Research Article

Engine performance and PM concentrations from the combustion of Iraqi sunflower oil biodiesel under variable diesel engine operating conditions

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Abstract:

Among alternative fuels for diesel engines, biodiesel is the most attractive. This study's biodiesel is made from locally renewable sunflower oil. Also, biodiesel is a clean and environmentally acceptable alternative to regular diesel. Compared to pure diesel, the biodiesel mixes (B20, B50, and B100) increased the brake specific fuel consumption (BSFC). The findings show that biodiesel mixes lowered brake thermal efficiency (BTE) and exhaust gas temperatures (EGT) during B20, B50, and B100 combustion. The exhaust gas temperature and BSFC increased with engine load and speed. The research showed that as compared to diesel, biodiesel blends lowered PM concentrations. Furthermore, compared to petroleum diesel, B20, B50, and B100 decreased PM concentrations by 16.847, 28, and 43.34 percent. The findings show that the oxygen content in biodiesel reduces PM concentrations.

1. Introduction:

Oil crises have lasted since 1970, signalling the end of its rule [1]. Not only does burning petroleum have harmful effects on human health and the environment, but it also produces greenhouse gases [1, 2].

The most significant of these possibilities is adding biofuels to diesel [12, 13]. Compared to fossil fuels, biofuels are cleaner and lower GHG. It is also a green fuel made from biomass and agricultural resources. Fuel systems like lubrication and fuel injection may be utilised with biodiesel as a pure fuel. The presence of oxygen in biofuels improves combustion and decreases pollutants released, except for nitrogen oxides, whose concentrations rise owing to this abundance [14]. Biofuels are derived from agricultural resources, causing food shortages. Many scientific investigations are still underway to create sustainable biofuels. The most renowned biofuel is ethanol, which is made from sugar cane, beets, and maize [15-17]. Making liquid biofuels from agricultural products damages everyone. However, because to its cheap cost and wide range of supply sources, this fuel has seen tremendous development in usage.

Reduced production costs will boost customer acceptability. This prompted further study into improving fuel quality and reducing the effects of climate change and global warming. In many tests, waste vegetable oil, biodiesel, cooking oil, methanol and ethanol were recommended as biofuel sources.

The interaction of agricultural oil with alcohol and surfactant produces biodiesel. It is combined with diesel fuel in various quantities, or used straight. Because pure biofuel has a larger LHV than diesel, it produces less power than diesel [18-20]. However, several researchers [21-23] believed that the power loss may be offset by the predicted energy gain. Biofuels are viscous and denser than diesel, affecting the characteristics of the injected mixture [24]. Murillo et al. [25] studied the effects of 100% biofuel on a 3-cylinder diesel engine. The findings indicated a 7.14 percent loss in engine power when compared to diesel, and a 13.5 percent decrease in calorific value when compared to diesel. Many investigations and researches have agreed [26, 27]. Due to its low LHV, biodiesel causes increased engine fuel consumption, according to several research. Other features of biodiesel that impact its energy content include its cetane number (smaller than diesel), viscosity (greater than diesel), and water content (dependent on preparation quality and efficiency) [28-30]. Researchers prefer blending biodiesel to diesel in varying quantities to reduce emissions while maintaining engine efficiency. Most studies agree that adding a surfactant to the fuel improves mixing, prevents separation, and increases thread stability. Surfactant is added to the mixture in very small amounts, not exceeding 2%, and has no influence on combustion [31, 32].

Razzaq et al. [33] utilised WCO to make biodiesel. It has a lower heating value than diesel but a greater density, viscosity, cloud point, and flash point. The performance of a CI engine running at 3000 rpm with varying percentages of biodiesel was studied. The findings demonstrated a 3.5 percent, 3.09 percent, 2.2 percent, 2 percent, and 1.45 percent drop in BT from B50, B40, B30, B20, and B10 combinations. It grew by 12.76%, 8.88%, 5.738%, 1.618% and 18% from B50 to B40 to B30 to B20 to B10. The effects of biodiesel and Crypthecodiniumcohnii dinoflagellates were studied in ref. They used a turbocharged diesel engine with varying loads. The biofuels were blended with diesel in various percentages: 50%, 20%, and 10% microalga oil methyl ester, and 20% waste cooking oil methyl ester. Using bio-algae diesel reduced engine torque and cylinder pressure by up to 4.5 percent when mixed with diesel. Due to the reduced calorific value of biodiesel, BSFC rose and BTE dropped with larger loads. The researchers determined that adding 50% biodiesel (produced from C. cohnii microalgae) to diesel improves fuel characteristics and reduces hazardous emissions while retaining performance, making it appropriate for use in diesel engines in transportation. The present research is part of the quest for the finest local biofuels. Iraqi sunflower oil was used to make biodiesel. To make this biofuel, the oil was treated with methanol and a catalyst to extract the glycerin, and then the result was cleaned of methanol and water. The impact of these compounds on the performance of a direct injection diesel engine was evaluated. This study's goal is to compare various biodiesel blends' effects on engine performance and PM concentration under varying engine loads and speeds.

