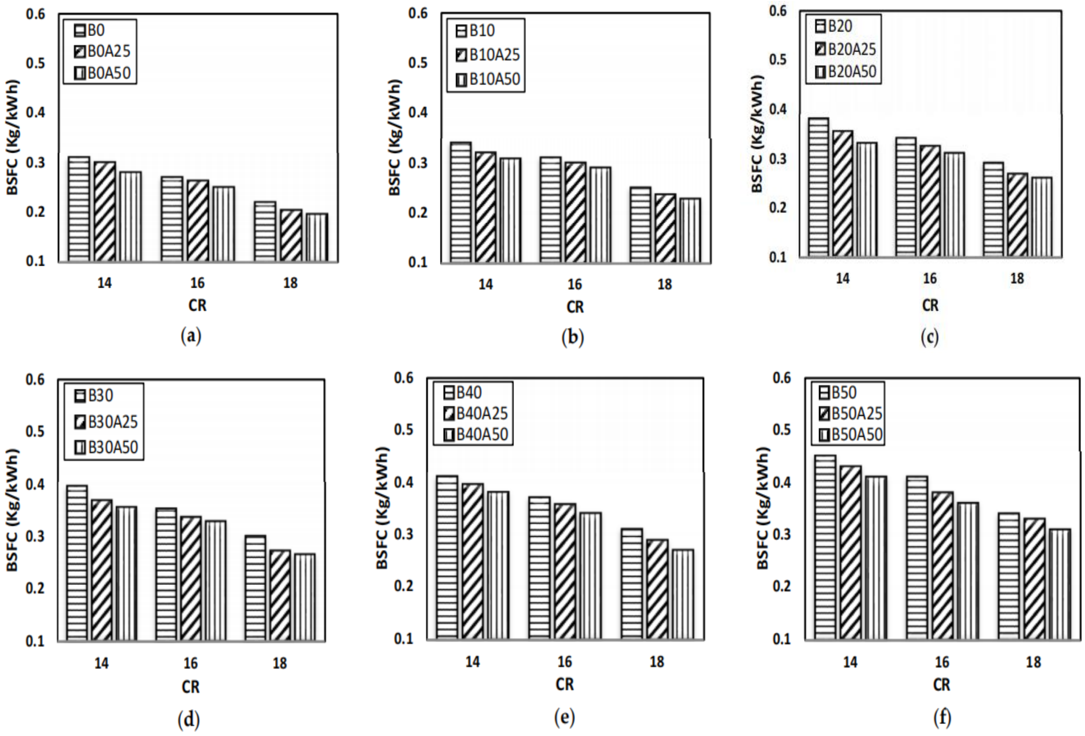

Figure 7. Brake-specific fuel consumption versus compression ratio (CR) for the following blends at a constant load of 8 kg: (a) B0, (b) B10, (c) B20, (d) B30, (e) B40, and (f) B50

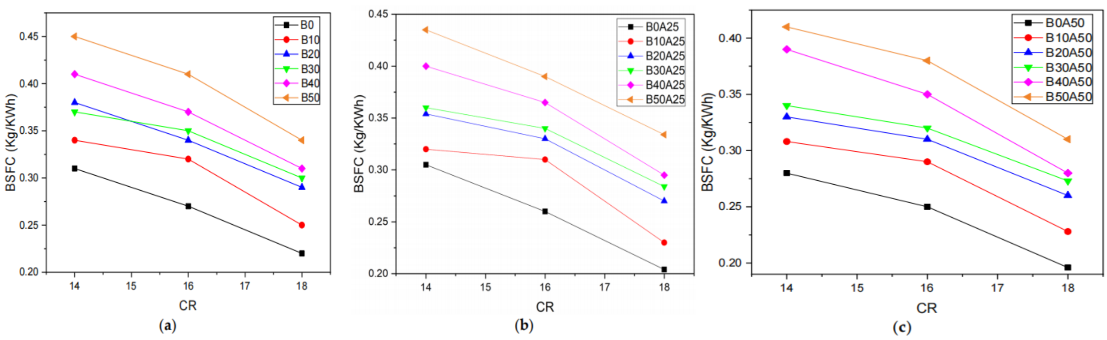

Figure 8. Brake-specific fuel consumption variation with blends of biodiesel in three different conditions: (a) without nanoparticles; (b) with 25 ppm Al_2O_3; and (c) with 50 ppm Al_2O_3

The BSFC was decreased by as little as 9% in CR14 hydrogen blends for the same nanoparticle concentration. Furthermore, as Figure 7(a-c) illustrates, the BSFC increases with increasing mix percentage of biodiesel due to increased density and decreased calorific value of diesel at all compression ratio levels. Figure 8. Variation of Brake-Specific Fuel Consumption (BSFC) with blends of biodiesel (B0 to B50) in three different conditions: (a) without nanoparticles (baseline); (b) with 25 ppm Al_2O_3 nanoparticles; and (c) with 50 ppm Al_2O_3 nanoparticles. The results indicate that BSFC increases for higher biodiesel blends in the baseline case due to lower calorific value. However, the addition of Al_2O_3 nanoparticles significantly reduces BSFC, with the 50 ppm concentration showing the greatest improvement in fuel efficiency.

