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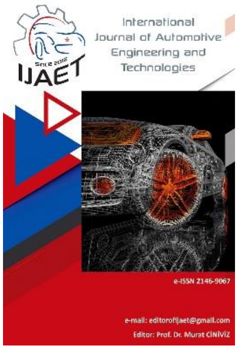

Original Research Article

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Experimental investigation of essential oils as fuel additives

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ABSTRACT

Essential oils were investigated as fuel additives in this research. Origanum Acutidens is used to make essential oil. In the oil recovery process, hydro distillation was used. With the transesterification reaction, the obtained oil was converted into biofuel. In a specific proportion, biofuel was combined with reference diesel fuel. Critical oils were studied for their effect on engine efficiency and combustion parameters. A Kirlaskor four-stroke diesel engine was used to test the mixed fuel and comparison diesel fuel. Engine tests were carried out at various loads and at a steady engine rpm. As compared to diesel fuel, the mixture fuel provided 1.63 percent more effective engine power and 1.31 Nm more engine torque. The maximum gas pressure, maximum cumulative heat dissipation, maximum average gas temperature, and maximum net heat emission rates all increased dramatically when the combustion data was analyzed. The findings revealed that the critical oil-based blended fuel enhanced the combustion event in diesel engines.

Keywords: Essential Oils, Internal combustion engines, Biodiesel, Combustion

1. Introduction

In the 18th century, England saw the start of the industrial revolution, which is known as the beginning of mechanization. The weaving, iron-steel, and railway industries have all been impacted by this drastic shift in production technology. In a short period of time, the industrial revolution, which is an expression of change and transformation, spread from England to Europe and then to the rest of the world [1,2].The invention and use of steam engines are not sufficient to define the industrial revolution. Such a significant change has numerous social, political, economic, and environmental implications. As the industrial revolution is discussed from an ecological perspective, which considers how living beings interact with one another and with their surroundings. Since the industrial revolution, it is clear that nature was destroyed carelessly in order to satisfy the demand for raw materials. Since human consciousness at the time was incapable of correctly perceiving resource use, ecological climate, and living life relations. He was also unaware that these natural resources, which were seen as raw materials, would eventually run out. The ideas of sustainable growth, ecology, and biodiversity came to the fore as the natural balance began to deteriorate and make itself felt by the ruined nature over time [3]. Biodiversity refers to the diversity of ecosystems, plants, and genes around the globe or within a specific habitat. Biodiversity offers the resources needed for the economic and social well-being of humans. Ecosystem services, such as pollination, climate control, flood protection, soil fertility, and the production of food, fuel, fiber, and pharmaceuticals, are all dependent on biodiversity. Therefore, biological diversity is extremely valuable for its existence and survival. Hence the biodiversity is of great importance in each country such as Turkey. Turkey is rich enough to be compared with the European continent in terms of plant biodiversity, this richness of protecting and building the infrastructure until today from the past for the sustainable use / development, research, relevant legislation, personnel and budget allocation is a leader in the region on issues such as. In addition, Turkey Euro-Siberian, Mediterranean and is the intersection of three different plant geography, including the Iran-Turan. Turkey, two from the Earth's center of 8 genes (Mediterranean and Near East) is located at the intersection of. Due to its geographical location and climatic conditions which Turkey has found a wide variety of plant species. Day et al. [4] The "First National Flora Our List" as they evaluate Turkey "Plant List" is working in total species and taxa number in Turkey, foreigners, including origin and crops 11 707 endemic taxa Number 3 649 and found the rate of endemism as 31.82%. Medical and Aromatic plants constitute approximately one third of this wealth [5,6]. These plants are members of the Lamiaceae family. Flora of Turkey Lamiaceae family 45 genera, species, and represented by 565 to 735 taxa [7]. Members of this family are the largest species in Turkey is Origanum genus. Plants of the Origanum genus are among the wild-collected herbs that are widely used as spices. Origanum genus consists of many species and subspecies with a great variation between and within the species [8]. The fuel capacity of essential oils, which make up the majority of our country's biological resources, was investigated in this report. A research on essential oils was conducted for this reason, and the oil productivity of 20 plants was examined. The highest oil yield was discovered to be Origanum accutidens at the end of the investigation. Hydrodestilation was used to extract oil from this plant, which had a large amount of oil. Biofuel is made from the oil obtained via the transesterification reaction. In an internal combustion diesel engine, biofuel was combined with 10% diesel fuel (EB-10) and tested.