2. Experiments and materials:

2.1 engine setup and tools:

This research employed a four-cylinder, direct-injection diesel (Fiat) engine. [35] Table 1: Main research engine features Figure 1 depicts the research engine and its attachments. A hydraulic dynamometer connected to a diesel engine. The equation used in earlier publications [36, 37] determined engine performance characteristics. The PM concentrations were tested using Whatmannglass micro-filters and a low volume air sampler (type Sniffer L-30). This was done before and after the exam. The plastic bags kept the filter samples safe until they were examined and weighted. The following equation [38] calculated PM concentrations:

$$PM\ in \left(\mu g/m^3\right) = \frac{w_2 - w_1}{Vt} \times 10^6 \quad (1)$$

Where: PM is the concentration of particulate matters (μg/m3), w1 is the weight of filter sample before operation in (g), w2 is the weight of filter sample after operation in (g), and Vt is the total volume of drawn air (m3).

equation below was used to calculate the Vt

$$Vt = Q_t .\ t \quad (2)$$

Where: Qt is the rate of air flow through the equipment (m3 /sec), while t (min) represented the time of sampling.

Table 1: Specifications of engine

Engine type	4cyl., 4-stroke
Engine model	TD 313 Diesel engine rig
Combustion type	DI, water cooled, natural aspirated
Displacement	3.666 L
Valve per cylinder	two
Bore	100 mm
Stroke	110 mm
Compression ratio	17
Fuel injection pump	Unit pump 26 mm diameter plunger
Fuel injection nozzle	Hole nozzle 10 nozzle holes Nozzle hole dia. (0.48mm) Spray angle= 160o Nozzle opening pressure = 40 Mpa

Figure 1: A picture of the engine and experimental setup.

2.2 Fuel preparation:

The biodiesel blends utilised in this investigation were B20 (20% biodiesel, 80% diesel), B50 (50% biodiesel, 50% diesel), and B100 (100 percent neat biodiesel). Three biodiesel blends were compared to diesel fuel in terms of PM emissions and engine performance. Table 2 shows the parameters of biodiesel blends and diesel fuels determined at UT-Chemical Iraq's Engineering facilities. The oxygen-born in the gasoline mixes ranged from 5.87 to 11.1 which is consistent with prior investigations.

Table 2: Specifications of tested fuels

Fuel type	Calorific value (kJ/kG)	Density (g/dm^3)	Viscosity (mm^2/s at 27 °C)	Cetane No.	Flame point (°C)	Cloud point (°C)	Pour point (°C)
Diesel fuel	44227	810	4.23	49	59	-13.8	-29
B100	39873	906	65	38.6	239	-3.7	-12.4
B50	40368	877	44.7	40.6	179	-10.2	-17.833
B20	41654	829	14.38	42.9	112	-11.78	-24.68

2.3 Test procedure:

This research examined three biodiesel blends (B20, B50, and B100) under varied engine loads and speeds. The diesel fuel was the first to be tried in the engine. The engine was then tested with various biodiesel mixes to compare emission and combustion outcomes (diesel fuel). For the true results, the engine's fuel lines were cleaned after each test. At addition, engine performance and particle emissions were studied in different loads and speeds. The equipment's data were averaged to produce more confident results. The difference in engine performance and PM emission from burning biodiesel blends was compared to the findings from burning diesel to determine the favourable impact of renewable fuel combustion.

3. Results and discussion:

It is generally known that biodiesel may be blended with diesel fuel in various proportions [41-43]. Figure 2 shows the impact of brake mean effective pressure and fuel mixes on brake specific fuel consumption. For fuel mixes including diesel, the BSFC clearly declined with engine load. Increasing the amount of biodiesel in fuel blends increases the BSFC at different engine loads (Figure 2).Because biodiesel has a low heating value, diesel engines need more of it. It took more biodiesel to create the same engine torque as diesel.The BSFC rose from B20, B50, and B100 combustion by 23, 27, and 35.7 percent correspondingly.

