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The Influence of Using Biodiesel Prepared from Cresson Oil on Emissions and Performance of CI Engines

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ABSTRACT

The experimental study was conducted to investigate the effect of using Cresson oil biodiesel on CI engine emissions and performance. This research aimed to examine how using innovative biodiesel blend formulations made from Cresson oil affected the performance and emissions of CI engines. The proportion of Cresson oil biodiesel added to conventional Iraqi diesel fuel into volume amounted to 10%, 20%, 40%, 60%, 80%, and 100%. The engine compression ratio was set to 18, and the fuel injection timing was set at 23° bTDC. The experiments show that this biodiesel reduces the thermal efficiency, heat release, delay time, and cylinder pressure of the engine while increasing the exhaust temperature (EGT) and brake-specific fuel consumption (BSFC). There has been an increase in emissions of nitrogen oxides (NO_X) and carbon dioxide (CO_2), in addition to a reduction in emissions of carbon monoxide (CO), soot, and unburned hydrocarbons (HC).

Keywords: cresson oil, biodiesel, CI engine, emissions, performance.

INTRODUCTION

Rapid improvement in people's level of life has resulted in exponential growth in the energy they use. Today, fossil fuels are indispensable in many fields, including transportation, industry, and agriculture. On the other hand, petroleum is a finite resource that is excessively being used up [1-3]. In addition, increasing the reliance on fossil fuels has serious environmental effects. Energy security and environmental concerns have spurred international efforts to identify sustainable energy sources. Biofuels are the most promising and cost-effective option [4, 5]. The energy problem and the public concern about the depletion of the planet's nonrenewable resources have prompted several industries to search for replacement fuels. Vegetable oils and their byproducts are commonly favored among alternative fuels [6]. Agarwal and Dhar [7] tested the physical, chemical, and thermal characteristics of Neem oil biodiesel. The emissions, efficiency, and combustion of DF combined with 20% biodiesel were examined. In comparison to DF, biodiesel blends have higher BSFC and low BTHE. However, NO emissions were higher for biodiesel blends, even though biodiesel-powered engines produced lower CO and HC emissions than DF. Combustion studies indicated that the engines running on biodiesel always began burning their fuel sooner, while the 20% mixes burned a little slower than the others. Gad and Abu Hashish [8] compared the effect of fueling diesel engines with DF and roselle biodiesel blends of 10% and 20% by volume on emissions, as well as the performance of CI engines. In experiments, engine load varied from zero to maximum capacity. The roselle biodiesel blend decreased the BSFC, CO and HC emissions but increased the BTHE and NOx emissions of the engine. Kassim et al. [9] studied the effect of utilizing palm oil biodiesel on CI engine performance and emissions. The fuel was blended with varying biodiesel volumes (5%, 10%, 15%, and 100%). The experiments revealed that the BSFC and emissions of CO_2 and NO_x were increased. BTHE improved, leading to a reduction in CO and HC emissions. Radhi and Imran [10] conducted experiments to find the influence of biofuel on engine emissions levels and performance. Various percentages of olive oil and Castrol oil biodiesel were added to DF to produce biofuels for consumption in CI engines. The quantities of these vegetable oils were added separately to create a 5% to 20% biofuel. The primary results obtained are a reduction in CO and UHC emissions levels but an increase in the emissions levels of CO_2 and NO_x. Under constant power output, the BSFC of the engine increases marginally.

Logesh et al. [11] examined the effects of coconut biodiesel on engine emissions and performance. Biodiesel was combined with diesel at 5% and 10% volumetrically. The experimental findings showed the CO, HC, soot, and NO_X emissions decreased by 1.7%, 1.9%, 2.1%, and 2.7%, respectively. The engine BTHE rose to 1.2%, while BSFC declined to 1.3%. Pandhare and Padalkar's [12] study compared diesel with Jatropha oil biofuel blends effect on CI engines. The experimental outcomes show that the Biodiesel B100 consumed 15% more fuel than diesel. Biodiesel and its blends have somewhat greater BTHE than DF. The biodiesel increases the engine EGT and emissions of NO_x and CO_2 but decreases the emissions of CO.

Savariraj et al. [13] investigated the performance as well as emissions of the CI engines using fish oil biodiesel blended with DF at volumetric percentages of B25, B50, B75, and B100, in comparison to DF, the B100 mix produced higher BSFC and BTHE during testing. A combustion study shows the fish-oil biodiesels burn more quickly than DF and have lower peak cylinder pressures. The EGT of the biofuel blend is higher than DF. At high load, the B100 fuel produced 34.95%, 1.65%, 14.6%, and 1.8% more smoke, NO_x, CO, and HC emissions than DF. Muralidharan et al. [14] used biodiesel mixtures in a CI engine and found that (BTHE) is directly proportional to engine load, whereas (BSFC) is inversely proportional. Moreover, the bound oxygen (O_2) of the biodiesel improves fuel combustion and reduces emissions. The study found that biodiesel-diesel mixtures reduce particulate matter and smog. The opacity, HC, and CO emissions decrease, but NO_x formation increases. Ozener et al. [15] tested the performance in addition to the emission levels characteristics of a diesel engine fuelled with soybean oil, biodiesel, and its mixtures. At different loads, B100 and EGT were lower than those of diesel. All biodiesel fuels were found to have lower heating values than DF, which resulted in decreased BTHE and increased BSFC.

Imran and Kurjib [16] tested the waste maize oil biodiesel on CI engines to see how it affected the engine emission levels and performance. The waste maize oil biodiesel was added with DF into volume ratios of 5%, 10%, 15%, and 20%. The waste cooking oil and traditional diesel combination increased BSFC by 11.4% in experiments. The findings showed that these mixes decreased HC and CO exhaust gas emissions by 32.2% and 25.625%, respectively, but increased CO_2 and NO_x emissions by 41.20% and 29.92%. Can et al. [17] made biodiesel using two types of leftover cooking oil supplied by a food processing plant and a fast food joint. The researchers mixed biodiesel fuel with DF at two different concentrations, 5% and 10%. When the biodiesel from cooking oil is blended with DF, injection and combustion could begin sooner. Using a biodiesel-DF combination resulted in higher BSFC and NO_x emissions. When using biodiesel fuel, CO and CO_2 emissions drop at high loads. Elkelawy et al. [18] created biodiesel blends with B30, B50, and B70 compositions by combining sunflower and soybean oils. Researchers discovered that the biodiesel blends considerably improved BSFC and BTHE. The emissions of HC and CO were reduced by 41.18% and 33.8%, respectively, whereas emissions of NO_X were shown to be higher than with DF.

