

Determination of Some Physicochemical Properties of Camelina Biodiesel Blends with Different Alcohols

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Abstract

As the world population increases, energy use, environmental pollution and energy prices are also increasing rapidly. Since energy resources are limited and not available everywhere, countries aim to increase alternative energy sources in order to produce their own energy. At the same time, in order to protect the environment from negative effects, research on biodiesel is diversified and the effects of its blends with different alcohols are examined. The Camelina plant seeds preferred in this study contain high levels of oil (42-45%), and the high erucic acid content of the oil (2.3-4.2%) makes the consumption of oil as human food unfavorable. In this case, it makes the use of oil in biofuel production more attractive in terms of sustainability of human food production. The properties of the fuels obtained by blending different alcohols (heptane, hexane, ethanol, butanol, n-pentanol, iso-pentanol) at 10% ratios into Camelina biodiesel (C100) obtained by the transesterification method were determined. It has been observed that the viscosity, density, calorific value and cold flow properties of the fuels obtained by blending alcohols with C100 biodiesel, which has fuel properties in accordance with TS EN 14214 standards, are improved in all blends. While the flash point of heptane, hexane, ethanol and butanol mixture fuels occurred at low temperatures, it was above 50°C in mixtures with high carbon n-pentanol and iso-pentanol. The high flash point is important for transportation and storage safety and highlights the usability of these fuels. When the fuel properties were examined, the best results among the alcohols blended with camelina biodiesel were obtained in the blend with n-pentanol.

Keywords: Camelina oil, biodiesel blends, alcohols, fuel properties

1. Introduction

The rapid advancement of technology and the ever-increasing world population have rendered it nearly impossible to meet the escalating energy demand with existing fossil fuels. As energy consumption rises, countries that cannot meet their production needs find themselves dependent on nations with abundant reserves. Simultaneously, the adverse environmental effects of fossil fuels cannot be ignored. Consequently, efforts towards the use of renewable energy sources have gained momentum, prompting many countries to regulate their legislation to enhance the production and consumption of such resources (Xu and Lin, 2023). The development and implementation of renewable energy (green energy) systems in today's world have become one of the most effective ways to combat energy scarcity, global warming, natural disasters resulting from global warming, ecosystem imbalances, and associated diseases (Xu and Lin, 2023). Therefore, countries worldwide are now implementing green transformation policies due to the adverse effects of fossil fuels, making clean energy transformation central to sustainable development (Öztürk and Çeykel, 2023). Energy sources can be categorized based on their convertibility (primary and secondary energy) and usability (renewable and non-renewable). Primary energies are directly extracted from nature (traditional), or obtained through renewable means, while secondary energies involve the conversion of primary energy sources into forms like electricity, petroleum products (diesel, gasoline, etc.), methanol, ethanol, and hydrogen (Örgeç and Gümüş, 2017; Şahin and Mengeş, 2022; Şimşek and Yiğit, 2017). Biofuels, derived from biomass sources, are liquid or gaseous fuels mainly used for transportation. Biofuels such as bioalcohol, biodiesel, and hydrogen emerge as promising alternatives for future transportation fuels. The United States Department of Energy has set an ambitious goal for 2030, aiming for 20% of transportation fuels to be produced from

biomass-based sources. With its rich plant diversity, Turkey stands out as a country with significant potential for biofuel production. Agricultural residues and dried plant residues offer an annual energy potential of approximately 55 million tons, equivalent to 16 million tons of total energy. However, accessing these resources, evaluating and classifying biomass sources, developing biomass conversion technologies, and enacting necessary legal regulations are crucial for utilizing this potential effectively and achieving a future where renewable energy sources dominate primary energy production (Toklu, 2017). Biodiesel, a liquid biofuel derived from vegetable oils, is at the forefront of liquid biofuels that could replace fossil-derived liquid fuels (Yilmaz and Atmanlı, 2016). Although the use of vegetable oils as fuel is not a new concept, the term biodiesel has gained prominence in recent years. Reducing taxes on biodiesel application encourages its production and usage, leading to a rapid growth in the biodiesel market driven by environmental concerns. However, challenges such as raw material supply and costs persist, with 75% of biodiesel costs attributed to raw materials. Overcoming these challenges is crucial for biodiesel to compete with petroleum-based diesel fuel (Oğuz et al., 2012; Öğüt and Oğuz, 2006). Biodiesel is defined as "a liquid fuel within the scope of biofuels, obtained from new or used vegetable and animal oils through chemical methods, environmentally friendly and renewable." In practice, biodiesel is also known as biomotorine, green energy, green diesel, super diesel, diesel-bi, or colloquially as oil diesel (Öğüt et al., 2007). Despite its various advantages, such as a high flash point, high cetane number, biodegradability, and lack of toxic effects, biodiesel has some disadvantages, including partially high viscosity, high pour point, and low calorific value (Rakopoulos et al., 2011). Improving the fuel properties of vegetable oils is necessary due to issues such as injector deposits, sticking of pistons