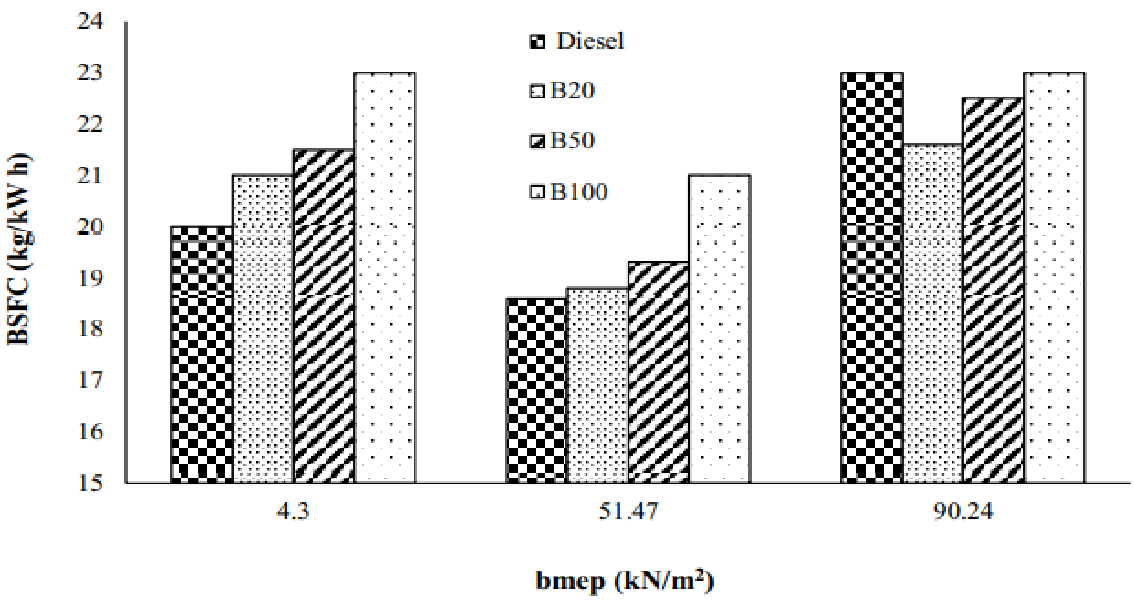


Figure 2: Effects of engine loads and biodiesel blends on brake specific fuel consumption (BSFC)

Figure 3 shows the impact of engine speed and fuel type on BSFC for a constant engine torque. The BSFC rose with engine speed for all biodiesel blends tested in B20, B50, and B100. The lower heating and calorific values of biodiesel fuel qualities enhanced the BSFC of biodiesel. These findings are in line with previous research [44-46]. However, the increased heating and calorific characteristics of conventional diesel fuel improves fuel efficiency compared to the three biodiesel mixes (Figure 3).

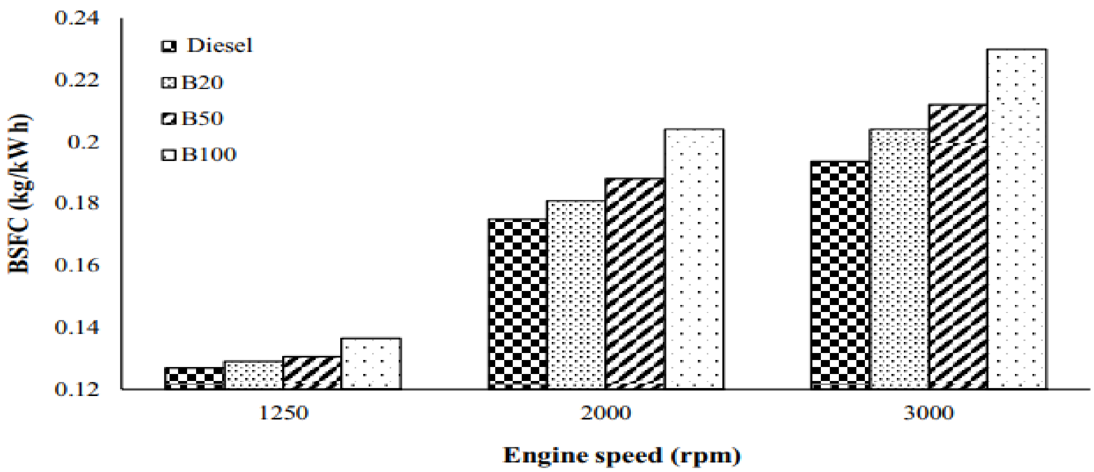


Figure 3: Effect of fuel blends and engine speeds on BSFC.