Liaquat et al. [19] investigated the performance and emission characteristics of a diesel engine powered by coconut biodiesel and its mixtures. The research showed that biodiesel blends released greater levels of NO_x at all loads while emitting lower CO, CO_2, and HC levels. In addition, compared to DF, the mix increased BSFC by 2.11%. Datta, Palit, and Mandal [20] examined the effects of varying the quantities of biodiesel blends produced using jatropha biodiesel on CI engine performance and emission levels. The authors found that the (BTHE) and (BSFC) of biodiesel blends declined and rose as the percentage of biodiesel in the blend changed. Greenhouse gas emissions were also decreased, except those of nitrogen oxide (NO_x). Raheman and Ghadge [21] studied the impact of utilizing Mahua biodiesel on CI engine emissions and performance. The BSFC rises with increasing blending ratios for all biodiesel and DF mixes and falls as engine speed rises. It was discovered that the emissions of CO, HC, and smoke of biodiesel blends were lower than those of DF, whereas the NOx emissions increased. Ekem Buyukkaya [22] studied the performance, in addition to emission levels of CI engines, using various rapeseed oil blends. The researcher found the biodiesel lowered smoke opacity by 60% and increased BSFC by 11% compared to DF. The CO emissions of a mixture of B5 and B100 were lower than DF, with a percentage of 9% and 32% respectively. Biodiesel has 8.5% greater BSFC than DF at high power and 8% more at peak torque. The rapeseed oil and its mixture ignite faster than DF.

Imtenan et al. [23] used diethyl ether (DEE), an oxygenated cold starting fuel, to improve the Palm biodiesel and DF (P20) blend. The results show the DEE blends outperformed (P20) in emissions and combustion. The oxygenated composition of DEE reduced CO and smoke emissions by 25% and 35.5% above (P20). The NO emission dropped 20% for P10D10 when compared with the P20 blend of fuel. The HC emission increased in DEE mixtures. The chemical variations cause the modified mixtures to have different ICP profiles and HR than the (P20) blend.

There are no research studies on the preparation of biodiesel blend from Cresson oil and DF as well as the use of a Cresson biodiesel and DF mixture as a diesel engine fuel, especially concerning its emissions characteristics when burnt in diesel engines. The primary contribution of this study is the determination of the Cresson biodiesel mixture effect on the performance in addition to emission level characteristics of the CI engine. Therefore, it is essential to determine how well Cresson biodiesel blends operate in diesel engines and how much pollution they produce. Various Cresson biodiesel mixtures were utilized in a diesel engine for experimentation.

PROCESS OF BIODIESEL FUEL PREPARATION

The Cresson biodiesel was produced using a multi-stage trans-esterification procedure, as seen in Figure 1. One gram of potassium hydroxide and 0.2 liters of pure methanol per liter of Cresson oil are mixed on a hot plate stirrer at 500 rpm to make methoxide. The Cresson oil was purchased from a local Iraqi market and heated to 60°C using a hot plate stirrer with precise temperature control. The methoxide was added to the heated Cresson oil and stirred on a hot plate. At 60°C and 500 rpm, the chemical reaction between the Cresson oil and methoxide occurred over 120 minutes. After the ingredients were well combined, they were transferred to a separate funnel where the glycerin could be removed. After being rinsed with deionized water, the biodiesel was heated to 110 degrees Celsius to evaporate any remaining water. Filtering the prepared biodiesel to eliminate the contaminants is the last stage in the preparation

Figure 1. Cresson oil biodiesel preparation steps

process. Various volumetric combinations of Cresson biodiesel and conventional Iraqi diesel fuel (10%, 20%, 40%, 60%, 80%, and 100%) were tested. The process of preparation was conducted using the resources cited [24, 25, 26].

Biodiesel fuel blends physical and chemical properties

The chemical and physical properties of the biodiesel blend were tested in the lab of fuel properties at the petroleum engineering department at Kerbela University, the Centre of Research and Development of the Ministry of Petroleum and the Centre of Research and Development of the Ministry of Manufacturing and Material. The final results of the test fuel are shown in Table 1. On average, 96.1% of biodiesel was produced through the transesterification of Cresson biodiesel. Gas chromatography-mass spectrometry (GC-MS) measurements of the Fatty acid methyl esters (FAME) in the produced biodiesel are shown in Table 2. Figue 2 displays the obtained chromatogram of Cresson biodiesel. Thirteen peaks can be seen on the chromatogram, corresponding to the esters found in the biodiesel produced.

EXPERIMENTAL SET-UP

Diesel and Cresson biodiesel blends (BC10 to BC100) were tested on VCR research engines to determine their effects on engine performance and emission level in the College of Musayyib Engineering laboratories at the University of Babylon, as illustrated in Figure 3. Table 3 details the specifications of the VCR motor. The starter motor turned on the engine. The test was done on a VCR engine that turned at 1500 rpm, CR of 18 and IT of 23°bTDC. The air box, fuel tank, digital temperature display, and fuel measurement device are all housed in a separate panel box. A strain gauge-type load sensor measuring 0–35 kg, a pressure transducer measuring ICP, a speed sensor measuring engine speed, an encoder measuring CA, and a pressure differential system measuring fuel flow rate; thermocouples in the exhaust system and a calorimeter measure

Table 1. Biofuel mixes physical and chemical qualities

Property	unit	DF	BC10	BC20	BC40	BC60	BC80	BC100
Density at 15ºC	Kg/m^3	831	835.9	841.8	853.6	865.4	877.2	889
Kinematic viscosity at 38.8ºC	mm^2/s	2.51	2.81	3.05	3.54	3.98	4.2	4.49
Flash point temperature	ºC	62	77	89	101.5	118	134	149
Fire point temperature	ºC	73	95	111.5	123.5	136	154	168
Calorific value	MJ/kg	46.5	45.8	45.1	43.6	42.2	40.8	39.3
Cetane number	-	46.3	47.9	50.9	54.2	55.9	58.4	59.4