2. Materyal and Metod

2.1. Essential oil plants

Essential essential oil is a mixture of substances produced by living things such as plants, animals and microorganisms. These substances, which are generally fragrant, are called "essential oil" or "essential oil" because they look like oil. It is possible to obtain essential oils from the material they are in by boiling with water or by passing water vapor through the material by distillation, cold squeezing and consumption with organic solvents or liquefied gas. Essential oils, with the exception of a few, such as clove oil, float on water as they are lighter than water and are obtained by being easily separated from water after distillation. Since essential oils are adversely affected by air, light and heat and lose their properties, they should be stored in a cool place, in colored glass or aluminum containers, full and tightly closed. The most important difference of essential oils from fixed oils is that when they are dropped on an absorbent paper and exposed, they fly without leaving any traces. The quality of the essential oil is determined by the volatile compounds it contains. Sometimes, hundreds of compounds, large and small, can be found in the composition of an essential oil. These compounds can be identified by separation using an advanced technique called Gas Chromatography / Mass Spectrometry (GC / MS). The main factors affecting the quality of essential oil are fragrance and chemical composition. For this reason, it is desirable that the natural chemicals that give each essential oil its characteristic feature are present in certain proportions and the unwanted chemicals are not present or in very small amounts.

2.2. Origanum acutidens

Origanum, a genus of the Lamiaceae family, was first described by Linnaeus in the 5th edition of Genera Plantarum, with reference to Tournefort [10]. In the following processes, many studies have been done on this breed. The genus Origanum has 43 species and 18 hybrids in the world [11; 12]. Flora of Turkey was detected in a total of 30 taxa [4]. Approximately 75% of the species belonging to the genus show distribution in the Eastern Mediterranean sub-region [14-15]. Most of the taxa belonging to the genus Orignaum, also known as thyme, are widely used in folk medicine in the treatment of diseases such as headache, dizziness, cough, flu, gastrointestinal disease, bronchitis, high cholesterol, diabetes, abdominal pain, hypertension, and toothache [16].

Figure.1 Origanum Acutidens

2.3. Water distillation (Hydrodistillation-HD)

Water distillation is the most common process for obtaining volatile compounds.(Figure.2) Though large distillation boilers are used in industrial applications, Clevenger style apparatus are used in small scale production. A glass bubble is connected to the cooler in the Water Distillation process. Water and plant material are boiled for 2-8 hours in this glass flask. The oil molecules travel with the water vapor and are condensed and isolated from the water in the cooler. Essential oil components are given in Figure 3.

Figure 2. Hydrodestilation and essential oil visual

2.5 Transesterification

Transesterification is the most favored main step method among the chemical modifications needed to use triacylglycerols instead of diesel fuels. Glycerides in lipids react with an alcohol in the presence of a catalyst to form ester and glycerol, according to another concept. The catalyst used in the reaction boosts the reaction's speed and performance. Since the transesterification reaction is reversible, excess alcohol in the atmosphere can speed up the process. Primary and secondary monohydric aliphatic alcohols with 1 to 8 carbon atoms are commonly used for this reason. Alcohols such as methanol, ethanol, propanol, butanol, and amyl alcohol are used. Methyl alcohol and ethyl alcohol are the most widely used alcohols. Methyl alcohol is the most commonly used alcohol in commercial applications due to its low cost. The catalyst in this experiment was potassium hydroxide, and the alcohol was methanol. Figure 4 depicts the reaction scheme.