Figure 4 shows the impact of biodiesel blends and BMEP on brake thermal efficiency.

BTE was 30.4 percent from full-load diesel combustion. Figure 4 shows that the BTE values for B20, B50, and B100 were 28.8%, 27.9%, and 27%, respectively. Under the same conditions, the biodiesel blends yielded lower BTE values than the diesel. The poor heating value of biodiesel blends (Table 2) [47, 48] is the fundamental issue. Compared to diesel, the BTE of B100 dropped by 3.45% at full engine load (Figure 4). Figure 5 shows the influence of engine speed and biodiesel mixes on BTE. The BTE of biodiesel blends is somewhat lower than that of pure diesel fuel at all engine speeds. This graph shows the trend of biodiesel blends at varying engine speeds and loads (Figure 5).

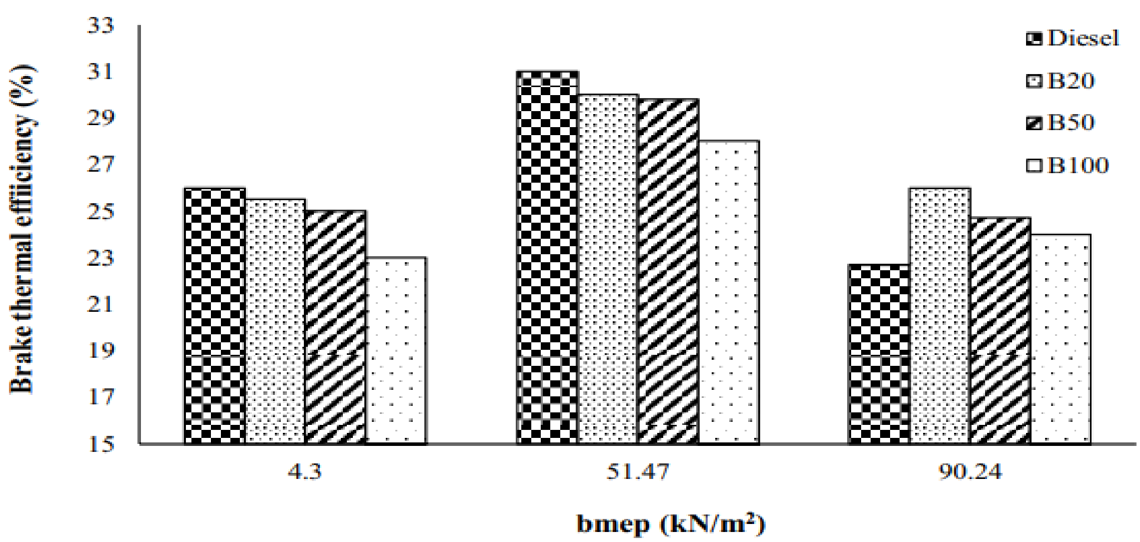


Figure 4: Effect of fuel blends and engine loads on brake thermal efficiency (BTE)