Table 2. Shows the amount of FAME that is included in Cresson biodiesel

Compounds detected	Molecular formula	Composition (%)	#Peaks
Methyl tetradecanoate	$C_{15}H_{30}O_2$	0.26	1
9-Hexadecenoic acid, methyl ester	$C_{16}H_{30}O_2$	0.31	2
Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	14.85	3
Pentadecanoic acid	$C_{15}H_{30}O_2$	0.12	4
9,12-Octadecadienoic acid, methyl ester	$C_{19}H_{34}O_2$	60.4	5
Heptadecanoic acid, 16-methyl-, methyl ester	$C_{19}H_{38}O_2$	4.01	6
Cis-5,8,11-Eicosatrienoic acid methyl ester	$C_{21}H_{36}O_2$	0.14	7
9-Octadecenoic acid (Z)-, methyl ester	$C_{19}H_{36}O_2$	12.52	8
Methyl 18-methylnonadecanoate	$C_{21}H_{42}O_2$	3.21	9
Dodecyl cyclohexane carboxylate	$C_{19}H_{36}O_2$	0.18	10
Erucic Acid	$C_{22}H_{42}O_2$	3.23	11
Methyl 20-methyl-heneicosanoate	$C_{23}H_{46}O_2$	0.59	12
Benzene, 1-methyl-3,5-bis(1-methylethyl)-	$C_{13}H_{20}$	0.15	13

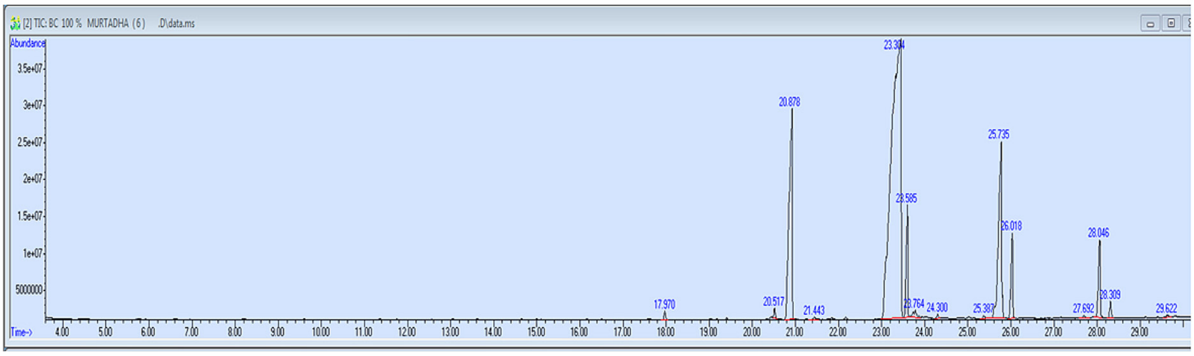
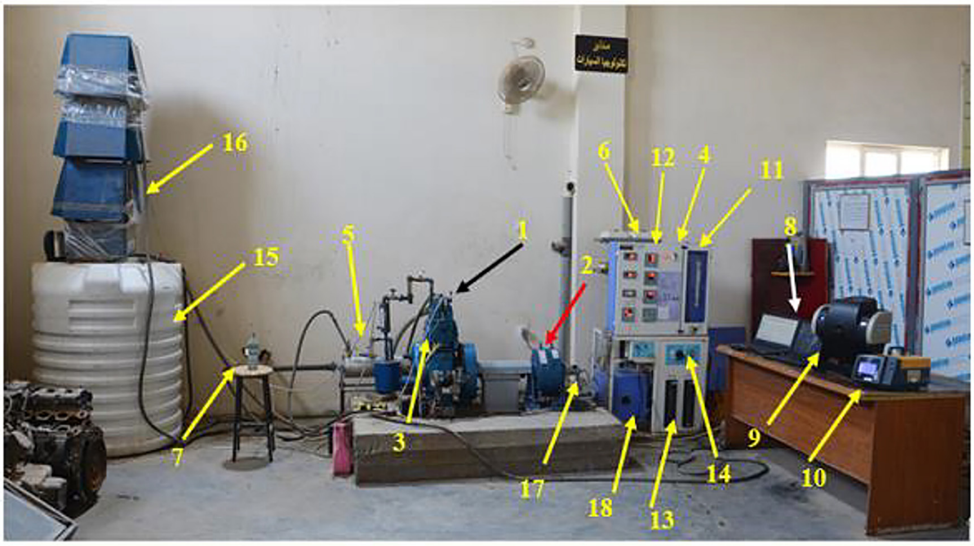


Figure 2. GC–MS chromatogram of biodiesel



1	**VCR engine**	7	**Noise meter**	13	**water flow meter**
2	**Eddy current dynamometer**	8	**Laptops**	14	**Load control**
3	**VCR mechanism**	9	**Smoke meter**	15	**Water tank**
4	**Power supply**	10	**Gas analyzer**	16	**Cooling tower**
5	**Calorimeter**	11	**Fuel tube**	17	**encoder**
6	**Control panel**	12	**Temperature recorder**	18	**Air box**

Figure 3. ICE test rig

the temperature of the exhaust, and hot wire sensor determines the velocity of the incoming air were all connected to the computer through an interface card, which operated by “VCR engine” software, which logs all operational measurement data in an Excel sheet. A self-priming pump provides water circulation for the engine and calorimeter. The exhaust gases were tested using a portable gas detector. The gas analyzer shows CO, CO_2, NO_x, O_2, and HC emissions. The level of smoke was recorded with a smoke meter.

MEASUREMENT ACCURACY AND UNCERTAINTY ANALYSIS

Analyzing the uncertainty of measuring equipment and the system’s precision is one way to ensure that the experimental data is reliable. Many factors, such as faulty instruments or inaccurate calibration, the nature of the test environment (steady-state vs. dynamic), the nature of the test strategy and plan, and the act of reading or seeing the data, may contribute to an increase

Table 3. Test engine specification

Engine model	Kirloskar TV1
General detail	four stroke, CI, DI
Number of cylinder	one
Cooling type	eater cooling
Bore	87.5 mm
Stroke	110 mm
Compression ratio	18:1
Swept volume	661.1 CC
Rate output	3.5 kW at 1500 rpm
Fuel injection at	23° before TDC
Inlet valve open at	4.5° before TDC
Inlet valve close at	35.5° after BDC
Exhaust valve open at	35.5° before BDC
Exhaust valve close at	4.5° after TDC

in uncertainty. The overall uncertainty may be considered the total of the uncertainties associated with each parameter under study. With the following help of the formula, it was possible to determine the overall percentage of uncertainty [27],[28]. Total uncertainty of the experiment = square root uncertainty of ((pressure transducer)^2 + (angle encoder)^2 + (NOx)^2 + (HC)^2 + (CO)^2 + (CO_2)^2 + (O_2)^2 + (Smoke opacity)^2 + (thermocouple)^2 = square root of ((0.11)^2 + (0.21)^2 + (0.2)^2 + (0.22)^2 + (0.21)^2 + (0.25)^2 + (0.22)^2 + (0.7)^2 + (0.23)^2) = square root of (0.84) = ± 0.84%

