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Investigation of Fuel Properties of Tea Seed Oil Biodiesel and Diesel Fuel Mixture

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Abstract

In this study, tea oil methyl ester was obtained from tea seed oil by transesterification method. D_{100}, B_{100}, $B_{50}D_{50}$ and $B_{20}D_{80}$ test fuels were obtained by mixing the methyl ester fuel obtained from tea oil with diesel oil at a rate of 50% and 20% volumetrically.

Fuel properties were determined by performing the density, kinematic viscosity, cetane number, pH amount, clouding, pouring and freezing point tests, and calorific value, color determination, flash point, cold filter plugging point and copper rod corrosion tests of the test fuels.

Considering the test results, it was concluded that the mixtures of $B_{50}D_{50}$ and $B_{20}D_{80}$ methyl ester produced from tea oil could be used in diesel engines without any modification on the engine and they were alternative fuels to diesel fuel. However, when it is used as B_{100} fuel, it is not suitable for use on diesel engines in terms of cold flow properties.

Keywords: Diesel engine, Tea oil methyl ester, Transesterification,

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1. Introduction

Many studies have been conducted worldwide to overcome the economic and environmental impacts of fossil fuel consumption and to find the best alternative fuels [1].

Fuels that do not cause toxic accumulation and have low emission value compared to petroleum diesel will ensure a balance between environment, agriculture and economic development. These fuels, which are de-rived from plant-derived oils as an alternative to fossil fuels, are called biodiesel [2].

Researchers are looking for new non-renewable raw materials, especially for biodiesel production [3].

Biodiesel production has accelerated in the world and in Turkey, especially after the 2000s. Biodiesel strengthens the agro-industry, reduces migration from rural areas and can be produced from agricultural products and waste. It has also features such as making a positive contribution to ecology by providing diversity in agricultural production and creating a sustainable agricultural structure, providing continuity to the farmer's production, expanding the agriculture of oil crops, supporting the closing of the domestic oil deficit and increasing the soil productivity by extending the crop rotation [4].

Tea, "Camellia SINENSIS", is known as the second most consumed beverage in the world and it is a plant belonging to the Theaceae family, made from the young leaves and buds of the tea plant [5]. In Turkey, tea is produced in the Eastern Black Sea Region, starting from the Georgian border to the town of Fatsa in Or-du. Tea production in this region is mainly in Rize, Ordu, Giresun and Trabzon. However, in Turkey where we can feel four climates, tea fields are left fallow for four to six months. The biggest advantage of the Turkish tea industry is that no pesticides are used. Since it snows in the province of Rize in the north-east of Turkey, it reduces harmful factors naturally. As a result, there is no need to use any pesticides. Because of this feature, Turkish tea is the "most natural tea" compared to other teas in the world [6]. The amount of oil in the seeds of the tea plant in Turkey is between 25-30% [7]. The tea plant is a short, perennial, shrub-type tree that grows in humid climates and is evergreen. The tea plant is grown in approximately 40 countries and can be considered as a semi-tropical plant depending on climatic conditions. An important part of tea plant production is carried out in China, Sri Lanka, Indonesia, Japan, India, Taiwan and central African countries [8-10]. It has been observed by researches that it is possible to bring the oil obtained from the tea seed to the economy by producing biodiesel with appropriate methods for the tea seeds economy, which are inactive in our country and in the world, to the economy [11]. Tea seed oil biodiesel is not significantly different from biodiesel produced from vegetable oils per se. Tea bean is a potential raw material for biodiesel production and has very similar properties to diesel fuel [12].

The innovative aspect of this study is that due to the limited alternative fuel sources used in internal combustion engines, we have determined in our research that the oil obtained from tea seed is a potential alternative fuel that is not used as food, compared to the oils consumed as food in our country. Thanks to the production stages and fuel properties of biodiesel obtained from tea oil, its usability in diesel engines has been determined by this study and will be a reference for future studies.

2. Materials and Methods

In this study, tea seeds obtained from Bilenköy in Hemşin district of Rize were annealed after roller mill process and roasted at 90 ^{0}C to obtain crude oil with the help of a press. After this oil was filtered, it was converted into Tea Oil Methyl Ester (TOME) by using NaOH as catalyst and methyl alcohol as alcohol with transesterification method.