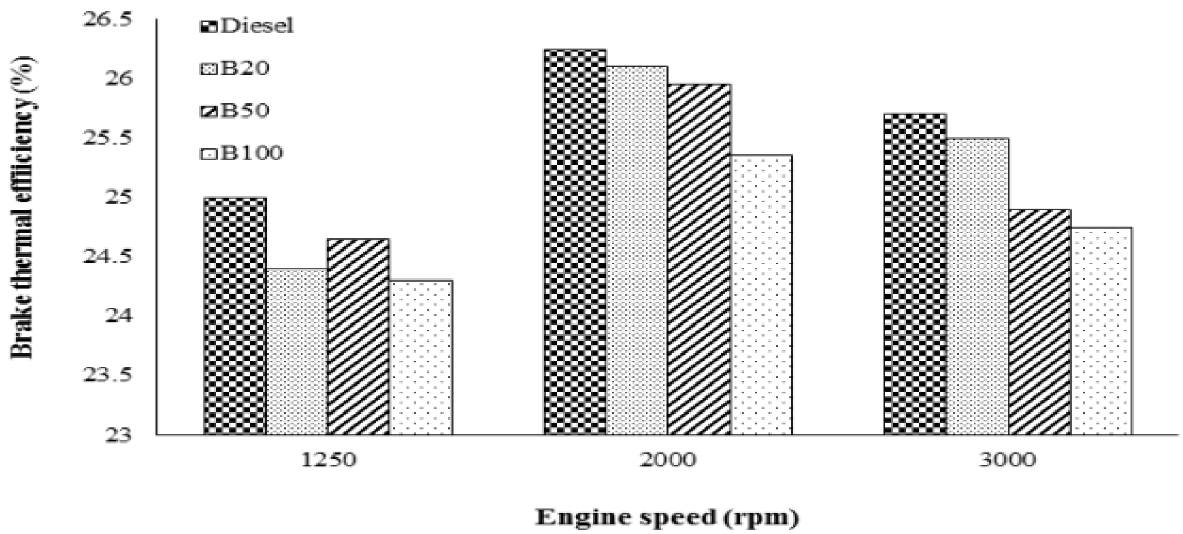


Figure 5: Effects of fuel blends and engine speeds on brake thermal efficiency (BTE).

Figure 6 shows higher and lower values of EGT from combustion of biodiesel blends under various loads. For fuel mixes and diesel, EGT rose with engine load. This is because more gasoline is fed into the combustion cycle, increasing engine torque [45]. Figure 6 shows that diesel fuel combustion increased exhaust gas temperatures, particularly with high loads. The temperature of the exhaust gas from B100, B50, and B20 combustion was lower than that of diesel fuel combustion (Figure 6). This may be related to decreased combustion temperatures owing to reduced heating value [49, 50]. Figure 7 shows the fluctuations in EGT from burning biodiesel mixes (B20, B50, and B100) at various engine speeds. The EGT rose with engine speed. For the same engine torque, more fuel may be fed into the combustion cycle. The similar EGT trend was seen with increasing engine RPM while using biodiesel mixes. The greater heating value of biodiesel blends is the main explanation for the somewhat lower EGT generated as compared to diesel fuel (Figure 7).

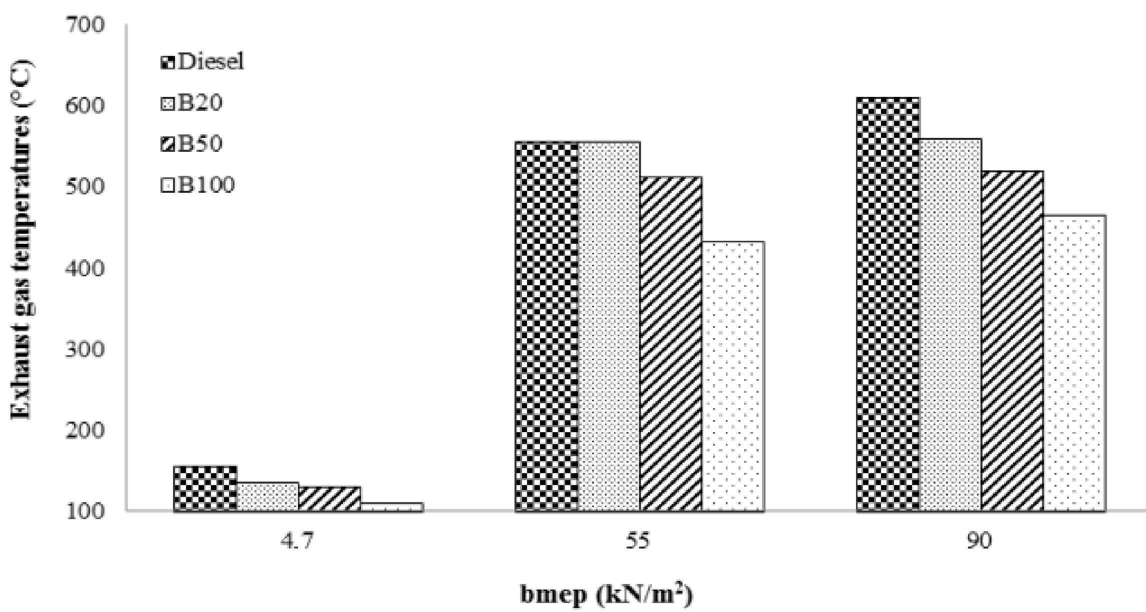


Figure 6: Effect of fuel blends and engine loads on exhaust gas temperatures (EGT)