RESULTS AND DISCUSSION

This study was conducted to illustrate the influence of using the biofuel made from Cresson oil on the emissions and performance of CI engines. Throughout the experimental work, BSFC, BP, ICP, ID, HR, the mass of fuel burned rate, and engine emissions were the primary operational variables examined about the proportion of Cresson biofuel in the biodiesel blend with the operation condition of constant speed of 1500 rpm, variable dynamometer load, constant CR of 18 and IT of 23° bTDC. In light of this, a brief overview of the most important findings is provided below:

Performance and emissions characteristics

Effect of biodiesel on engine BTHE

BTHE is the ratio of BP to the energy liberated due to fuel combustion in the engine cylinder. Generally, BTHE is increased along with the engine load due to increased engine BP with the use of different types of fuel. The BTHE of the engine was decreased with an increased concentration of Cresson biofuel in the fuel blend, as shown in Figure 4. The reduction in the BTHE when using fuel blends of BC10, BC20, BC40, BC60, BC80 and BC100, was 1.29%, 1.74%, 2.19%, 2.54%, 2.92%, and 3.29% respectively, at full engine load. This reduction of BTHE is

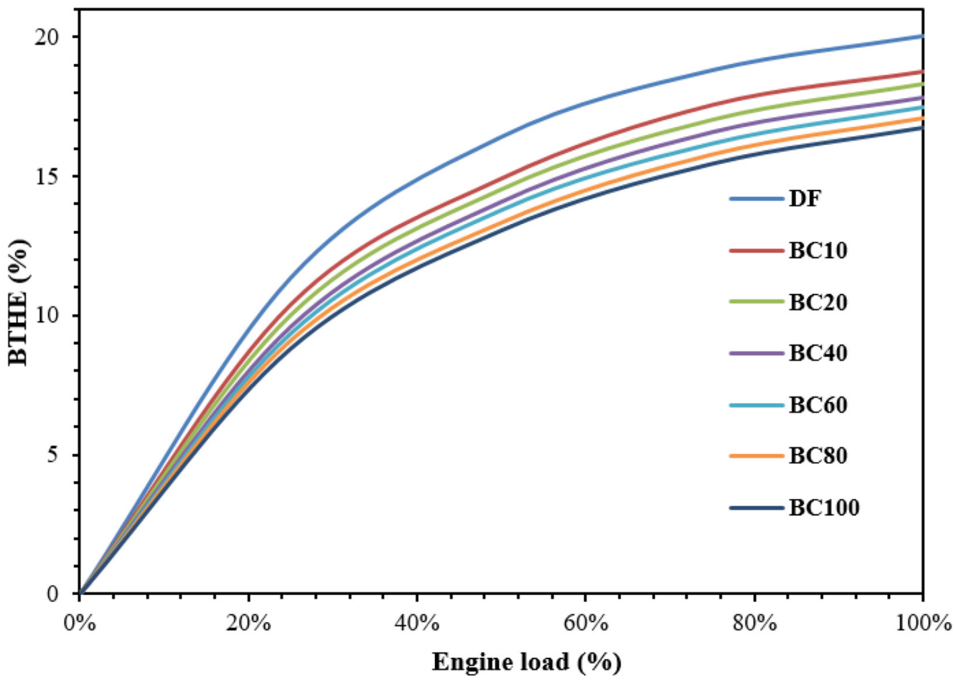


Figure 4. BTHE and engine load relationships for different fuel

attributed to the biodiesel blend having a low HV compared to conventional DF. The combustion process, which was accomplished with a low HV of fuel, produces low temperature and ICP so that the power produced by the engine will reduce, and the BTHE of the engine will decrease [29].

Effect of biodiesel on engine BSFC

When the proportion of Cresson biodiesel in Iraqi diesel fuel was raised, the BSFC also rose. The BSFC increased by a percentage of 5.11%, 7.38%, 9.68%, 11.43%, 13.36% and 15.24% when utilizing BC10, BC20, BC40, BC60, BC80 and BC100 at a total engine load, as illustrated in Figure 5. This rise in fuel consumption is attributable to the fact that the blending process reduces the fuel HV due to oxygen in its chemical composition. The fuel reduction HV causes burning more fuel to meet the exact power requirements or maintain the same operating conditions. The final result is that BSFC will increase [30, 31].

Effect of biodiesel on engine in-cylinder pressure

ICP was raised with the rise in the engine load due to increasing the fuel injection rate with the engine load, which is responsible for the rise in the combustion temperature and pressure. The cylinder pressure was lowered with the increased volumetric fraction of Cresson oil biodiesel in the fuel blend. The maximum pressure for BC10, BC20, BC40, BC60, BC80 and BC100 was 80.42, 78.65, 76.92, 75.28, 73.40 and 71.59 bar, respectively, as shown in figure (6). The reason for this decrease in pressure is related to the fact that the biodiesel and its blend have a low energy content, high viscosity, latent heat of evaporation and surface tension property, which play essential roles in heat generation inside the combustion chamber and has a direct relation with combustion temperature and pressure [32, 33].