and segments, and dilution of engine oil caused by the long-term use of vegetable oils (Budak et al., 2009). High alcohols are preferred in biodiesel blends, and in modern fermentation processes, genetically engineered microorganisms (*Escherichia coli*, *Cyanobacteria*, *Saccharomyces cerevisiae*, etc.) have been used to increase the yield of alcohol types such as butanol and pentanol from glucose through biosynthesis (Kumar and Saravanan, 2016).

1.1. Camelina

Camelina [*Camelina sativa* (L.) Crantz] is one of the 6 widely known Camelina species (*C. sativa*, *C. laxa*, *C. rumelica*, *C. microcarpa*, *C. hispida* and *C. anomala*) in the Brassicaceae family. *C. sativa* (L.) Crantz is the only economically important species in the genus Camelina and is also known by various names such as Camelina, false Camelina, German sesame, Siberian oilseed. Cultivated Camelina varieties are annual and wild forms are generally perennial. Plant height generally varies between 25-100 cm. The camelina plant is grown as summer and winter crops. It is relatively drought tolerant and can grow in many different areas with different climatic and soil structure except heavy clay and organic soil. The growing period of summer varieties is around 120 days and reaches the flowering period in about 60 days from germination. Due to the small size of the camelina seed, it is very important to make good soil preparation for sowing. Adding the weeds germinated by doubling before sowing is very important in terms of weed competition. Camelina is a plant suitable for

machine harvesting (Orhan and Seyis, 2012). Camelina oil is classified as high-quality edible oil with its low saturated fatty acid ratio, but it contains high levels of polyunsaturated fatty acids that shorten the shelf life and increase the sensitivity to combustion. It is also classified as drying oil in terms of iodine number (144) (Robinson, 1987). In this study, the properties of fuels obtained by blending different alcohols (heptane, hexane, ethanol, butanol, butanol, n-pentanol, iso-pentanol) with Cameline biodiesel (C100) obtained by transesterification method at 10% ratios were determined. The viscosity, density, cold filter plugging point, flash point, water content and calorific values of the fuels obtained by blending alcohols into C100 biodiesel were analysed and their compliance with TS EN 14214 standards was examined.

2. Material and Methods

2.1. Determination of fuel properties

The fuel analyses of the prepared fuels and blends were carried out in the fuel analysis laboratory established within the scope of DPT Project No. 2004/7 (Öğüt et al., 2004) and located in the Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Selçuk University. In the study, the properties of Cameline oil biodiesel and blend fuels; kinematic viscosity, density, calorific value, water content, flash point, cold filter plugging point were determined according to the devices and working methods given in Table 1. The properties of diesel and alcohols are given in Table 2.

Table 1. Characteristics of test equipment

Fuel Characteristic	Devices	Measuring range	Unit	Measuring accuracy	Manufacturer	Standard
Density	Kem Kyoto DA-130N	0.0000 - 2.0000	$\frac{g}{cm^3}$	± 0.0001	Kem Kyoto Electronics, Japan	EN ISO 3675 EN ISO 12185
Kinematic viscosity	Koehler K23377	Ambient temperature – 150	$^{\circ}C$	± 0.01	Koehler Instrument Company, US	EN ISO 3104
Flash point	Koehler K16270	Ambient temperature - 370	$^{\circ}C$	± 0.01	Koehler Instrument Company, USA	EN ISO 2719 EN ISO 3679
Water content	Kem Kyoto MKC-501	10 μ g-100mg	μ g	± 0.01	Kem Kyoto Electronics, Japan	EN ISO 12937
Calorimeter	IKA C 200	0-40.000	J	± 0.0001	IKA, UK	DIN 51900
Cold filter plugging point	Tanaka AFP-102	With refrigerant up to - 60 $^{\circ}C$	$^{\circ}C$	± 0.01	Tanaka Scientific Limited, Japan	EN ISO 3015 EN ISO 3016