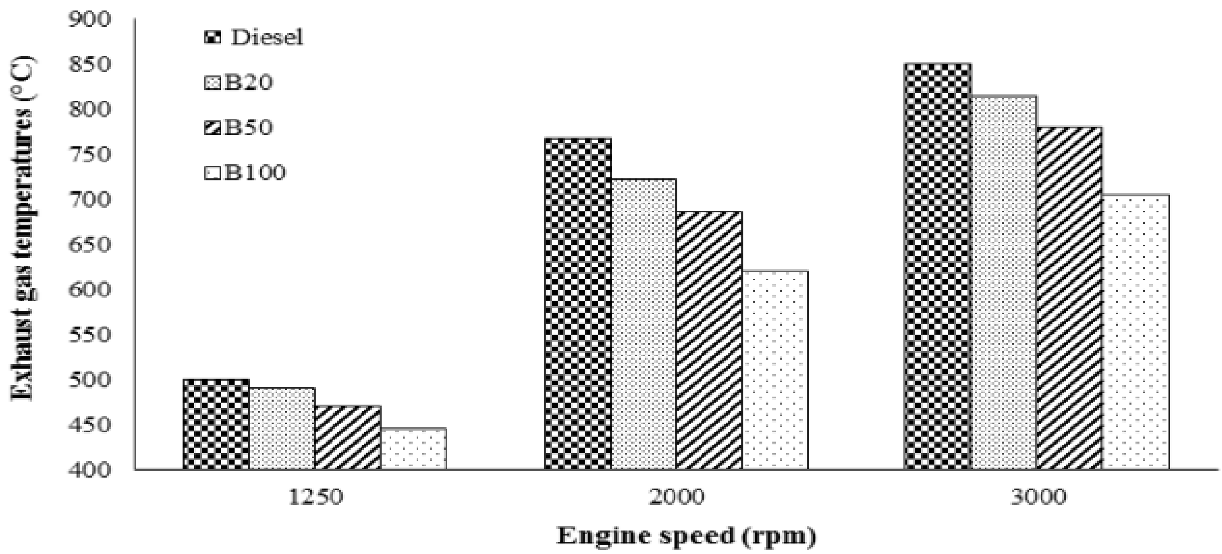


Figure 7: Effects of fuel blends and engine speeds on exhaust gas temperatures (EGT).

Figure 8 shows PM emission concentrations from several biodiesel blends burned at varied engine loads and constant engine speed. Carbon soot particles are the principal component of PM formed when the fuel lacks oxygen to react with all carbon. During combustion, the PM created in the fuel-rich zone enters the combustion cycle. Biodiesel combustion produced a few changes in PM emission at low load (Figure 8). The combustion of biodiesel blends lowered PM concentrations compared to combustion of diesel fuel. Under full engine load, the PM concentration was reduced by 34.96 percent when using plain biodiesel over diesel. Under varying engine loads, smoke emissions from biodiesel blends reduced. Incomplete combustion and liberated soot particles from oxygenated fuel (biodiesel mixes) cause this [51, 52]. Previous research has shown that oxygenated fuels reduce smoke and soot emission in various engine operating circumstances [53-55].

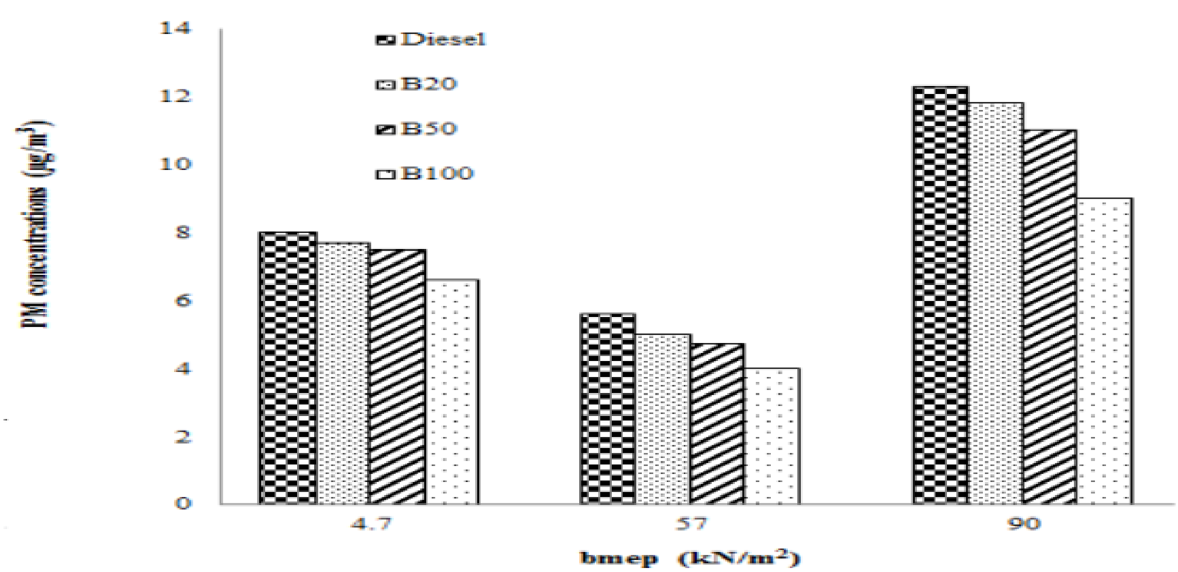


Figure 8: Effect of fuel blends and engine loads on particulate matter (PM) concentration