To produce tea oil methyl ester, a biodiesel production reactor was used in the Energy Systems Engineering Laboratory of the Faculty of Engineering at Necmettin Erbakan University. D100, B100, B50D50 and B20D80 test fuels were obtained by mixing the methyl ester fuel obtained from tea oil with diesel oil at a rate of 50% and 20% volumetrically. Density, PH value, kinematic viscosity, cloud, pour and freezing point tests of the fuels obtained as a result of the mixtures were carried out in the Energy Systems Engineering laboratory at Necmettin Erbakan University, Faculty of Engineering. Heating value, flash point, cold filter plugging point, color and copper rod corrosion tests were performed in the Fuel Analysis Laboratory at Department of Agricultural Machinery and Technologies Engineering, Selçuk University Faculty of Agriculture.

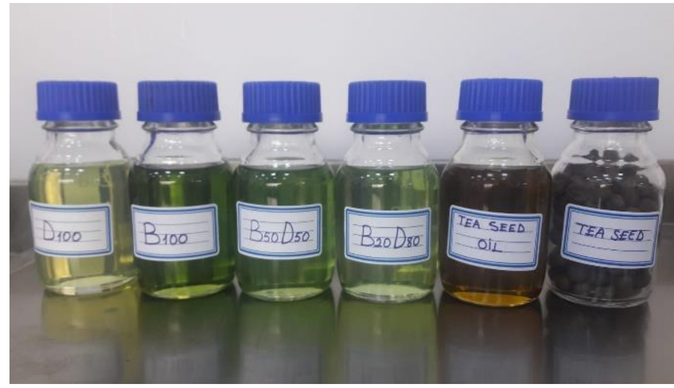

Fig. 1. Fuel Samples

The fuel samples prepared for the experiments are given in Figure 1, and the fuel mixture ratios by volume are given in Table 1.

Table 1. Names and mixing ratios of fuel mixtures

Fuels	Tea Seed Oil Biodiesel	Eurodiesel
$B_{20}D_{80}$	20	80
$B_{50}D_{50}$	50	50
B_{100}	100	0
D_{100}	0	100

TS EN 14214:2012+A2 standard was used to determine the fuel properties of TOME and TS EN 590:2013+A1 standard was used to determine the Euro diesel fuel properties. The analysis results of the test fuels are given in Table 2.

Table 2. Analysis Results of Test Fuels [13]

Characteristic Property	Unit	Tea Seed Oil	$B_{20}D_{80}$	$B_{50}D_{50}$	B_{100}	D_{100}	Limiting Values	
							Diesel	Biodiesel
Density (15 ºC)	g/cm³	0.913	0.841	0.857	0.893	0.827	0.82- 0.84	0.86-0.90
Kinematic Viscosity (40 ºC)	mm²/s	36.507	3.173	5.036	8.813	2.929	2-4.5	3.5-5
Cetane Number	---	65	54.1	59.2	68.1	52.9	51	---
pH	---	7.58	5.95	6.41	6.83	5.12	---	---
Cloud Point	ºC	-10.7	-3.76	-3.1	-2.3	-4	---	---
Pour Point	ºC	-17.3	-11.2	-8.1	-4.5	-15	---	---
Freezing point	ºC	-22.1	-18.3	-15.7	-12.6	-21	---	---
Calorific Value	Cal/gr	-------	10344	10234	9582	10399	---	---
Color	ASTM	0.5	0.5	0.5	0.5	0.6	---	---
Flash Point	ºC	188	73	82	123	61	55	120
CFPP	ºC	-------	-9.5	-7	-3.8	-14	-20	-15
Copper Strip Corrosion	---	1a	1a	1a	1a	1a	No:1	No:1

3. Result and Discussion

3.1 Density values of the fuels

Density values of fuels are shown in figure 2. When the density values were examined, it was seen that the density value of tea seed oil was high, the density values of B_{100} and D_{100} fuels remained within the standards, and the density values of $B_{50}D_{50}$ and $B_{20}D_{80}$ mixture fuels were close to D_{100} fuel.

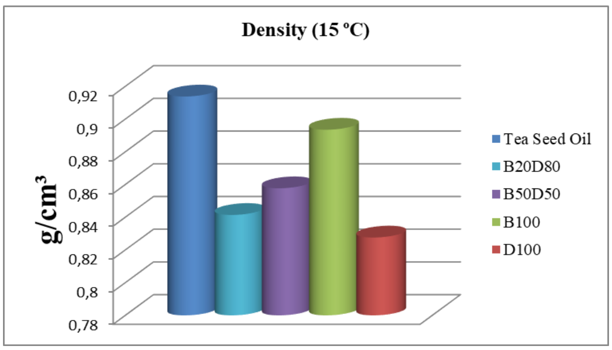

Fig. 2. Density analysis results of test fuels [13]

3.2 Kinematic viscosity values of fuels at 40°C

The kinematic viscosity values of the fuels at 40 ^{0}C are shown in figure 3. When the values were examined, it was determined that the kinematic viscosity value of the tea seed oil was high, the kinematic viscosity value of the D_{100} fuel remained within the standards, the kinematic viscosity value of the B_{100} fuel was out of standard and therefore B_{100} fuel would be called methyl ester. It was determined that the lowest viscosity value among the mixture fuels was in $B_{20}D_{80}$ fuel.

