INVESTIGATION ON ENGINE PERFORMANCE AND EXHAUST EMISSIONS OF TEA OIL BIODIESEL, EURO DIESEL AND BIOETHANOL BLENDS UNDER DIFFERENT FUEL PRESSURES

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This research delves into a comprehensive exploration of the effects of tea oil biodiesel, Eurodiesel, and bioethanol blends on the motor performance and exhaust emissions of a diesel engine. The study specifically focuses on the dynamic interplay between different fuel compositions, examining the combinations of tea oil biodiesel with Euro diesel and bioethanol, while varying injector pressures in a diesel engine. The primary objective is to elucidate the multifaceted influence of these fuel mixtures on engine performance and emission characteristics. Through an extensive series of experiments and detailed analyses, this research unveils critical insights into the complex relationships between fuel types, injector pressures, and motor performance. The investigation not only aims to discern the immediate effects on combustion processes but also seeks to contribute to the broader discourse on sustainable and environmentally conscious energy solutions for diesel engines. The findings of this study hold significance for both academia and industry, offering a nuanced understanding of alternative fuel utilization and its implications on engine dynamics. Ultimately, the research aims to pave the way for advancements in cleaner and more efficient energy sources, fostering a greener and more sustainable future for diesel engine technology.

Keywords. Engine performance, Exhaust emissions, Fuel Pressures, Tea Oil Biodiesel, Transesterification.

1. Introduction

The utilization of alternative fuels in internal combustion engines has gained significant attention due to the need for sustainable and environmentally friendly energy sources. One of the promising alternatives is the use of biodiesel and bioethanol blends in conventional diesel and gasoline engines. The investigation of engine performance and exhaust emissions of these blends under different fuel pressures is crucial for understanding their potential as viable alternatives to traditional fossil fuels. Biodiesel, a renewable and clean fuel, has gained attention as a potential alternative to petroleum-based diesel fuel due to its potential to reduce carbon monoxide, carbon dioxide, hydrocarbons, and particulate matter emissions compared with conventional diesel fuel [1]. The use of biodiesel as a blended fuel, mixed with petroleum-based diesel fuel at various concentrations, is a common practice in many countries [2]. The addition of alcohols such as methanol and ethanol is also practiced in biodiesel–diesel blends, due to their miscibility with pure biodiesel [3]. Biodiesel can be widely used in diesel engines with little or no alteration, and it has been demonstrated that B_{20} biodiesel can be used in diesel engines without modifying their specifications [4-5]. The physicochemical properties of biodiesel, such as cetane number, calorific value, viscosity, cloud and pour points, as well as oxygen content, vary with respect to conventional diesel fuel, leading to variations in engine performance when biodiesel is used [6]. The high viscosity of biodiesel leads to poor fuel atomization and evaporation characteristics, and its low volatility results in inferior cold flow properties [7]. Moreover, the properties of biodiesel change during storage, with the viscosity and acid value increasing over time [8]. In terms of performance and emissions, biodiesel has been evaluated in diesel engines, with studies reporting on its impact on engine performance, emissions of NOx, hydrocarbons, and CO, as well as combustion characteristics [9-12]. In conclusion, biodiesel offers a promising alternative to conventional diesel fuel, with potential environmental and performance benefits. However, challenges related to its physicochemical properties, stability during storage, and low-temperature tolerance need to be addressed to further enhance its viability as a sustainable fuel source. Bioethanol, a renewable and sustainable energy source, has gained significant attention due to its potential to reduce greenhouse gas emissions and dependence on fossil fuels. The production of bioethanol involves various feedstocks and processes, each with its own set of challenges and advantages. Research has been conducted to explore different feedstocks such as algae, duckweed, agricultural residues, and waste materials for bioethanol production [13-14].