Effect of biodiesel on heat release

HR was examined to determine the quantity of heat needed for combustion in the engine cylinders. Figure 7 shows how the HR rate varies with CA under full load for DF and biodiesel fuels. Since the accumulated fuel had to be vaporized slowly during ID, a negative heat discharge was seen at the start of combustion. After the start of combustion, this has become positive. This graph illustrates that the peak HR rate for pure diesel and biodiesel blends was reduced with the increased volumetric ratio of biodiesel in the fuel blend. The maximum heat release for DF, BC10, BC20, BC40, BC60, BC80 and BC100 was 28.45, 27.88, 27.33, 26.78, 26.24, 25.72, and 25.20 J/deg respectively. Due to the low HV of biodiesel, the heat discharge rate was also low compared to diesel. Also, the greater volatility of diesel and superior blending with air, its HR during premixed

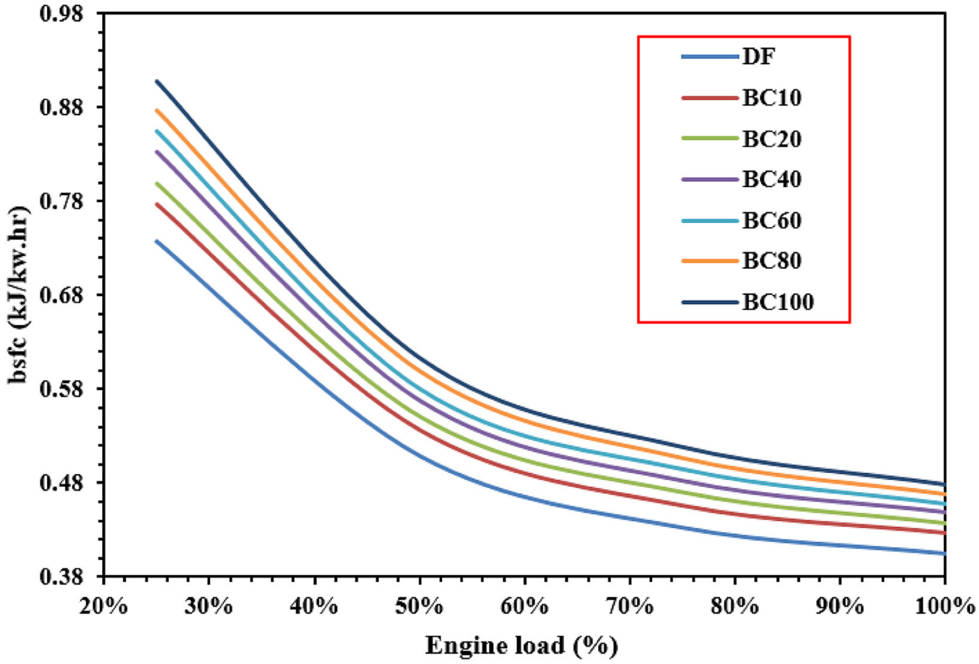


Figure 5. BSFC and engine load relationship for various fuel mixes

combustion was greater than that of bio-diesel mixtures [34, 35].

Effect of biodiesel on delay period time

The duration of the ID time is influenced by a range of characteristics, primarily physical and chemical factors. The physical delay is attributed to atomization, mixing, and vaporization processes, while the chemical delay arises from the pre-combustion reactions occurring inside the fuel and air combination [36]. The ID of the engine has a negative correlation with the rise in BP. The observed phenomenon may be attributed to the increase in gas temperature inside the cylinder, resulting in lessening the physical ID period. Figure 8 illustrates the relationship between the variation in ID and BP for all the tested fuels. The ID of Cresson oil biodiesel and its blends is lesser than that of DF due to the higher CN of Cresson oil biodiesel. These properties result in a delayed

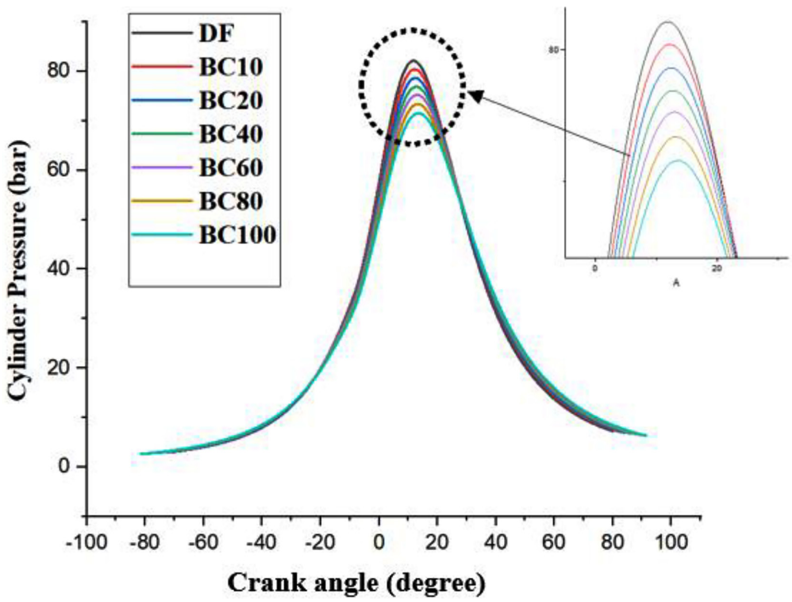


Figure 6. Correlates cylinder pressure and CA with biodiesel ratios

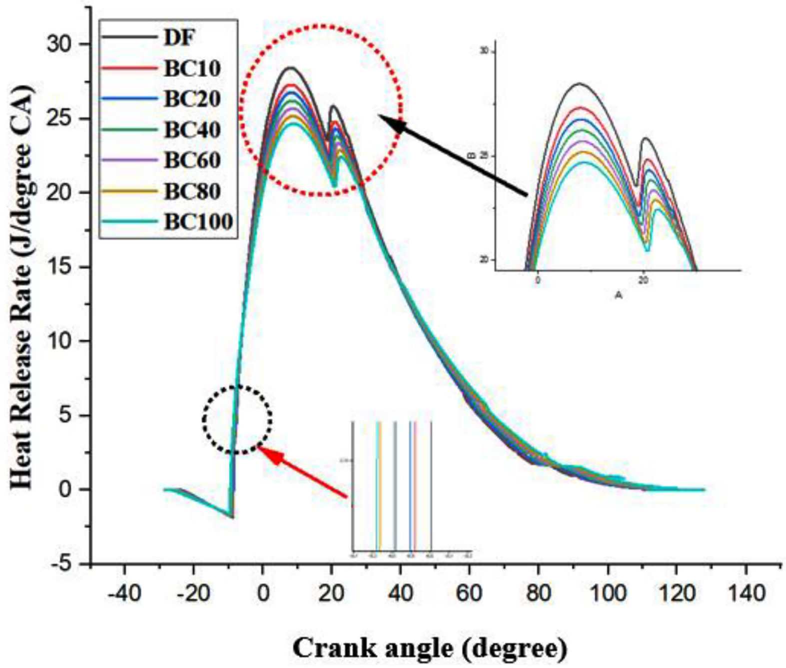


Figure 7. The HR rate-CA relationship with biodiesel ratios in fuel blends

start of combustion compared to DF, as shown by previous studies [37, 38].