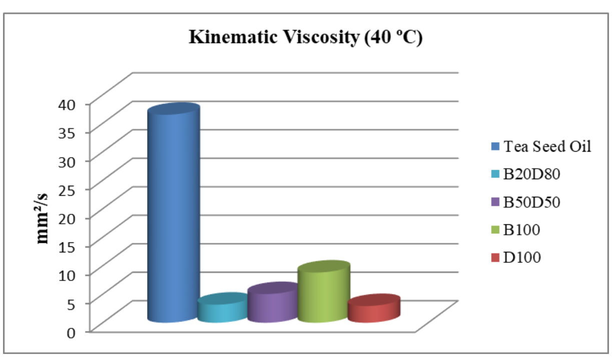

Fig. 3. Kinematic viscosity analysis results of test fuels

3.3 Cetane number values of the fuels

Cetane number values of fuels are shown in figure 4. When the values were examined, it was determined that the cetane number value of D_{100} fuel remained within the standards, and the highest cetane number among other fuels was found in B_{100} fuel. The cetane number of tea seed oil and tea oil methyl ester is higher than diesel fuel. Because according to the literature, stearic acid, which is one of the fatty acid components of tea oil, is high.

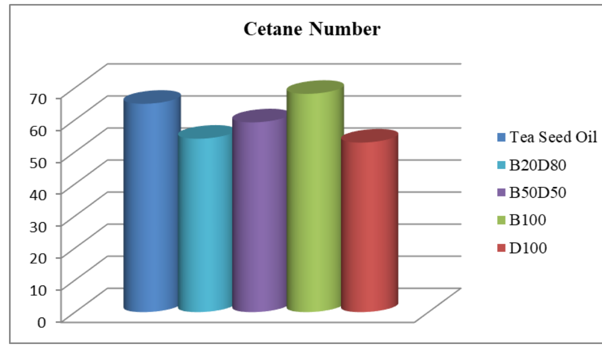

Fig. 4. Cetane number analysis results of test fuels

3.4 pH values of the fuels

The pH values of the fuels are shown in figure 5. pH is a unit of measure that describes the acidity or alkalinity of a solution. It stands for "Power of Hydrogen". The pH value of a substance directly depends on the ratio of the concentration of hydrogen ion [H+] and the hydroxide ion [OH-]. If the H+ con-centration is higher than the OH- concentration, the solution is acidic; that is, the pH value is less than 7. If the OH- concentration is higher than the H+ concentration, the substance is alkaline; i.e. pH value is greater than 7. If equal amounts of OH- and H+ ions are present, the substance is neutral with a pH of 7. When the values are examined, it is seen that the pH value of tea seed oil is basic and other fuels are acidic.

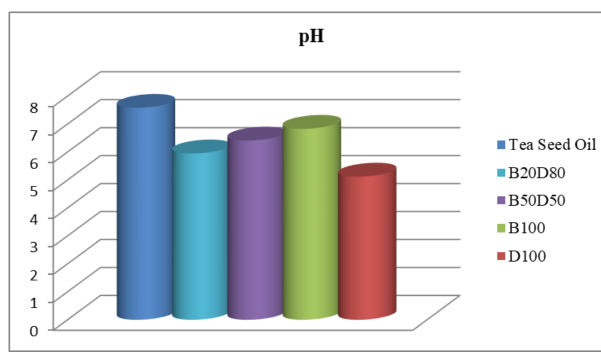

Fig. 5. pH analysis results of test fuels

3.5 Cloud point values of the fuels

Cloud point values of fuels are shown in figure 6. When cloud point values were examined, it was seen that the cloud point value of tea seed oil was high, and D_{100} fuel gave better results than B_{100} fuel and other fuel mixtures.

3.6 Pour point values of the fuels

Pour point values of fuels are shown in figure 7. When the pour point values were examined, it was seen that the pour point value of tea seed oil was high, and D_{100} fuel gave better results than B_{100} fuel and other fuel mixtures.