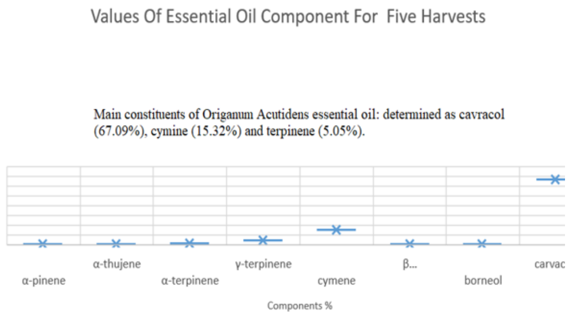

Figure 3. Essential oil components

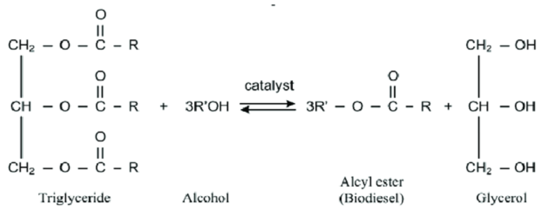

Figure 4. Chemistry of biodiesel production [16].

3.Experimental Setups

Experiments on engines were conducted in the Automotive Test Laboratories of Batman University. A Kirlaskor TV-1 internal combustion diesel engine was used in the research. Experiments were conducted at a fixed engine speed of 1550 rpm and with various engine loads. For each test fuel, data on effective engine capacity, torque, and combustion were collected. The maximum values of 10 cycles and the crank angles from which these values were taken were used as combustion data. Table 1 lists the technical characteristics of the test engine used in the report. Figure 5 shows the layout of the test setup.

Table 1. Technical specifications of the test engine

Specifications	Descriptions
Engine Model	Kirlaskor TV-1
Engine Power [Kw]	3.5
Engine Volume[cc]	661
Cylinder diameter[mm]	87
Stroke Length (mm)	110
Compression Rate	17/1
Spray Advance	Before TDC, between 0-25 degrees
Number of Srok	4
Number of Cylinders	1
Cooling Type	Water Cooled
Dynamometer Type	Eddy Current
Dynamometer Cooling type	Water
Load Indicator	Digital, 0-50 kg

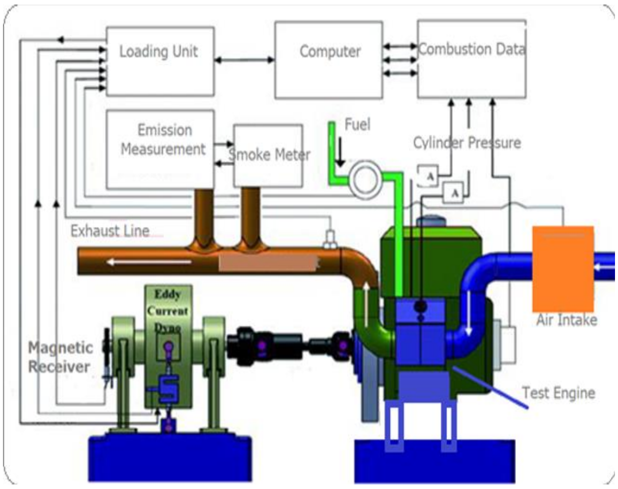

Figure 5. Schematic view of the experimental setup

4. Results and Discussion

4.1.Torque and power changes

Effective power is also called useful power, effective power or braking power. This power is the real power of the engine. From the indicated power obtained in the cylinders; It is the power measured from the flywheel or pulley of the engine after the forces required for the operation of the engine are removed. [18]. The changes of effective engine power and engine torque depending on engine load are given in Figure 6. When the engine torque curves were examined, it was seen that the engine torque values increased with the engine loading in both experimental fuels, while it was determined that the EB-10 fuel torque curves were larger than the DF torque curves. Again in the same graph, when the changes in engine effective power are examined, the engine load in both test fuels and the engine effective power values increasing with the engine speed are seen. Effective power values that increase with the increase in speed are due to the increase in the number of cycles occurring per unit time [19]. In the case of a 4kg load, EB-10 fuel is 0.36Nm more than DF fuel in torque values, and 1.87 HP more at effective engine power values. has been formed. In the case of 8kg load, the EB-10 fuel was produced 2.27Nm more in torque values and 1.40 HP more in effective engine power values than DF fuel. This increase in engine performance in favor of biofuels can be explained by high pressure curves [20]. The evaporation enthalpy of biodiesel fuels increases the amount of air taken into the cylinder, which increases the volumetric efficiency and pressure curves that increase the power and torque curves associated with it [21].