CO Emission

Figure 9(a-b) depicts that with an increased compression ratio the CO emission for neat diesel decreases and is also further supported by adding Al_2O_3 nanoparticles in facilitating low levels of CO emissions at high load. In comparison to pure diesel, the addition of 25 ppm and the maximum tested concentration of alumina nanoparticles (50 ppm) at CR > ←18 lead to CO reduction by 5% and around up to nearly 12%, respectively. From the above graphs (Figure 9(b-f)), it is clear that Al_2O_3 nanoparticles and used temple oil biodiesel reduce harmful CO emissions. As the biodiesel content increases, so does the amount of oxygen in a blend which allows more area for burning fuel (Ren *et al*., 2022). Furthermore, the incorporation of nanoparticles yields more consistent combustion conditions, favorable conditions for full combustion, and reduced carbon dioxide emissions. Blends B20 and B20 A50 showed reductions in CO emissions of 24% and 36%, respectively, at CR 18. Increased CR takes into consideration the viscosity and density of the fuel, which lowers and ultimately results in complete combustion, which lowers CO. A 36% decrease in CO was seen for the B50 mix, and a comparable decrease was seen when 20% biodiesel was blended with 50 ppm nanoparticles. In comparison to pure diesel, we observed a 12% reduction at CR 18 when 50 ppm Al_2O_3 was added to the diesel. At 8 kg load, the B50A50 blend showed the greatest reduction in CO emissions, at 39%, when compared to pure diesel. The impact of combining biodiesel with different alumina nanoparticle concentrations on CR is depicted in Figures 9(a-c). We can deduce that CO emission decreases with increasing CR and that the inclusion of alumina nanoparticles catalyzes CO reduction.

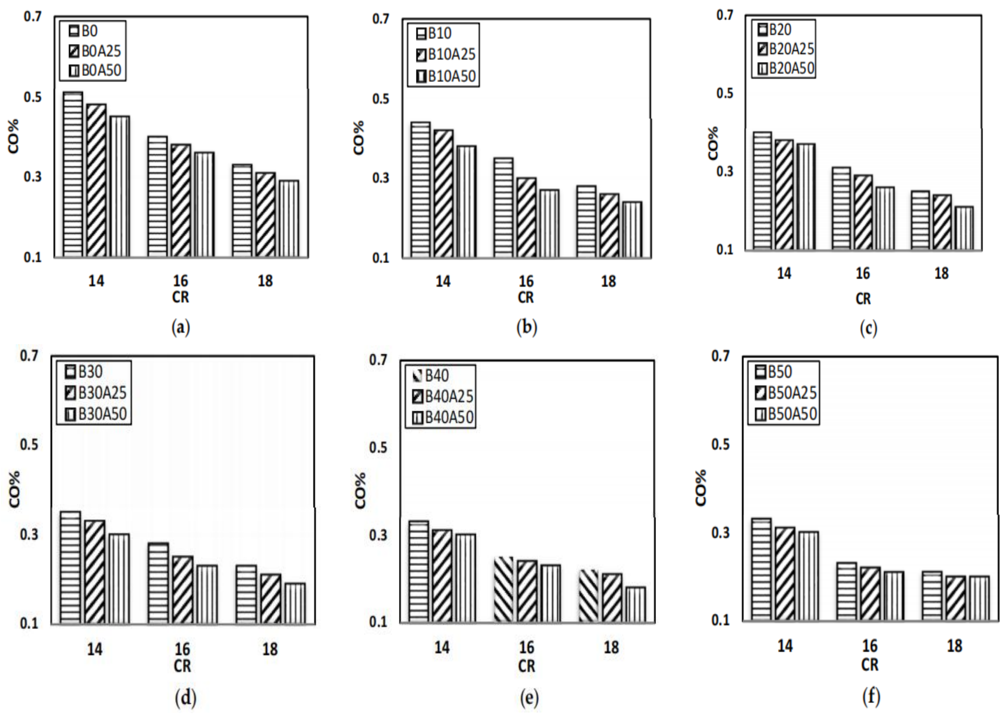

Figure 9. CO versus compression ratio (CR) for the following blends at a constant load of 8 kg: (a) B0, (b) B10, (c) B20, (d) B30, (e) B40, and (f) B50

Figure 10 Carbon Monoxide (CO) emission variation with blends of biodiesel (B0 to B50) in three different conditions: (a) without nanoparticles (baseline); (b) with 25 ppm Al_2O_3 nanoparticles; and (c) with 50 ppm Al_2O_3 nanoparticles. The results demonstrate that CO emissions decrease with higher biodiesel content due to the fuel's inherent oxygen content. The addition of Al_2O_3 nanoparticles further reduces CO emissions significantly, with the 50 ppm concentration showing the greatest reduction.