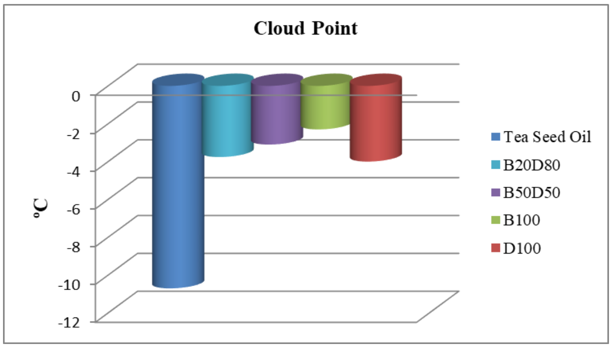

Fig. 6. Cloud point analysis results of test fuels

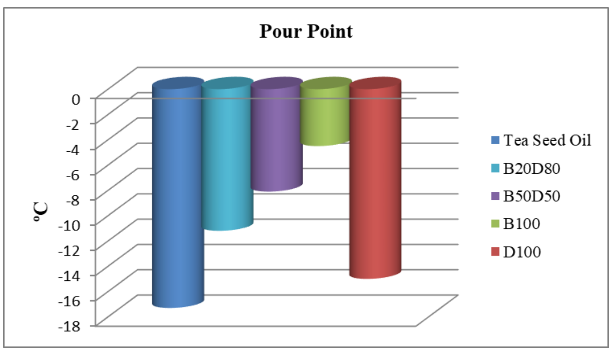

Fig. 7. Pour point analysis results of test fuels

3.7 Freezing point values of the fuels

Freezing point values of fuels are shown in figure 8. When the freezing point values were examined, it was seen that the freezing point value of tea seed oil was high, and D_{100} fuel gave better results than B_{100} fuel and other fuel mixtures.

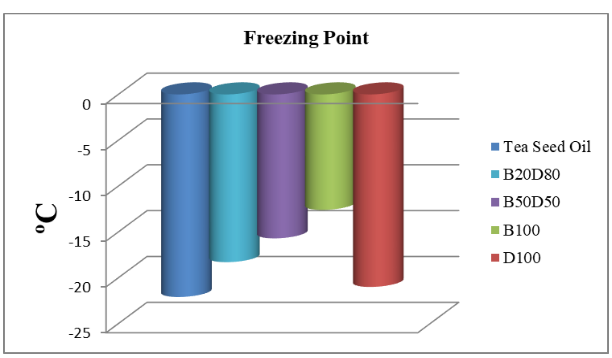

Fig. 8. Freezing point analysis results of test fuels

3.8 Calorific values of the fuels

The calorific values of the fuels are shown in figure 9. When the calorific values were examined, it was seen that D_{100} fuel is higher than B_{100} fuel, and other fuel mixtures had values close to the calorific value of D_{100} fuel.

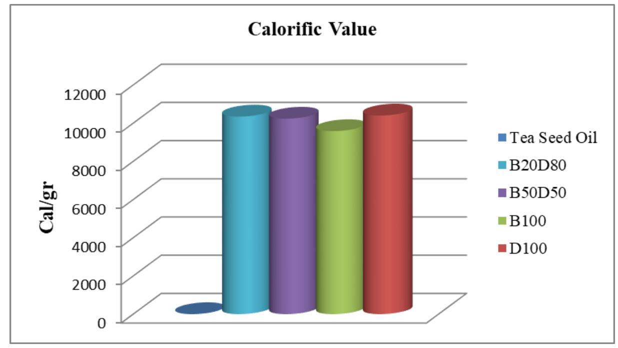

Fig. 9. Calorific value analysis results of test fuels

3.9 Color values of the fuels

The color values of the fuels are shown in figure 10. When the color values were examined, it was seen that the tea seed oil had the same color tone as the B_{100}, $B_{50}D_{50}$ and $B_{20}D_{80}$ fuels, D_{100} fuel the darker than the other fuel types.