Effect of biodiesel on fuel mass fraction burned rate

The mass fraction of fuel burned rate directly depended on the fuel CN which was measured by the ability of fuel auto ignition. The mass of fuel burned rate amplified with the rise in the engine load and the volumetric percentage of Cresson oil biodiesel in the fuel blend, as shown in Figure (9). The reason for the rise in the burned rate of biodiesel fuel is attributed to the high value of CN and oxygen concentration for biodiesel fuel [39].

Effect of biodiesel on exhaust temperature

Figure 10 describes the deviation of (EGT) with a change in engine load. EGT increases along with the engine load. The higher ratio of biodiesel has elevated EGT compared to DF for all engine loads. This is due to the oxygen content of the biodiesel, which improves the combustion process, resulting in a higher EGT associated with high CN of the biodiesel, which reduces premixing time and enhances combustion efficiency [40]. At full engine load, the EGT of, DF, BC10, BC20, BC40, BC60, BC80 and BC100 were 389.33ºC, 404.57ºC, 424.90ºC, 445.83ºC, 467.40ºC, 489.61ºC and 512.49ºC respectively.

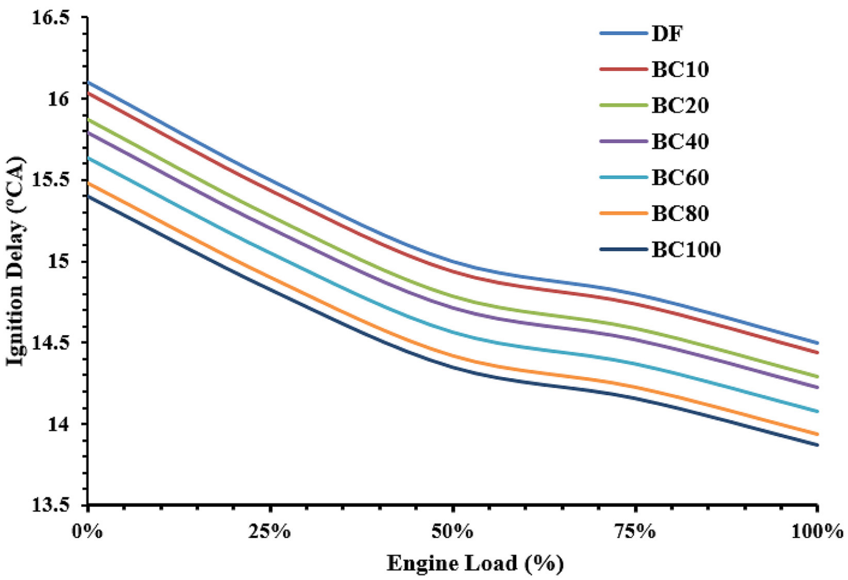


Figure 8. The relation between ID and engine load with different volumetric ratio of biodiesel in the fuel blend

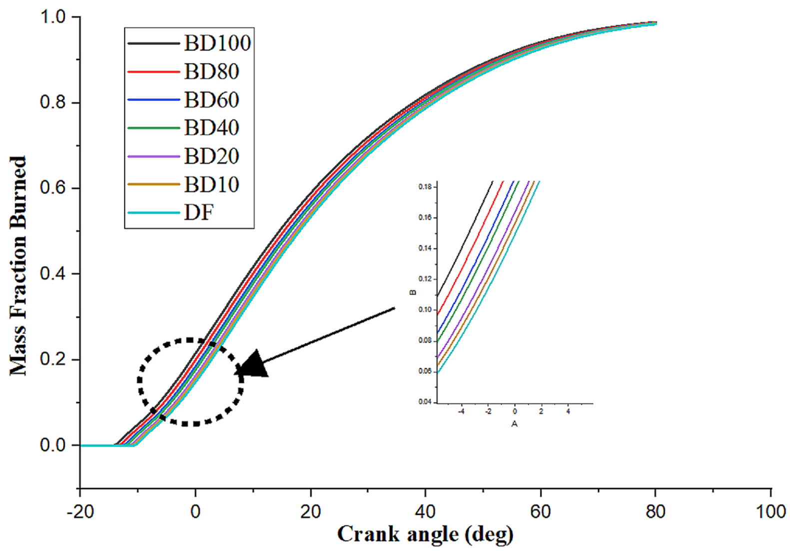


Figure 9. The relation between mass fractions of fuel burned and CA for various fuel blends

Effect of biodiesel on HC emissions

HC was emitted from the engine exhaust system due to lower oxygen concentration in the engine cylinder or bad air and fuel vapor mixing before combustion. Figure 11 illustrates that the HC emissions increased with the rising engine load because of a rise in the fuel-to-air ratio with the rise in the load but decreased with an increase in the Cresson biodiesel in the fuel blend. The lessening in HC emission for combustion of BC10, BC20, BC40, BC60, BC80 and BC100 biodiesel fuel reached 4.31%, 11.65%, 15.54%, 21.29%, 25.64% and 31.81%, respectively, at maximum engine load. The first reason for the lessening in HC emissions with the rise in the biodiesel volumetric percentage is the high concentration of oxygen atoms in the chemical structure of biodiesel, which makes more oxidizers in the combustion chamber to complete the combustion and produce more CO^2. The second reason is that the high CN of Cresson biodiesel causes earlier combustion and reduces the delay period. In this situation, the

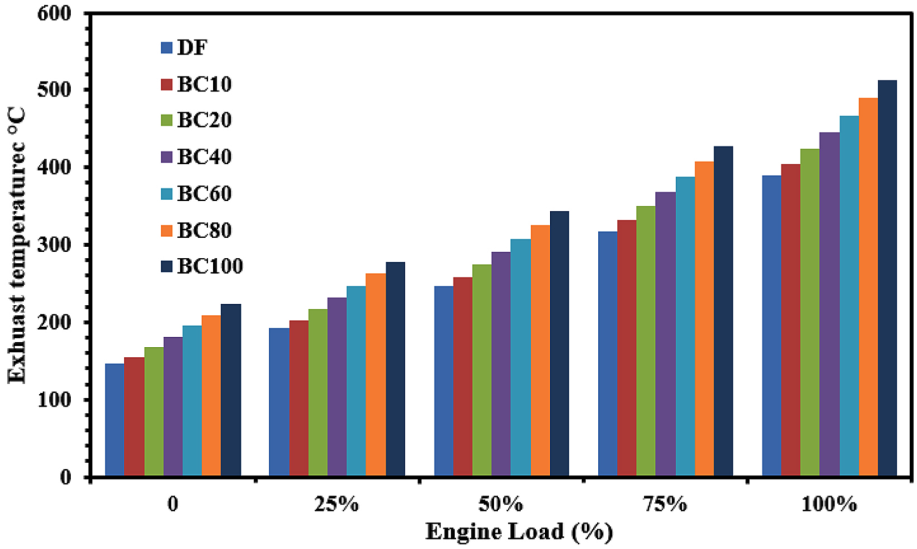


Figure 10. The relation between exhaust temperature emissions and engine load with different volumetric ratios of biodiesel in the fuel blend