The findings from Figure 9 illustration the effect of biodiesel blends and engine speeds on the concentrations of PM. Adding biodiesel to the fuel blends significantly reduced the concentrations of PM for all operating conditions of engine speeds. It was observed that the B20, B50, and B100 decreased the PM concentrations by 16.847, 28, and 43.34%, respectively, compared with conventional diesel. These outcomes gives a good indication that the PM concentrations affected by the engine operation mode.

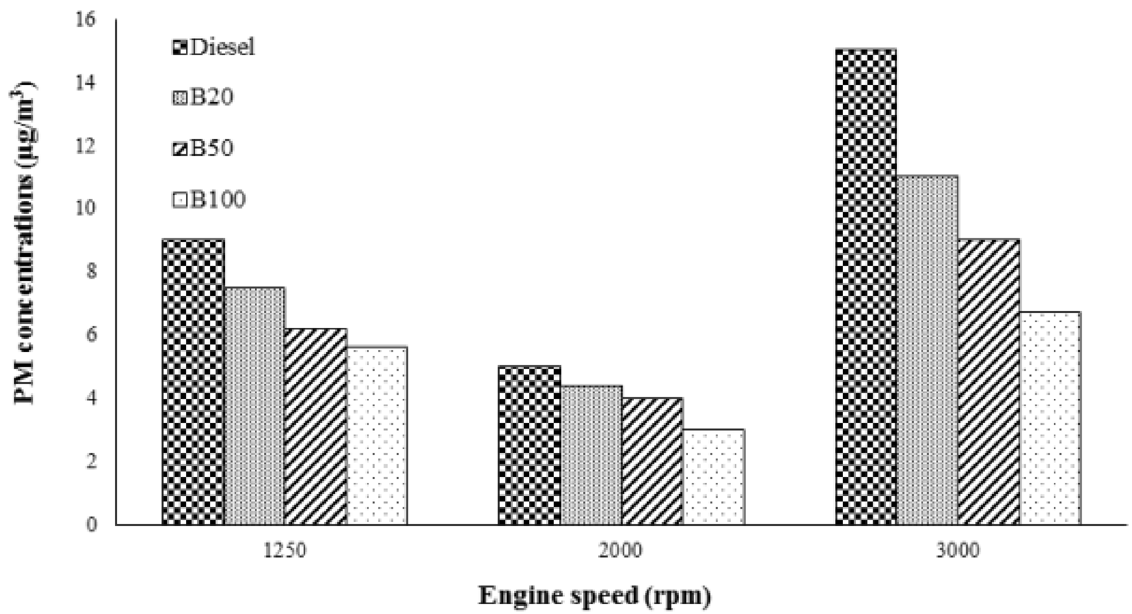
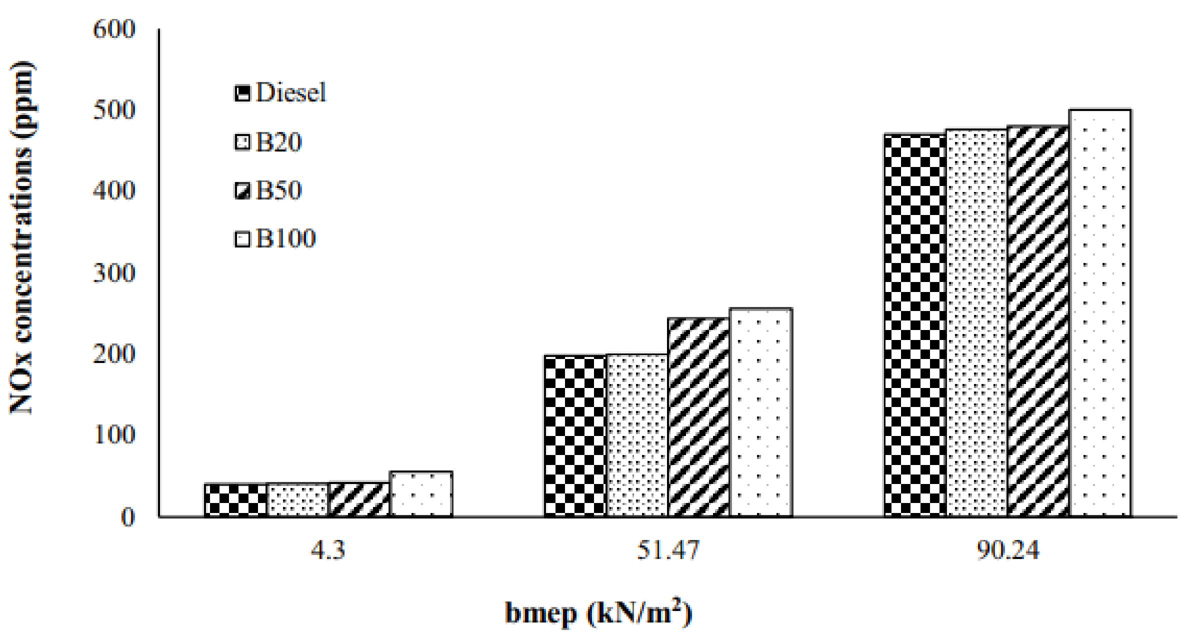
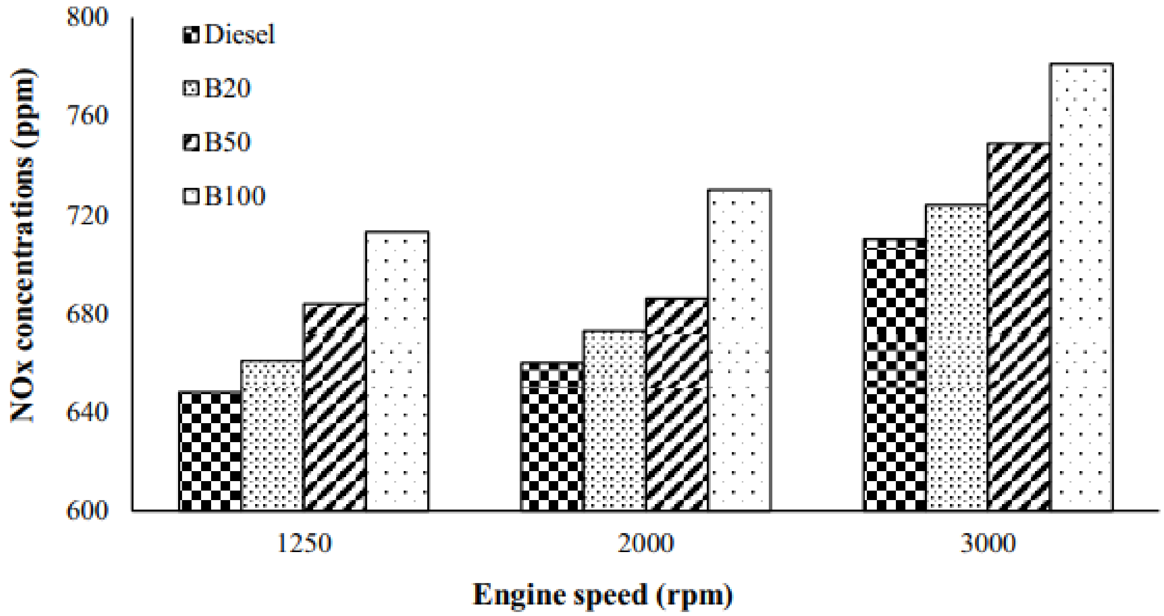


Figure 9: Effect of fuel blends and engine speeds on particulate matter (PM) concentration





4. . Conclusions

This research examined the impact of various biodiesel blends on engine performance and PM concentrations at varying engine loads and speeds. Compared to diesel, the B20, B50, and B100 increased fuel usage by 23, 27, and 35.7 percent, respectively. The engine's BTE reduced as the biodiesel % increased in the fuel mixes. Moreover, 3.45 percent BTE was formed from the combustion of B100.

The EGT of biodiesel blends was lower than that of conventional diesel fuel at varied engine loads and speeds. During the combustion of biodiesel blends, overall PM concentrations were suppressed. Fuel mixes with higher oxygen concentration help oxidise PM under varied engine settings. Also, compared to diesel fuel, biodiesel (B100) reduced PM by 34.96 percent.

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