HC

Due to the shortage of oxygen near the fuel particles when lean or low-mix combustion occurs, the unburned hydrocarbon (HC) is emitted from the engine. All the factors such as air-fuel ratio, air-fuel mixing, the particle size of fuel, and the temperature

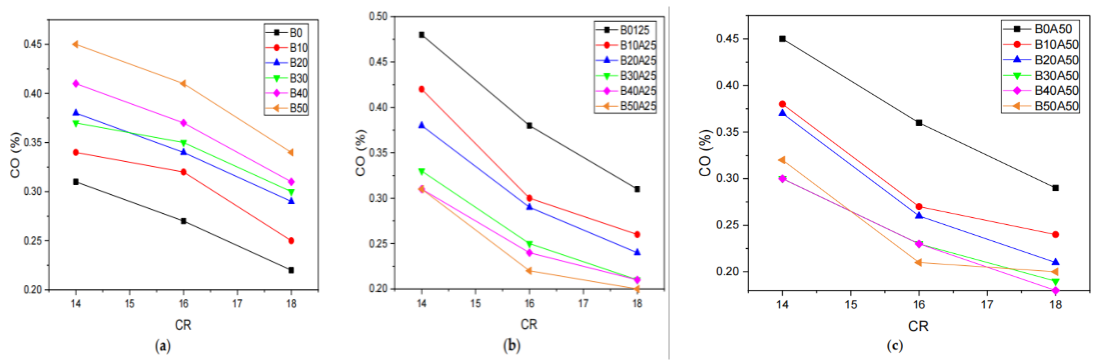

Figure 10. CO variation with blends of biodiesel in three different conditions: (a) without nanoparticles; (b) with 25 ppm Al_2O_3; and (c) with 50 ppm Al_2O_3

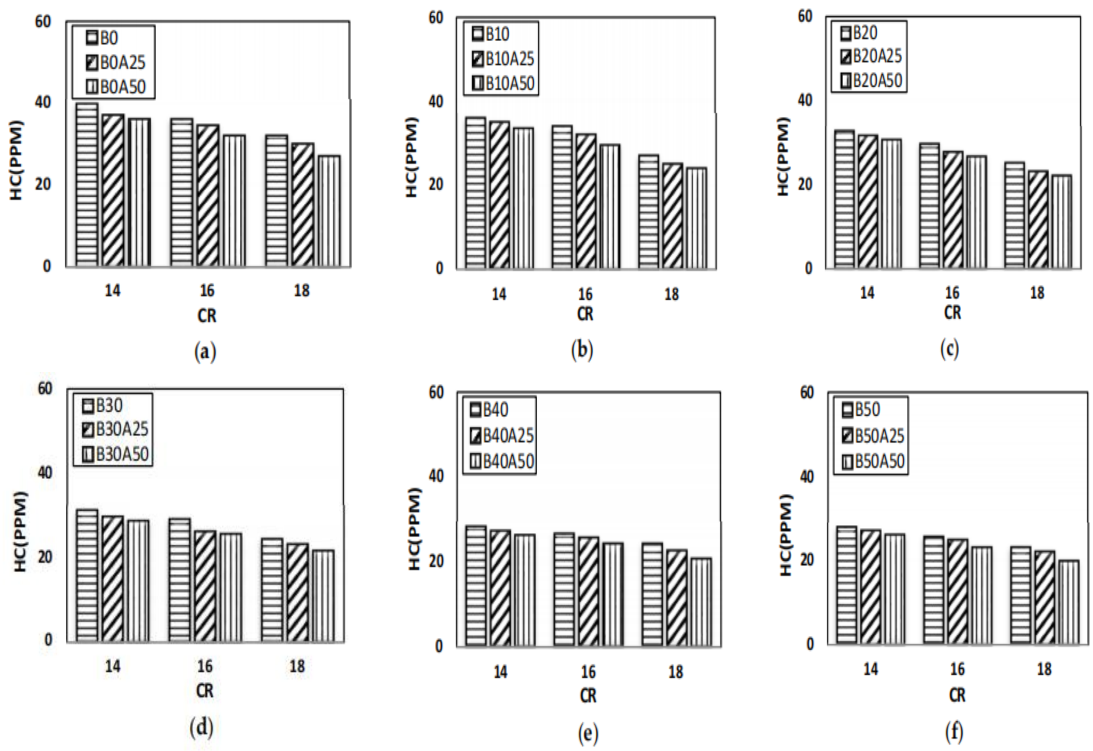

Figure 11. HC versus compression ratio (CR) for the following blends at a constant load of 8 kg: (a) B0, (b) B10, (c) B20, (d) B30, (e) B40, and (f) B50