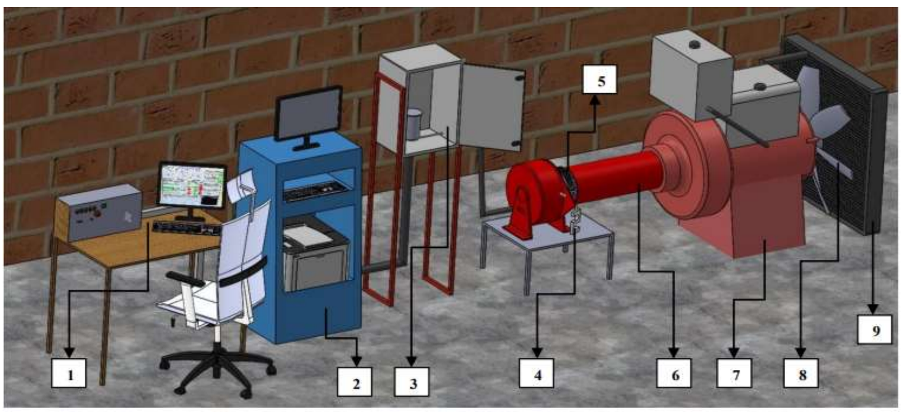
This article aims to provide an academic overview of the research conducted on the topic, drawing from reputable sources to establish the context and significance of the study. Yelbey & Ciniviz (2020) [15], investigated the effects of bioethanol as an additive in biodiesel-diesel blends on engine performance, emissions, and combustion characteristics, highlighting the relevance of examining the impact of bioethanol on fuel properties. Örs et al. (2021) [16], conducted an experimental investigation of diesel fuel-biofuel blends at different injection pressures in a direct injection diesel engine, emphasizing the need to assess the combustion parameters, engine performance, and exhaust emissions of these blends compared to conventional diesel fuel. Paluri & Patel (2022) [17], explored the combustion and performance characteristics of bioethanol blended fuels in spark ignition engines, shedding light on the influence of different blends and engine speeds on combustion behavior. Yasar (2023) [18], utilized advanced methodologies to evaluate the engine performance and exhaust emission outputs of biodiesel blends in a turbocharged direct injection diesel engine, emphasizing the significance of accurate assessment techniques in understanding the impact of alternative fuels on engine performance. Temizer & Arı (2022) [19], focused on the long-term endurance analysis of the effects of biofuel on ring wear and lubricating oil in a direct injection diesel engine, highlighting the importance of durability and lubrication considerations when using biofuels. Kanokkhanarat et al. (2022) [20], investigated the impact of bioethanol blends on combustion characteristics, engine performance, and emissions of diesel engines, emphasizing the environmental and health implications of diesel engine emissions.

The references selected provide a comprehensive overview of the academic research conducted on the topic, highlighting the significance of investigating the engine performance and exhaust emissions of biodiesel and bioethanol blends under different fuel pressures. The synthesis of these references establishes the context for the academic investigation and underscores the importance of understanding the potential of alternative fuels in internal combustion engines. The originality of this study is that there is no study in the literature on the engine performance and exhaust emission of tea oil biodiesel, euro diesel and bioethanol mixture on diesel engines for different fuel injection pressures. This study will add innovation to the literature.

2. Materials and method

The tea seed used in the study was sourced from Rize /Turkey. The oil extraction process from tea seeds was conducted through hot pressing by Esen Oil Company in Konya/Turkey. Biodiesel production from this tea seed oil was carried out within Necmettin Erbakan University. Euro diesel fuel was purchased from Opet. A single-cylinder, water-cooled Super Star diesel engine with a power rating of 15 HP (11.029 kW) was employed in the study. Figure 1 illustrates the engine and dynamometer setup. The recommended OPET 20W-50 diesel engine oil by the engine manufacturer was used as the lubricating oil in the experimental engine. Prior to commencing the experiments, routine maintenance of the engine and calibration of the experimental apparatus in the test facility were conducted.

In our study, tea seeds obtained from the Black Sea region were initially processed to extract tea oil and subsequently converted into biodiesel. The resulting biodiesel was blended with diesel fuel and bioethanol, and the exhaust emissions and performance values were determined on the engine at various fuel injection pressures.



(**1:**Dynamometer control unit, **2:**Exhaust emission measuring device, **3:**Fuel consumption measuring, **4:**S type load-cell, **5:**Magnetic pick-up, **6:**Hydraulic dynamometer, **7:**Test engine, **8:**Propeller, **9:**Radiator)

Figure 1. Test set-up

The experimental fuels were prepared by volumetrically blending biodiesel derived from tea seed oil through transesterification with diesel, along with the addition of ethanol at 10% and 20% concentrations. This resulted in the formulation of test fuels in two configurations: a blend consisting of 70% euro diesel, 20% tea oil biodiesel, and 10% bioethanol, and another blend comprising 70% euro diesel, 10% tea oil biodiesel, and 20% bioethanol. The names and mixing ratios of the fuel mixtures created are given in Table 1.

Table1. Names and mixing ratios of fuel mixtures

Fuels	Volumetric Mixing Ratio
D_{100}	100% euro diesel
$D_{70}B_{20}E_{10}$	70% euro diesel + 20% biodiesel + 10% bioethanol
$D_{70}B_{10}E_{20}$	70% euro diesel + 10% biodiesel + 20% bioethanol
B_{100}	100% biodiesel

The fuel properties of the experimental fuels were assessed in comparison to the TSEN590 standards for diesel fuel and TSEN14214 standards for biodiesel. Engine tests were conducted following the EN 1231 standards. The characteristics of the fuels employed in the experiments are detailed in Table 2 [21].