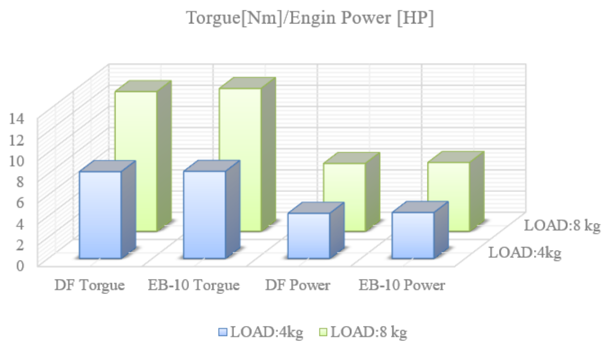

Figure 6. Torque and motor power changes under different load conditions

4.2. Combustion and combustion data

4.2.1. Combustion

In a diesel engine, the combustible mixture is obtained by spraying pressurized fuel into compressed air. The energy source for ignition is the compressed air in the combustion chamber that has reached high temperatures. In this case, the injected fuel starts to burn (self-ignites). In order for the air in the combustion chamber to ignite, it must reach high temperatures, ie be compressed. This is achieved with high compression ratios. In diesel engines, compression ratios are generally between 15 and 23. This means that the air is reduced to one 15-23 of its original volume. Combustion occurs in 3 phases in a diesel engine. These phases contain both physical and chemical parts. Increasing the temperature of the air by compressing it and obtaining the air-fuel mixture are physical, while the fuel starts to burn and energy is released are its chemical parts.

Phase 1: Start of Ignition

This phase begins with the spraying of the first fuel drops into the combustion chamber. The combustion chamber temperature is approximately 500 °C. This temperature is high enough for combustion, but it takes some time for combustion to start. This period is called the ignition start (ignition delay) phase. In this phase;

Sprayed fuel breaks up into very fine particles.

These particles evaporate and become flammable mixture by mixing with air.

In the air-fuel mixture, pre-combustion oxidation occurs.

Usually the ignition initiation phase ends in 0.001 seconds

Phase 2: Uncontrolled Combustion and Instant Pressure Rise (Flame Release Phase)

Combustion starts with the formation of ignition and spreads to the air-fuel mixture formed in the 1st phase. Combustion is uncontrollable, pressure and temperature suddenly increase. The rate and magnitude of pressure increase depends on the amount of fuel present in the combustion chamber. Therefore, the length of the ignition initiation phase and the injection time of the fuel affects this speed and size. After the ignition starts, the pressure increase and the rate at which the fuel droplets meet with oxygen control the combustion. This pressure increase and the rate of meeting with oxygen are mostly determined by the engine design.

Phase 3: Controlled Combustion

In this last phase, the pressure rises more slowly. Then it decreases gradually depending on the movement of the piston. Pressure and temperature are very high in the beginning. Therefore, the fuel starts to burn as soon as it enters the combustion chamber. Thus, combustion can be controlled by the injection flow rate of the fuel. When the fuel jet ends, combustion continues until all the fuel has been burned.

4.2.2. Combustion data

4.2.3. Maximum cylinder pressures [MCP]

The maximum cylinder pressure point is the highest point in the pressure diagram obtained with the help of a pressure sensor placed in the combustion chamber of the diesel test engine.(Figure.7) The maximum point position is the crank angle at which this value is obtained.

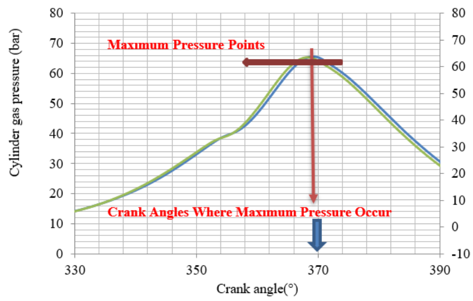

Figure 7. Maximum cylinder pressure points and crack angles where maximum cylinder pressure points ocur