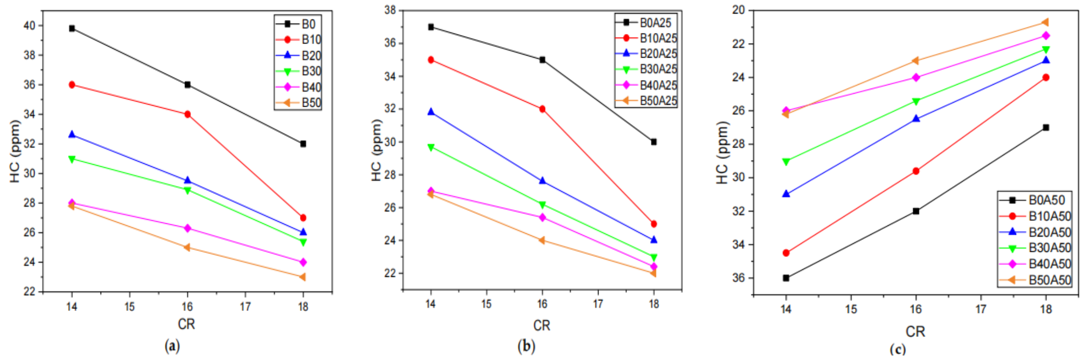

Figure 12. HC variation with blends of biodiesel in three different conditions: (a) without nanoparticles; (b) with 25 ppm Al_2O_3; and (c) with 50 ppm Al_2O_3

of cylinder head affect the availability of oxygen. The engine's compression ratio causes the chamber's temperature to rise while HC emissions drop. Additionally, when the fuel's percentage of used temple oil biodiesel increases, the fuel's oxygen content increases for improved combustion, which lowers HC emissions (Zhang *et al.*, 2022). The extent of blending alumina nanoparticles with pure diesel, compared with CR is illustrated in Figure 11(a). When nanoparticles at 50 ppm were in the pure diesel, there was a 16 percent reduction in HC emission. The effect of the biodiesel blending at volume fractions of 10%-50% with concomitant dispersion of nanoparticles at 25 ppm and 50 ppm is illustrated in Figure 11(b-f) about hydrocarbon emission. Decreasing HC emission by 25% at 18 CR, when operating B10A50 compared to pure diesel.

Figure 11(c) illustrates a 31% decrease in B20A50's HC emissions at CR 18. Because of the atomization impact of the nanoparticles and hydrocarbon oxidation, there is a reduction in HC emission upon the addition of nanoparticles (Anjappa and Ramesha., 2025). For B50A50, a maximum decrease of 38% was attained. The data clearly show that blending biodiesel and dispersing nanoparticles both reduce HC emission and doing both at the same time results in even more decrease. Figures 12(a-c) show an inverse relationship between the compression ratio and HC emission. In all blends, the HC emission decreases with increasing CR.

Conclusions

The inclusion of alumina nanoparticles did not significantly alter the physiochemical characteristics. Engine performance is improved when alumina nanoparticles are added to diesel, although the harm caused by mixing biodiesel was only slightly lessened. This study looked at the impact of very low amounts of alumina nanoparticles added to diesel and diesel-biodiesel blends. Higher amounts might lessen the bad performance caused by incorporating biodiesel more effectively. It's allowed for in this study. The main conclusions of the study are as follows.

- However, we found that produced linear dependence on CRS and BSFC, CO, and HC emissions, but the nation. Adding Al_2O_3 nanoparticles into the fuel blend led to a similar result. The improved performance of the engine could be directly attributed to improved combustion characteristics.
- B0 results exhibit 8.3% lower HC, 4.5% higher BTE, 11.1% lower BSFC, and 12.2% lower CO than diesel with CR 18 and 8 kg load.
- At 18 CR and 8 kg load, while blending B0 with 20% B20 A50 the BTE is lowered to −2% of that of the pure diesel B0, in terms of B20 the result is 5% better, but diesel fuel consumption gets 18% worse as compared to straight diesel fuel, or 11% worse than B20.
- There was a discernible 37% and 31% drop in CO and HC emissions, respectively, when compared to pure diesel fuel for the same CR and load; however, there was only about a 16% and 12% decrease in CO and HC emissions, when compared to B20.
- All of the results point to B20A50 as the mix that works best in terms of performance and exhaust emissions.

Statements and Declarations

Funding
Not Applicable

Data Availability
All data is included within the text of this manuscript

Conflict of Interest
Authors declare no conflict of interests

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