Table 2. Analysis Results of Test Fuels

Characteristic Property	Unit	Camellia Sinensis Oil	B_{100}	D_{100}	Bio ethanol	$D_{70}B_{20}E_{10}$	$D_{70}B_{10}E_{20}$	Limiting Values	
								Diesel	Biodiesel
Density (15 ºC)	g/cm³	0.914	0.895	0.825	0.791	0.829	0.821	0.82 - 0.84	0.86 - 0.90
Kinematic Viscosity	mm²/s	36.71	8.814	2.918	1.26	3.009	2.584	2 – 4.5	3.5 - 5
Cetane Number	---	64	67.5	53.1	14	52.9	51.8	51	---
pH	---	7.28	6.95	5.35	5.11	5.51	5.32	---	---
Cloud Point	ºC	-10.9	-2,5	-4,5	<-25	-7.9	-7.2	---	---
Pour Point	ºC	-17.5	-4.7	-16	<-25	-18	-17	---	---
Freezing point	ºC	-22.2	-12.8	-22	<-25	<-25	<-25	---	---
Calorific Value	Cal/gr	---------	9596	10415	7068	10231	9930	---	---
Color	ASTM	0.9	0.8	0.7	<0.5	0.9	0.8	---	---
Flash Point	ºC	186	125	62	-------	-------	-------	55	120
CFPP	ºC	---------	-3.9	-13	<-50	-26	-24	-20	-15

2.1 Error and uncertainty analysis

Uncertainty analysis is essential for verifying random errors or the accuracy of tests. Kanoğlu [22] and Aydin and Şahin [23] provide a comprehensive example of such analysis. Considering the result $F, (x_1 \ldots . x_n)$ as a function of the nth measured variable:

$$F = f.(x_1, x_2, x_3, \ldots \ldots \ldots . x_n) \quad (1)$$

In the estimation of maximum uncertainty, as proposed by Wheeler and R Ganji [24], it can be expressed as follows:

$$W_{F_{max}} = \left[\sum_{i=1}^{n}\left(W_{xi}\frac{\partial R}{\partial x_i}\right)^2\right]^{1/2} \quad (2)$$

All terms are assumed to be positive W_{xi} represents the accuracy or error of the measured parameter. Equivalent to equation (2), uncertainty is estimated in calculated values such as brake power and brake-specific fuel consumption [25-26]. Power can be formulated as follows:

$$P = \frac{F.L.n}{9549(kW)} \quad (3)$$

An example of the uncertainty analysis for engine power measurement is presented for an operating condition where the engine runs at 1900 rpm, which corresponds to the maximum power output using D_{100} fuel at a fuel injection pressure of 200 kg/cm². Under these conditions, the measured engine power is $9.1715\ kW$. The associated mechanical parameters include a force of $131.697\ N$ and a lever arm length of $0.35\ m$. These values serve as the basis for calculating the uncertainty in engine power using the partial derivative method, taking into account the influence of each parameter on the overall measurement accuracy.

$$\frac{\partial P}{\partial F} = \frac{L*n}{9549} = \frac{0.35*1900}{9549} = 0.069 \quad (4)$$

$$\frac{\partial P}{\partial L} = \frac{F*n}{9549} = \frac{131.697*1900}{9549} = 26.204 \quad (5)$$

$$\frac{\partial P}{\partial n} = \frac{F*L}{9549} = \frac{131.697*0.35}{9549} = 0.004 \quad (6)$$

$$W_p = [(0.069)^2 * (0.077)^2 + (26.204)^2 * (0.001)^2 + (0.004)^2 * (50)^2]^{1/2} \quad (7)$$

$$W_p = 0.201\% \quad (8)$$

3. Discussion and Conclusions

3.1 Torque (Engine)

The variations in torque values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 2.