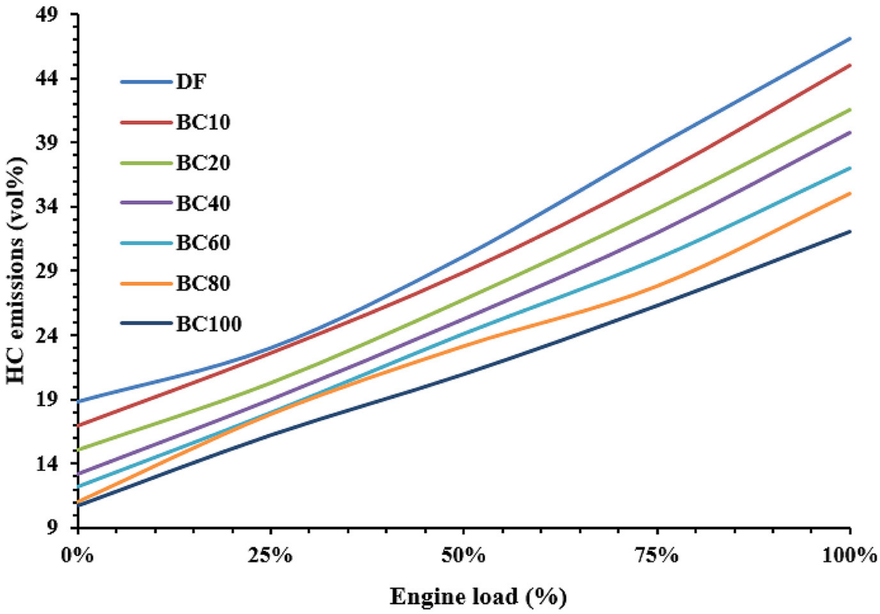


Figure 11. The relation between HC emissions and engine load with different volumetric ratio of biodiesel in the fuel blend

rate of fuel evaporation rate will rise for all fuel will burn approximately [41, 42, 43].

Effect of biodiesel on CO emissions

The scarcity of oxygen within the CC during the combustion process results in incomplete combustion and produces more CO emissions from the exhaust system. The emissions of CO raised with the engine load due to the increase in the fuel-to-air ratio with increasing the engine load. The CO emission reduced with the rise in the volumetric percentage of biodiesel in the fuel blend, the maximum decrease at complete load condition for BC10, BC20, BC40, BC60, BC80 and BC100 was 1.04%, 5.57%, 10.24%, 14.96%, 19.51% and 25.12% respectively, at a full load, as shown in figure (12). The reduction in CO emissions is related to the fact that the biodiesel fuel contains oxygen atoms in the chemical composition structure, which oxides CO and converts it to CO^2, producing more heat in this oxidation process [44].

Effect of biodiesel on NO_X emissions

Nitric oxide and nitrogen dioxide are the nitrogen oxide (NOx) constituents in engine emissions. The production of nitrogen oxides (NOx) is highly influenced by factors such as the temperature inside the CC, the oxygen existence fraction in the fuel, and the duration of the chemical reactions. The NO_x emissions increased with the rising concentration of biodiesel in fuel. The percentage of increasing NO_x emissions for a blend of BC10, BC20, BC40, BC60, BC80 and BC100 was 1.95%, 8.79%, 11.70%, 13.75%, 16.38% and 19.97%, respectively, at a total engine load, as shown in Figure 13. The NO_X emissions increase with the rising engine load due to the increase in the combustion chamber temperature and the volume fraction of biodiesel in the fuel blend due to greater occurrence of oxygen [45].

Effect of biodiesel on CO_2 emissions

The complete combustion of fuel inside the CC produced more CO_2 when the air-to-fuel ratio reached a stoichiometric value. The CO_2 emissions increased with engine load due to the rise in fuel burning rate inside the CC also increased along with the volumetric percentage of Cresson oil biodiesel in the blend, as shown in Figure (14). The percentage of increase of CO_2 emissions with biodiesel blend of BC10, BC20, BC40, BC60, BC80 and BC100 was 3.38%, 14.62%, 26.69%, 39.88%, 49.69% and 60.6%, respectively, at full engine load. The real reason behind this rise is the oxygen content of the biodiesel blend, which plays an essential role in the fuel vapor or CO oxidation process and is converted to CO_2 [46, 47].

Effect of biodiesel on soot emissions

The soot emissions increased along with the engine load because of increasing the fuel-to-air ratio but decreased with increasing volumetric

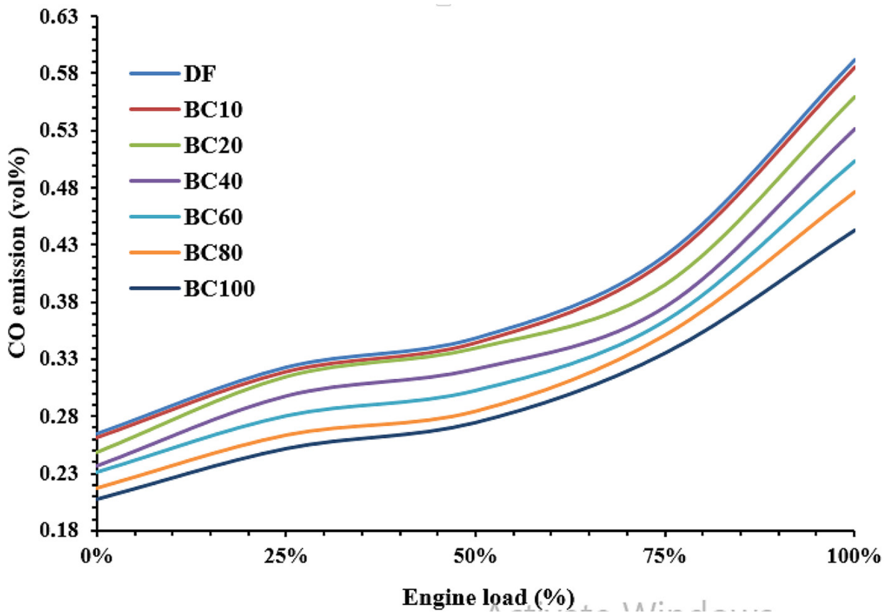


Figure 12. The relation between CO emission and engine load with various volume ratio of biodiesel in the fuel blend