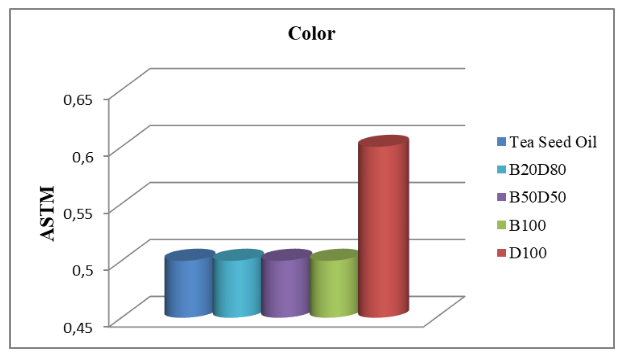

Fig. 10. Color analysis results of test fuels

3.10 Flash point values of the fuels

Flash point values of fuels are shown in figure 11. When the flash point values were examined, it was seen that the flash point of tea seed oil was the highest, the flash point values of D_{100} and B_{100} fuels gave results in accordance with the standards and other fuel types could be used within safe limits

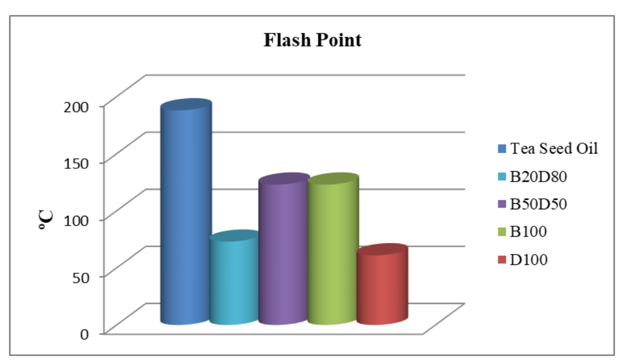

Fig. 11. Flash point analysis results of test fuels

3.11 Cold filter plugging point values of the fuels

The cold filter plugging point (CFPP) values of the fuels are shown in figure 12. When the CFPP values were examined, it was seen that D_{100} fuel gave better results than B_{100} fuel and other fuel mixtures.

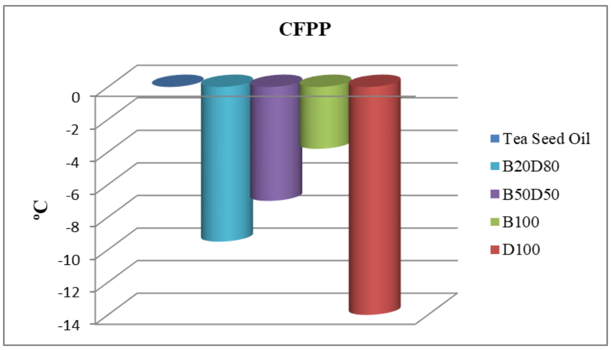

Fig.12. CFPP analysis results of test fuels

3.12 Copper Strip Corrosion values of the fuels

After a clean copper strip is kept in biodiesel at 50°C for 3 hours, the corrosion degree is determined by comparing it with the copper strip test scale. The test method is carried out according to EN ISO 2160.

4. Conclusions

In this study, tea oil methyl ester was obtained from tea seed oil by transesterification method. D_{100}, B_{100}, $B_{50}D_{50}$ and $B_{20}D_{80}$ test fuels were obtained by mixing the methyl ester fuel obtained from tea oil with diesel oil at a rate of 50% and 20% volumetrically. Fuel properties of the test fuels were determined by performing the density, kinematic viscosity, cetane number, pH amount, cloud, pour and freezing point tests, and calorific value, color determination, flash point, cold filter plugging point and copper rod corrosion tests of the test fuels.

Compared with D_{100} fuel, since the heating values and other properties of $B_{50}D_{50}$ and $B_{20}D_{80}$ fuels were close to D_{100} fuel, it was concluded that fuel mixtures can be used in diesel engines without any modification on the engine and they are alternative fuels to diesel fuel. However, when it is used as B100 fuel, it is concluded that it is not suitable for use on diesel engines in terms of cold flow properties.

When all values are examined, it is seen that $B_{20}D_{80}$ fuel gives the best results.

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This study is prepared as a part of Sena ÇALIŞKAN's MS Thesis. (Advisor: Dr. Fatih AYDIN)

Nomenclature

B_{100}	: % 100
$B_{20}D_{80}$	: % 20 TOME + % 80 Euro Diesel
$B_{50}D_{50}$	: % 50 TOME + % 50 Euro Diesel
TOME	: Tea Oil Methyl Ester
D_{100}	: % 100 Euro Diesel
^{0}C	: Celsius Degree
CFPP	: Cold Filter Plugging Point

Conflict of Interest Statement

The authors have no competing financial interests of the community or personal relationships that are known to declare that might have influenced the study reported in this paper.

CRediT Author Statement

Fatih Aydın: The investigation, writing - original draft, software, conceptualization, methodology, formal analysis, visualization, supervision.
Sena Çalışkan: The investigation, writing - review & editing, supervision.

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