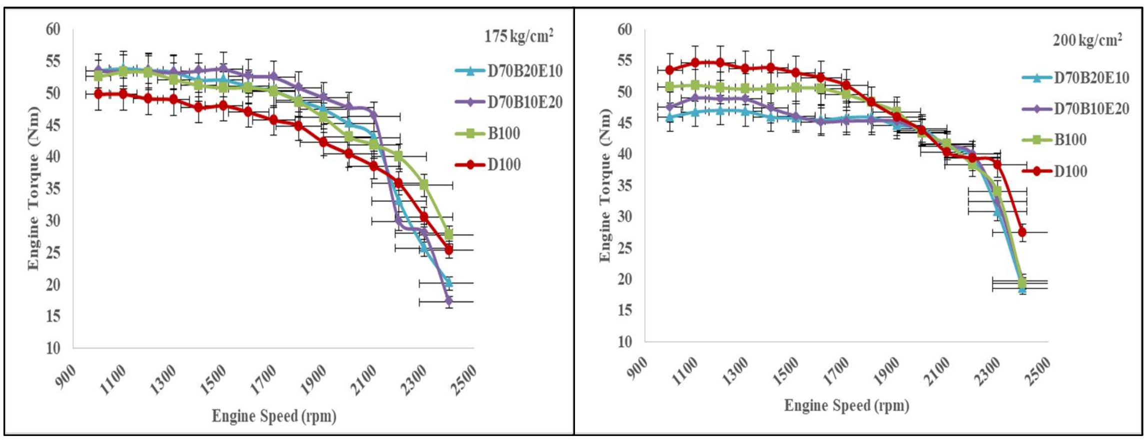


Figure 2. Moment changes of test fuels at different fuel pressures

At the operating condition of 175 kg/cm^2 motor injection pressure, the maximum engine torque was measured at 53.809 Nm for the $D_{70}B_{20}E_{10}$ fuel at 1100 rpm. When compared with the D_{100} fuel, the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100} exhibited 8.02%, 7.04%, and 6.94% higher torque output, respectively. Under the operating condition of 200 kg/cm^2 motor injection pressure, the maximum engine torque was measured at 54.570 Nm for the D_{100} fuel at 1100 rpm. In comparison with the D_{100} fuel, the fuels B_{100}, $D_{70}B_{10}E_{20}$, and $D_{70}B_{20}E_{10}$ showed 6.49%, 10.28%, and 14.30% lower torque output, respectively.

3.2 Power (Engine)

The variations in power values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 3.

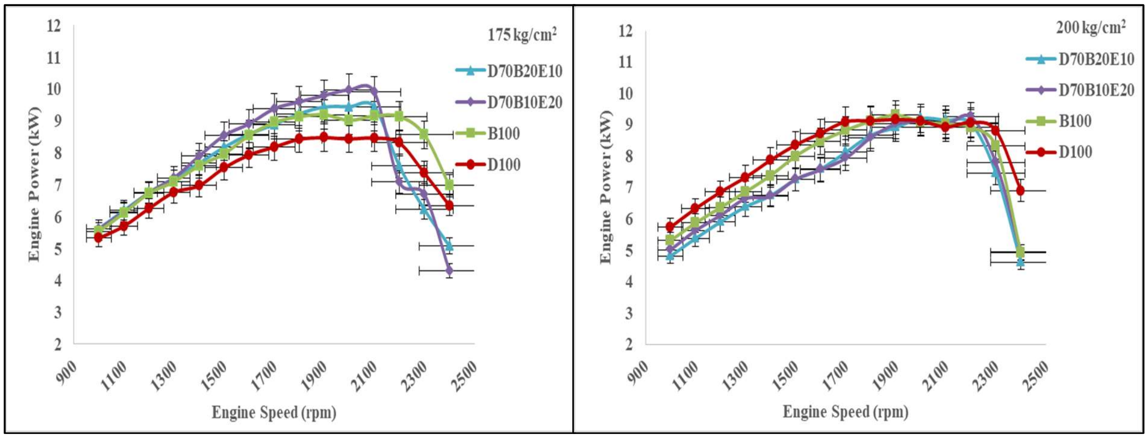


Figure 3. **Power changes of test fuels at different fuel pressures**

At the operating condition of 175 kg/cm^2 motor injection pressure, the maximum engine power was measured at 9.795 kW for the $D_{70}B_{10}E_{20}$ fuel at 1900 rpm. In comparison with the D_{100} fuel, the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100} exhibited 15.62%, 11.34%, and 8.48% higher power output, respectively. Under the operating condition of 200 kg/cm^2 motor injection pressure, the maximum engine power was measured at 9.311 kW for the B_{100} fuel at 1900 rpm. While there was a 1.52% increase in power output for B_{100} compared to D_{100}, fuels $D_{70}B_{10}E_{20}$ and $D_{70}B_{20}E_{10}$ showed 1.59% and 2.73% lower power output, respectively.

3.3 Fuel Consumption (Specific)

The variations in specific fuel consumption values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 4.