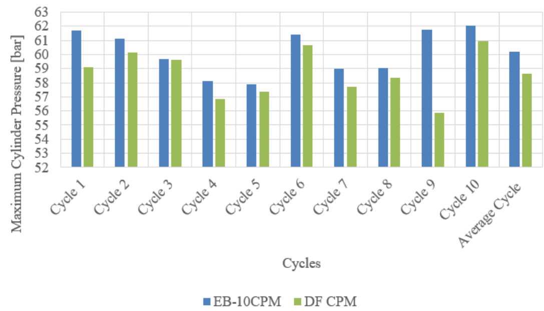

Figure 8.a. Maximum Pressure values of test fuels

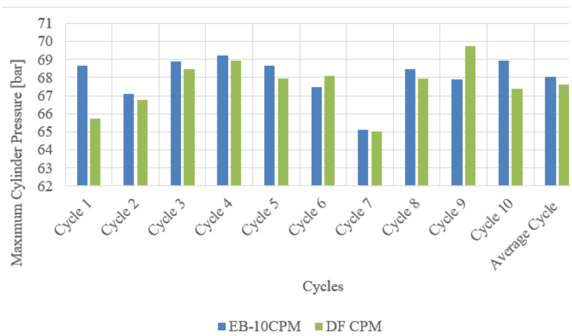

Figure 8.b. Maximum Pressure values of test fuels

Figure 8.a.b. Maximum cylinder pressure values are given at different loads. Here, it is seen that the maximum cylinder pressure increases parallel to the increase in the loading on the test engine. With the loading of the engine, the amount of fuel sent into the cylinder increases and the volumetric efficiency increases, the combustion efficiency increases and the maximum cylinder pressure increases. It was observed that the crank angles at which the [MCP] values of the experimental fuels were obtained were similar, occurring after the upper dead point. It was also determined that EB-10 fuel produced higher maximum cylinder pressure values than DF fuel. It is thought that the high latent heat of vaporization decreases the

combustion chamber temperature and increases the inlet charge density and related volumetric efficiency, resulting in an increase in cylinder pressure value in favor of biodiesel blended fuel. [21, 22].

4.2.4. Cumulative heat release [CHR]

Combustion start (SOC) is taken as the point where the heat output starts, and the end of combustion is the point where the cumulative heat output is 90%. The time remaining between the start of combustion and the end of combustion is expressed as the burning time. Cumulative heat dissipation is obtained by adding the values of heat dissipation according to the crank angle within this burning period. When the CHR changes depending on the load are examined (Figure 9.a-b), it is seen that the EB-10 fuel values are higher than the DF fuel values. it was seen that EB-10 fuel values were higher than the DF fuel values. This difference is due to the prolongation of the ignition delay [ID] time and the increase in the amount of filling taken in, depending on the height of the vaporization latent heat of the mixture fuel [23].

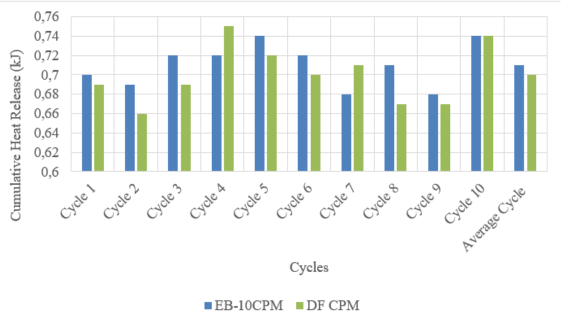

Figure 9.a. Maximum cumulative heat release rates

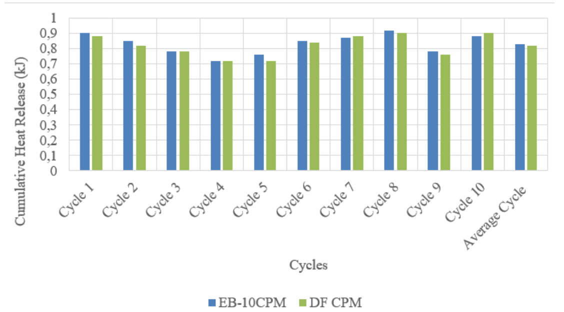

Figure 9.b. Maximum cumulative heat release rates

Çakmak and Özcan stated in their studies that diesel fuel offers the highest heat release compared to blended fuels due to its high calorific value and low kinematic viscosity [24].