Table 2. Properties of diesel and alcohols

Feature	Diesel	Methanol	Ethanol	Propanol	Butanol	Pentanol	Hexanol	Heptanol
Molecular formulation	C _x C _y	CH ₃ -OH	C ₂ H ₅ -OH	C ₃ H ₇ -OH	C ₄ H ₉ -OH	C ₅ H ₁₁ -OH	C ₆ H ₁₃ -OH	C ₇ H ₁₅ O
Molecular weight (kg kmol ⁻¹)	190-211	32.04	46.07	60.09	74.12	88.15	102.18	116
Density 15 $^{\circ}C$ (g cm ⁻³)	835	791.3	789.4	803.7	809.7	814.8	821.8	824
Kinematic viscosity 40 $^{\circ}C$ (mm ² s ⁻¹)	2.72	0.58	1.13	1.74	2.22	2.89	3.32	3.32
Flash Point ($^{\circ}C$)	>55	11-12	17	11.7	35-37	49	59	76
Cetane Number	52	5	8	12	17	19	23	23
Cold Filter Plugging Point ($^{\circ}C$)	-17	< - 51	< - 51	< - 51	< - 51	-40	-	-
Calorific value (MJ kg ⁻¹)	42.49	19.58	26.83	30.63	33.09	34.65	39.1	34.65
% C	86.13	37.48	52.14	59.96	64.82	68.13	70.52	72.16
% H	13.87	12.48	13.02	13.31	13.49	13.61	13.7	13.71
% O	0	49.93	34.73	26.62	21.59	18.15	13.7	14.13

2.2. Biodiesel Production

Biodiesel production of crude oil obtained from camelina seed (*Camelina sativa L. Crantz*) is a two-stage process using transesterification method, temperature controlled, magnetic mixer with probe heater. Here are the details of this process: *Stage 1:* Preparation of Raw Oil and Filtration Camelina (*Camelina sativa L. Crantz*) seed oil is first filtered to remove impurities. *Stage 2:* For the reaction, which was carried out in two stages, a total of 20% of the crude oil was methyl alcohol (CH₃OH) and 3.5g of NaOH for each liter of oil. In the first reaction, 75% of the total methyl alcohol (CH₃OH) to be used and 50% of the total catalyst to be used were mixed with the help of a NaOH magnetic stirrer to obtain methoxide. Camelina crude oil was heated to 55 $^{\circ}C$ and methoxide was added to it. The mixer speed was set at 1000 rpm and mixed for 90 minutes. The heating and stirring elements

are then turned off, and the glycerol is allowed to settle for 2 hours before being separated. *Stage 3:* Camelina biodiesel, whose first reaction was completed, was heated again to 55 $^{\circ}C$ in a heated magnetic stirrer, and while mixing continued, methoxide was added and the temperature was kept constant and mixed for 60 minutes. Then the mixer and heater were turned off. It was left to rest for 2 hours for the glycerol to precipitate again and the precipitated glycerol was separated. The temperature of Camelina crude biodiesel was increased to 75 $^{\circ}C$ and the methyl alcohol remaining in the crude biodiesel was removed. The glycerol remaining in the camelina oil crude biodiesel was waited for 15 hours to precipitate and the glycerol was removed. *Stage 4:* During the washing phase, the temperature of the biodiesel was 50 $^{\circ}C$ and the temperature of the pure water used for washing was 50 $^{\circ}C$, and the pH of the biodiesel was washed using pure water

using the misting method until the pH became neutral. After the washing process was completed, 12 hours were waited for the water to settle and the settled wastewater was separated. The raw biodiesel, from which the precipitated water was removed, was subjected to a drying process at 100°C for 120 minutes in a magnetic stirrer with a probe heater, and the water in it was removed. *Result:* Biodiesel production with the completion of these stages, the

production of camelina oil biodiesel has been successfully accomplished (References: Eryılmaz, Yeşilyurt, Cesur, Yumak, Aydın, Çelik & Yıldız, 2014; Cesur, Eryılmaz, Uskutoğlu Doğan, Coşke Şenkal & Alnıak Sezer, 2021; Özgün & Eryılmaz 2018). Camelina biodiesel was homogenously mixed with 10% by volume of n-butanol, n-amyl alcohol, iso-amyl alcohol, hexanol, ethanol and heptane and blend fuels were prepared (Figure 1).