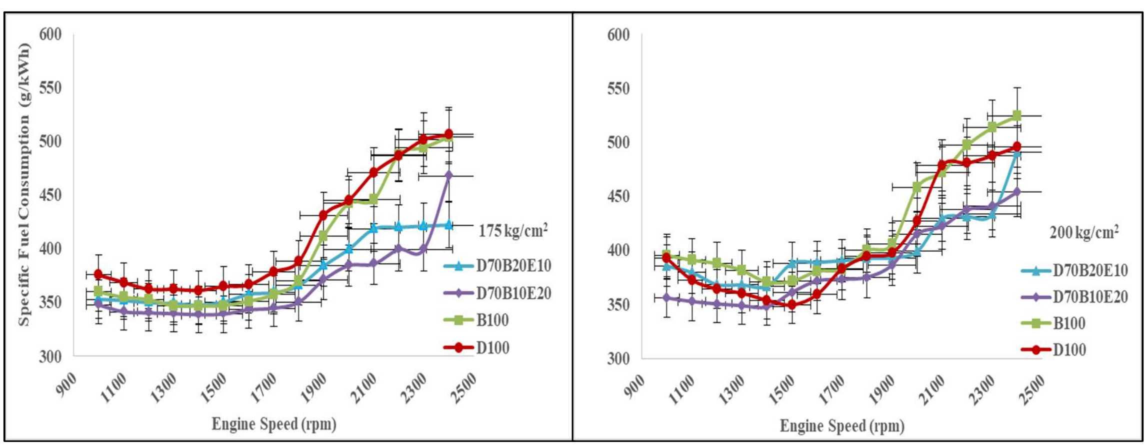


Figure 4. Specific fuel consumption changes of test fuels at different fuel pressures

At the operating condition of 175 kg/cm^2 motor injection pressure, the minimum specific fuel consumption was measured at 338.729 g/kWh for the $D_{70}B_{10}E_{20}$ fuel at 1400 rpm. In comparison with the D_{100} fuel, the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100} exhibited 6.27%, 3.80%, and 3.98% lower fuel consumption, respectively. Under the operating condition of 200 kg/cm^2 motor injection pressure, the minimum specific fuel consumption was measured at 347.887 g/kWh for the $D_{70}B_{10}E_{20}$ fuel at 1400 rpm. In comparison with the D_{100} fuel, the $D_{70}B_{10}E_{20}$ fuel showed 1.71% lower fuel consumption, while the fuels $D_{70}B_{20}E_{10}$ and B_{100} exhibited 3.61% and 4.72% higher fuel consumption, respectively.

3.4 Exhaust Emissions

The variations in CO values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 5.

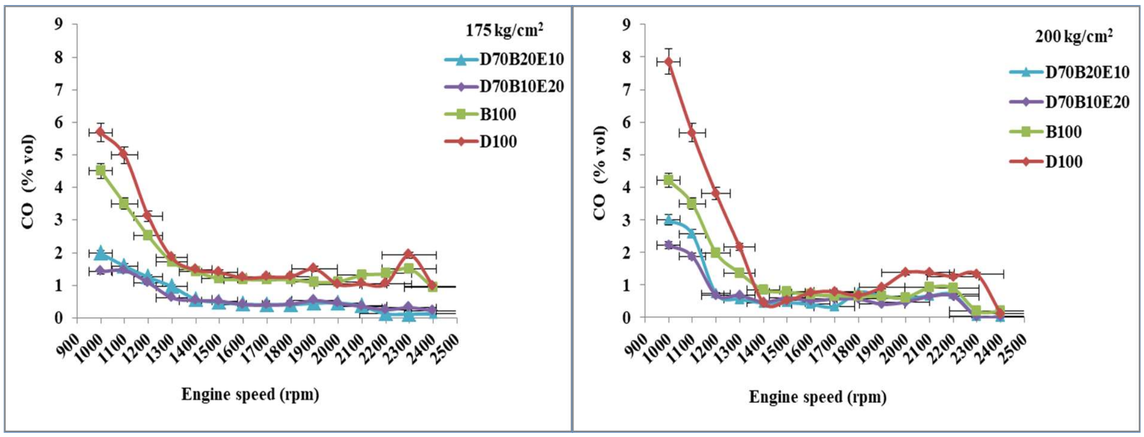


Figure 5. Carbon monoxide emission changes of test fuels at different fuel pressures

The carbon monoxide emission for the working condition with an injection pressure of 175 kg/cm^2 was measured at 0.454% in the $D_{70}B_{20}E_{10}$ fuel, with the maximum engine power observed at 1900 rpm. When compared to the D_{100} fuel, reductions of 69.81%, 64.49%, and 27.32% were identified for the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 1.454% was recorded for the $D_{70}B_{10}E_{20}$ fuel. In comparison to the D_{100} fuel, reductions of 70.86%, 68.14%, and 29.69% were determined for the $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100} fuels, respectively.