4.2.5. Mean gas temperature [MGT]

The average gas temperature values of diesel and mixed fuel depending on the crank angle are given in the figure 10.a.b The difference between DF and EB-10 fuel at 4_{kg} loading was 2.71 while the difference between DF and EB-10 at 8_{kg} loading was 0.80 in favor of EB-10. has been formed. It can be said that the higher oxygen content of the blend fuel makes the combustion process more stable, increasing the temperatures. Because the oxygen content increases the combustion efficiency. Studies have reported that while the combustion efficiency in an environment containing 7% oxygen is 50%, the combustion efficiency in an environment containing 25% oxygen reaches 70% [25].

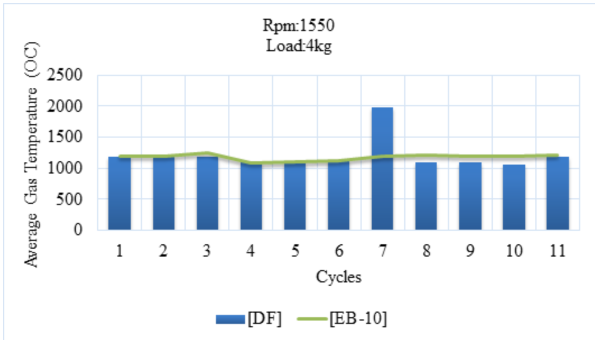

Figure 10.a. Maximum Average Gas Temperature Values

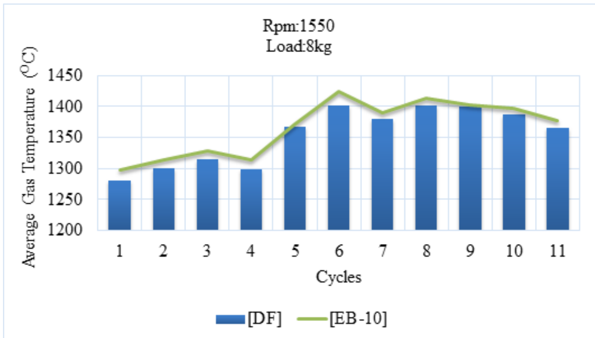

Figure 10.b. Maximum Average Gas Temperature Values

4.2.6. Heat release [NHR]

The net heat release rate is calculated based on the first law of thermodynamics as stated in equation 1.

$$\frac{dQn}{dt} = p\frac{dV}{dt} + mcv\frac{dT}{dt} = \left(1+\frac{cv}{R}\right)P\frac{dV}{dt} + \frac{cv}{R}V\frac{dp}{dt} \quad \frac{dQn}{d\theta} = \frac{k}{k-1}\,p\frac{dv}{d\theta} + \frac{1}{k-1}\,V\frac{dp}{d\theta} \qquad (1)$$

P: combustion chamber pressure
V: combustion chamber volume
k: adiabatic exponent
m: mass of the combustion chamber
cv is specific heat at constant volume
dt: time spent at each crankshaft angle depending on speed

Although the most important parameters affecting the NHR value calculated with Equation 1 are the injection time and ignition delay, the physical and chemical properties of the fuels used in the experiments also affect the heat dissipation[26]. In general, the heat release rate is used to determine the effects of different operating conditions on engine performance [27]. When the load-dependent changes of NHR values (Figure 11.a.b) were examined, EB-10 fuel produced 0.90% more heat release than DF fuel at 4 kg engine loading. At 8kg engine loading, EB-10 fuel produced 7.74% more heat release than DF fuel.