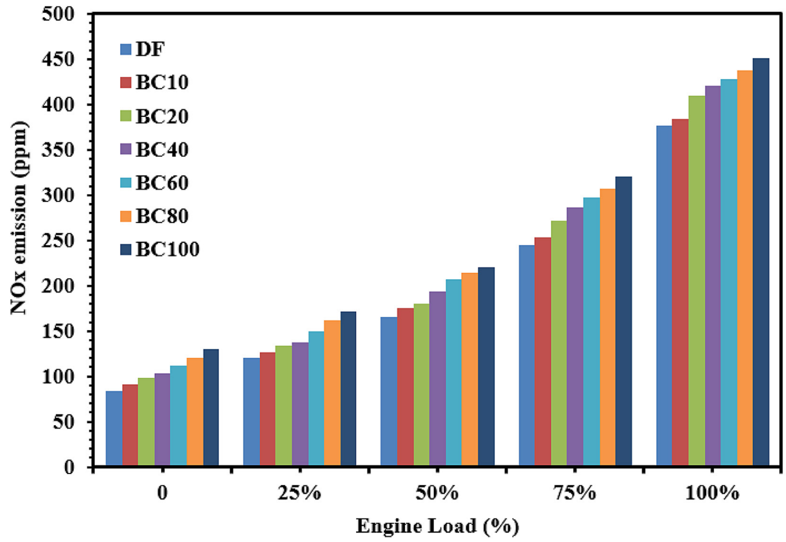


Figure 13. The relation between NO_X emissions and engine load with different concentration of biodiesel in the blend of fuel

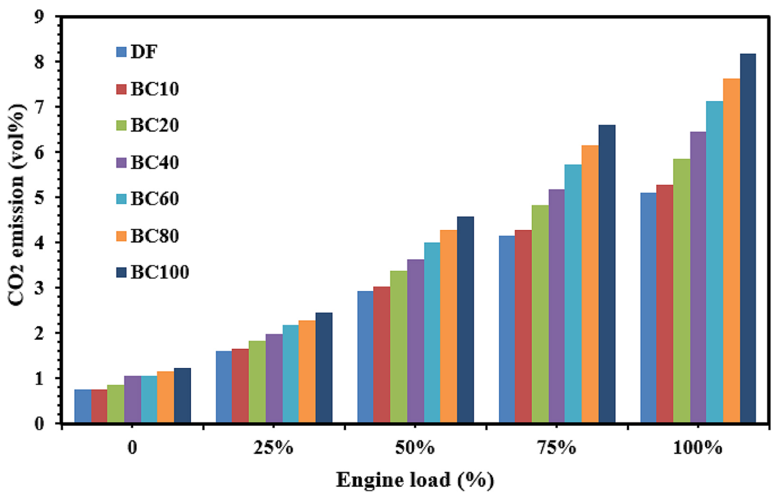


Figure 14. CO_2 emissions and engine load with varying biodiesel

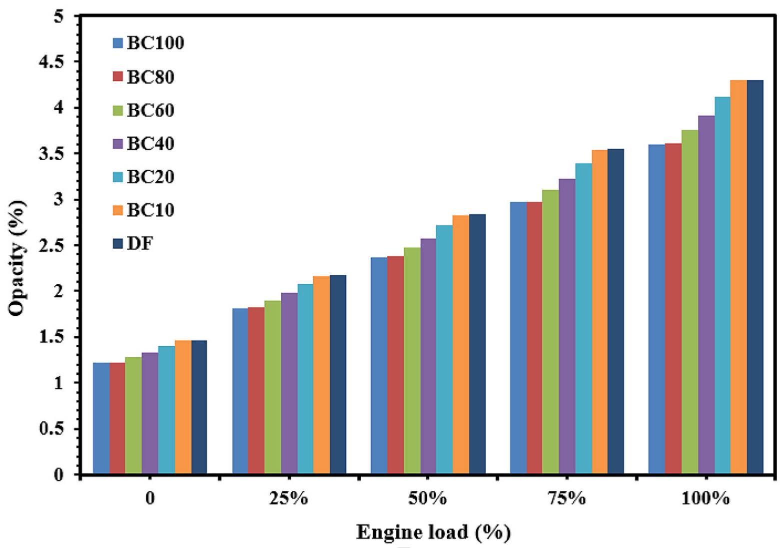


Figure 15. Soot emissions and engine load with varying biodiesel percentages

percentage of biodiesel in the fuel blend, as revealed in Figure 15. The soot emissions decreased for the fuel blend of BC10, BC20, BC40, BC60, BC80 and BC100, and amounted to 0.31%, 4.49%, 8.84%, 14.57%, 19.34% and 19.60%, respectively at a full engine load. The soot emissions were reduced using biodiesel fuel due to oxygen in bio-fuel chemical composition, which plays an essential role in fuel oxidation [48, 49].

CONCLUSIONS

The current research aimed to evaluate several aspects of Cresson oil biodiesel and DF mixed fuels, including biodiesel preparation, features of the biodiesel, combustion parameters, engine emission and performance characteristics. The following inferences may be made from experimental findings. The BTHE of the engine using biodiesel and its various mixes exhibited a lower value than that of DF. Compared to other blends, the B20 blend exhibited a slightly lower level of thermal efficiency but still fell within the permissible range when compared to DF. The BSFC and EGT of the engine exhibit an upward trend while using neat biodiesel or its blends. The biodiesel mixed fuels demonstrate a lower maximum ICP and HR rate than DF. The emissions of CO, soot and UHC from the engine powered by biodiesel and its mixes were reduced compared to those from DF. The use of fuel blends and biodiesel resulted in a rise in the emissions of NO_X and CO_2. Incorporating biodiesel blends in fuel production yields fuels with elevated oxygen content, contributing considerably to improved combustion and their renewable nature.

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