For the operating condition with a motor injection pressure of 200 kg/cm^2, the carbon monoxide emission was measured at a minimum of 0.401% in the $D_{70}B_{10}E_{20}$ fuel, with the maximum engine power observed at 1900 rpm. When compared to the D_{100} fuel, reductions of 56.17%, 28.52%, and 30.38% were identified for the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100}, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 1.875% was recorded for the $D_{70}B_{10}E_{20}$ fuel. In comparison to the D_{100} fuel, reductions of 66.91%, 54.86%, and 38.43% were determined for the $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100} fuels, respectively.

The variations in HC values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 6.

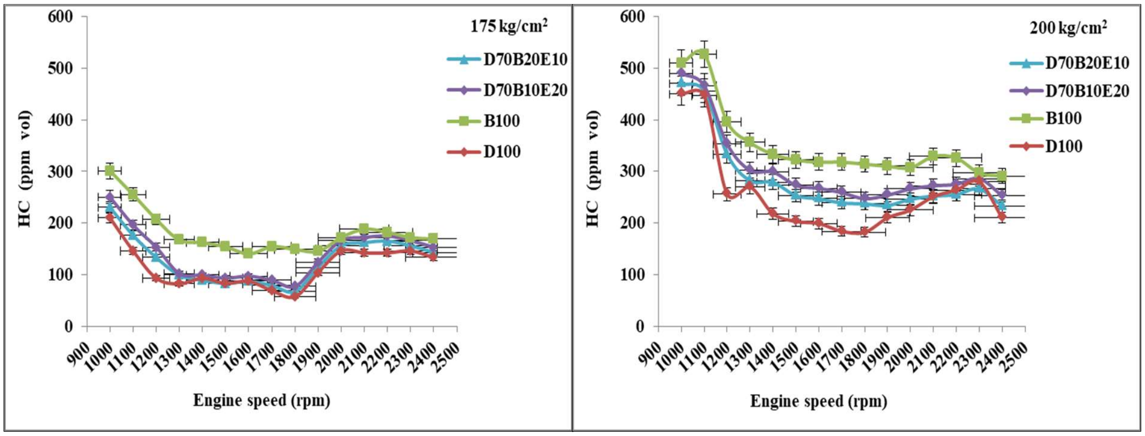


Figure 6. Hydrocarbon emission changes of test fuels at different fuel pressures

For the operating condition with a motor injection pressure of 175 kg/cm^2, the hydrocarbon emission was measured at a minimum of 104 ppm in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 9.61%, 19.23%, and 39.42% were identified, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 146 ppm was recorded for the D_{100} fuel. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 52.54%, 34.24%, and 74.65% were determined, respectively.

For the operating condition with a motor injection pressure of 200 kg/cm^2, the hydrocarbon emission was measured at a minimum of 210 ppm in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 11.42%, 20.95%, and 47.61% were identified, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 447 ppm was recorded for the D_{100} fuel. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 2.01%, 4.25%, and 17.89% were determined, respectively.

The variations in CO_2 values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 7.

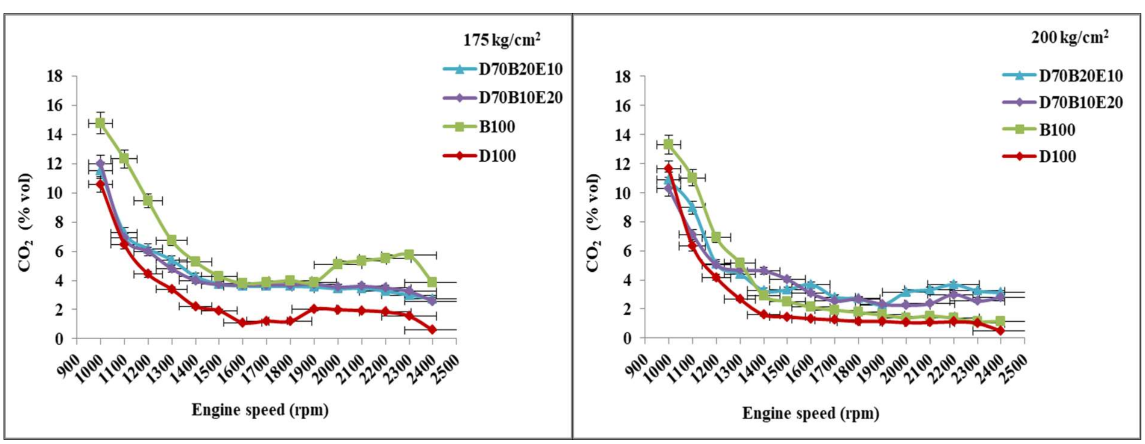


Figure 7. Changes in carbon dioxide emissions of test fuels at different fuel pressures

For the operating condition with a motor injection pressure of 175 kg/cm^2, the carbon dioxide emission was measured at a minimum of 3.756% in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 75.14%, 85.20%, and 90.53% were identified, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 6.468% was recorded for the D_{100} fuel. When compared to the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100}, increases of 6.67%, 12.24%, and 90.72% were determined, respectively.