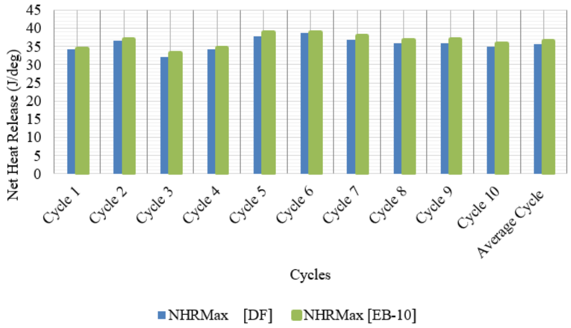

Figure 11.a. Maximum Net Heat Release Rates

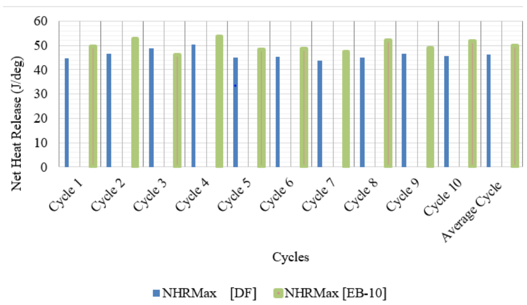

Figure 11.b. Maximum Net Heat Release Rates

4.2.2.5. Pressure increase rate

Pressure increase rate is one of the important parameters in transferring the energy released during the combustion process to the crankshaft [28]. The maximum pressure rise rates for ten cycles depending on the crank angle are given in Figure 12. While the difference in pressure increase ratio between DF and mixed fuel at 4 kg loading is 2%, the difference between DF and mixed fuel at 8 kg loading is 1.40%. While the pressure increase rates for all of the test fuels increased with the loading, the difference between them decreased. In the case of a 4kg load (low load), the amount of fuel accumulated during the ignition delay period is low, which reduces the pressure rise rate [29]. however, increasing the amount of fuel with increasing engine load increases the pressure increase rate. EB-10 fuel produced a higher pressure rise value than DF fuel. With the sudden burning of the amount of EB-10 fuel accumulated in the cylinder, the engine will run with more knocking as the pressure increase rate increases.

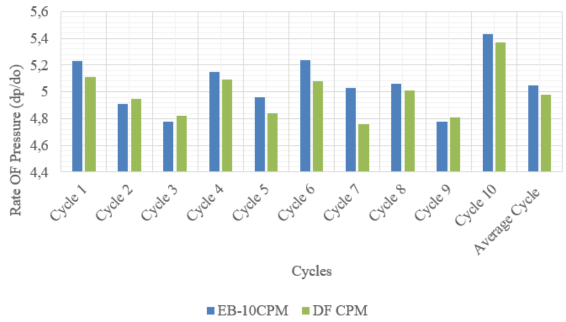

Figure 12.a. Maximum Pressure Increase Rate

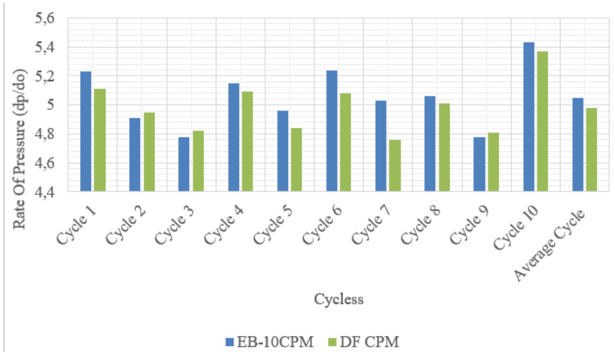

Figure 12.b. Maximum Pressure Increase Rate

5. Conclusions

The data obtained at the end of the experimental study;

The main components of essential oil; kavracol (67.09%), simine (15.32%) and terpinene. (5.05%)

Oil viscosity is slightly lower than other biodiesel sources. (2.34 mm^2/s)

Oil yield is low compared to other biodiesel sources (6-9 ml in 100 g).

It is intensely close to traditional biofuel sources

It is 0.843 g/cm^3 at 20 ° C.

EB-10 fuel produced 1.26% more engine power and 1.26 more engine torque than reference DF fuel. The blend fuel generated higher combustion data than DF fuel.

As a result, it was determined that the mixed fuel can be used in diesel engines without the need for modification and it is a fuel that increases combustion and performance.

As a suggestion, different volumetric mixtures of this fuel should be tested under different operating conditions and emission data should be examined.

CRediT authorship contribution statement

Erdal ÇILĞIN: Writing - original draft, Investigation, Visualization, Supervision, Conceptualization, Methodology, Software, Formal analysis. Investigation, Supervision, Writing - review & editing. Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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