Figure 1. Blend Fuels

3. Results and Discussion

Kinematic viscosity, density, calorific value, water content, flash point, cold filter plugging point and copper strip corrosion

values of camelina oil biodiesel and blended fuels are given in Table 2 and compared with TS EN 14214 standard.

Table 2. Fuel properties of camelina biodiesel and blend fuels

Fuels / Properties	Density (kg m ⁻³) (15 °C)	Kinematic viscosity (mm ² s ⁻¹) (40 °C)	Flash point (°C)	Calorific value (Mj kg ⁻¹)	Water content (mg kg ⁻¹)	Cold filter plugging point (°C)
C100	877,6	4,31	146	39,52	378,8	-4
C90Bu10	877,3	3,78	48	39,54	420,5	-6
C90isoP10	876,8	3,86	57	38,25	650,5	-3
C90nP10	860,4	3,92	55	38,85	642,41	-6
C90Hex10	846,7	3,95	Ambient temperature	39,31	699,57	-6
C90E10	876,7	3,6	Ambient temperature	38,89	920,5	-3
C90Hep10	866,5	3,96	Ambient temperature	39,74	745,5	-3
EN 14214	<u>Min.</u> <u>Max.</u>	860 900	3.5 5	>129 38	- 500	< -10

It was determined that all fuel properties of camelina oil biodiesel were within the limit value according to TS EN 14214. High density and viscosity values in fuels cause the fuel not to be atomized at the desired size from the injector system and as a result of this, the combustion is worsened by prolonging the ignition delay time affecting the combustion event (Akdere, 2006). Except for the C90Hex10 fuel blend, the density values of Cameline biodiesel and blended fuels were found within the limit values. Erol et al. (2023) also reported that the density values of hexanol blended fuels were low. The kinematic viscosity values of all fuels were within the limit values. The low viscosity values of alcohols decreased the viscosity value in blends with camelina biodiesel. Viscosity changes in blended fuels depending on the viscosity values of alcohols are also observed in the studies of Campos-Fernández et al. (2012); Kumar and Saravanan (2016). The lowest viscosity value in blended fuels was obtained in C90E10 fuel. Too low viscosity can cause leaks in the fuel pump due to easy flow of the fuel (Acaroğlu, 2010). High viscosity, on the other hand, may cause clogging in the injectors, poor atomization of the fuel and as a result, poor combustion, carbon accumulation in the piston rings and deterioration of the lubricating oil (Oğuz, 2004). The calorific values of camelina biodiesel and blended fuels were within the standard. Depending on the heating values of the alcohols, the change in the heating values of the blend fuels was proportional. The highest calorific value was obtained in C90Hep10 with a value of 39.1 MJ kg^{-1} and the lowest was obtained in C90isoP10 blend fuel with a value of 38.25 MJ kg^{-1} . These changes in blend fuels depending on the alcohol ratio are also observed in Campos-Fernández et al. (2012); Kumar and Saravanan (2016) studies. Flash point is important in the risk classification of fuels and high flash point values of fuels are required for transport and storage (Öğüt and Oğuz, 2006). Flash point of blended fuels is outside the EN14214 standard. The cold

filter plugging point (CFPP) is the lowest temperature at which crystals formed when the fuel reaches the cloud point will clump and flow through a particular filter. It was observed that the cold filter plugging points of camelina biodiesel and fuel blends were outside the standard.

4. Suggestions

Engine performance and exhaust emission tests can be carried out with the fuels used in this study. Long-term tests should be carried out in different engine types to investigate the effects of fuels on engine parts and fuel system. Long-term tests should be carried out and the effect on engine oil should be analysed. The fuels used in the study can also be analysed in terms of thermodynamic, environmental and economic aspects.

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