For the operating condition with a motor injection pressure of 200 kg/cm^2, the carbon dioxide emission was measured at a minimum of 1.148% in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels B_{100}, $D_{70}B_{20}E_{10}$, and $D_{70}B_{10}E_{20}$, increases of 37.97%, 98.95%, and 99.39% were identified, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 6.322% was recorded for the D_{100} fuel. When compared to the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100}, increases of 12.68%, 42.04%, and 74.24% were determined, respectively.

The variations in O_2 values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 8.

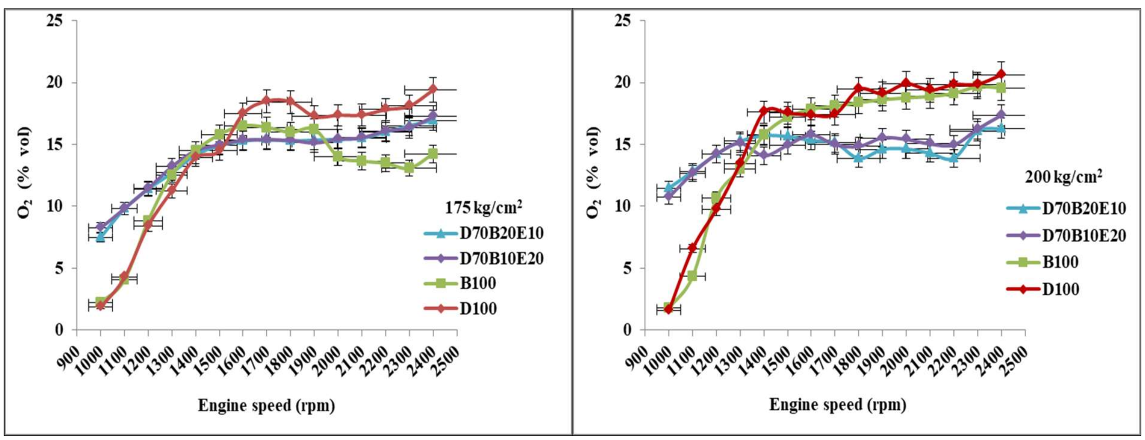


Figure 8. Oxygen changes of test fuels at different fuel pressures

For the operating condition with a motor injection pressure of 175 kg/cm^2, the oxygen values were measured at a maximum of 17.26% in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100}, decreases of 12.39%, 11.06%, and 5.90% were identified, respectively. At the maximum engine torque at 1100 rpm, the measurement for the D_{100} fuel was 4.25%, with a decrease of 4.70% in B_{100} and increases of 130.82% and 131.05% in $D_{70}B_{20}E_{10}$ and $D_{70}B_{10}E_{20}$ fuels, respectively.

For the operating condition with a motor injection pressure of 200 kg/cm^2, the oxygen values were measured at a maximum of 19.11% in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, decreases of 23.60%, 18.73%, and 2.56% were identified, respectively. At the maximum engine torque at 1100 rpm, the measurement for the D_{100} fuel was 6.58%, with a decrease of 34.04% in B_{100} and increases of 92.55% and 94.83% in $D_{70}B_{10}E_{20}$ and $D_{70}B_{20}E_{10}$ fuels, respectively.

The variations in NO_x values for the fuel mixtures comprising tea oil biodiesel, euro diesel, and bioethanol in the experiments conducted at 175 and 200 kg/cm^2 fuel pressures under full load conditions, within the engine speed ranges of 1000 and 2400 rpm, are depicted in Figure 9.

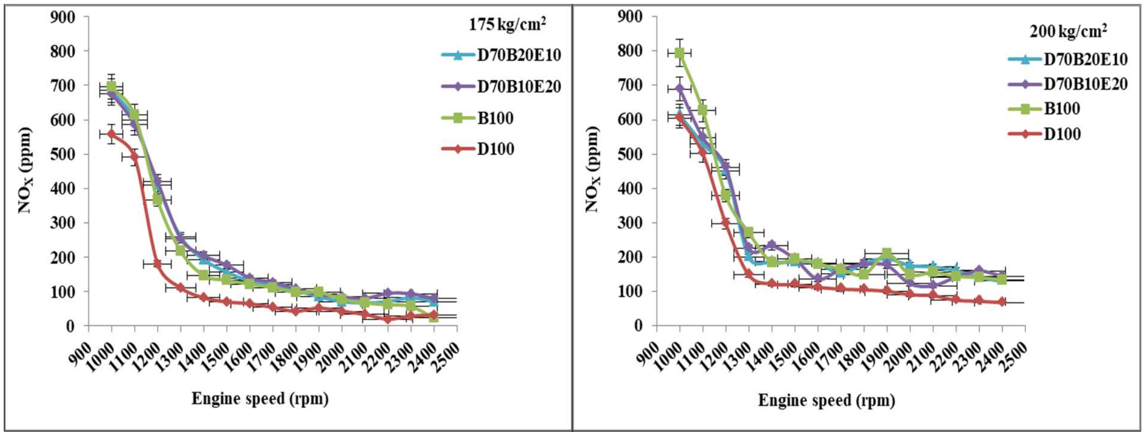


Figure 9. Nitrogen oxide emission changes of test fuels at different fuel pressures

For the operating condition with a motor injection pressure of 175 kg/cm^2, the nitrogen oxide emission was measured at a minimum of 52 ppm in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 63.46%, 76.92%, and 90.38% were identified, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 491 ppm was recorded for the D_{100} fuel. When compared to the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100}, increases of 19.14%, 21.99%, and 25.05% were determined, respectively.

For the operating condition with a motor injection pressure of 200 kg/cm^2, the nitrogen oxide emission was measured at a minimum of 101 ppm in the D_{100} fuel, with the maximum engine power observed at 1900 rpm. When compared to the fuels $D_{70}B_{10}E_{20}$, $D_{70}B_{20}E_{10}$, and B_{100}, increases of 74.25%, 94.05%, and 107.92% were identified, respectively. At the maximum engine torque at 1100 rpm, the minimum measurement of 501 ppm was recorded for the D_{100} fuel. When compared to the fuels $D_{70}B_{20}E_{10}$, $D_{70}B_{10}E_{20}$, and B_{100}, increases of 5.78%, 7.98%, and 24.95% were determined, respectively.

4. Conclusions

This study presents a comprehensive academic investigation into the engine performance and exhaust emissions of tea oil biodiesel, Euro diesel, and bioethanol blends under different fuel pressures. The investigation involves varying injector pressures in a diesel engine and analyzing the interactions between different fuel compositions, specifically blends of tea oil biodiesel with Euro diesel and bioethanol. The research not only aims to discern the immediate effects on combustion processes but also seeks to contribute to the broader discourse on sustainable and environmentally conscious energy solutions for diesel engines. The findings of this study have significant implications for both academia and industry. The nuanced understanding of alternative fuel utilization and its impact on engine dynamics can inform future developments in cleaner and more efficient energy sources. The study contributes to the ongoing efforts to pave the way for advancements in greener and more sustainable diesel engine technology. The materials and methods section outlines the sourcing and preparation of the experimental fuels, involving the extraction of tea oil from tea seeds and the subsequent production of biodiesel. The study utilizes a single-cylinder, water-cooled Super Star diesel engine with a power rating of 15 HP for experimentation. The analysis of the experimental fuels based on TSEN590 standards for diesel fuel and TSEN14214 standards for biodiesel provides crucial insights into the physicochemical properties of the fuels. This includes density, kinematic viscosity, cetane number, pH, cloud point, pour point, freezing point, calorific value, color, flash point, and cold filter plugging point. The error and uncertainty analysis ensures the reliability of the experimental results, considering factors such as engine speed, power, length, force, and their respective uncertainties. The torque and power variations are presented for different fuel mixtures under various fuel pressures and engine speeds, providing a comprehensive overview of their performance characteristics. The specific fuel consumption analysis reveals variations in fuel efficiency for different fuel mixtures, emphasizing the importance of considering specific fuel consumption as a metric for evaluating fuel performance. Exhaust emissions are thoroughly examined, focusing on carbon monoxide, hydrocarbon, carbon dioxide, oxygen, and nitrogen oxides. The study quantifies the emissions at different operating conditions and injector pressures, offering valuable insights into the environmental impact of the fuel mixtures. In conclusion, this academic investigation contributes substantially to the existing body of knowledge on alternative fuels for diesel engines. The detailed analysis of tea oil biodiesel, Euro diesel, and bioethanol blends under different fuel pressures provides a comprehensive understanding of their effects on engine performance and emissions. The study's originality lies in its focus on tea oil biodiesel and its unique blend with Euro diesel and bioethanol, filling a gap in the literature. The results and insights presented in this research aim to guide future research endeavors and technological advancements towards more sustainable and environmentally conscious diesel engine solutions.

Acknowledgments

This study is prepared as a part of Betül Erçek Serin’s MS Thesis. (Advisor: Dr. Fatih AYDIN)

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Submitted: 22.03.2025.
Revised: 28.04.2025.
Accepted: 10.05.2025.