Selcuk Journal of Agriculture and Food Sciences

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Research Article

SELCUK UNIVERSITY PRESS

(2023) 37(3), 505-514 DOI:10.15316/SJAFS.2023.048 e-ISSN: 2458-8377 Selcuk J Agr Food Sci

Investigation of the Usability of Biodiesel Produced from Coriander *(Coriandrum Sativum L.)* Gürbüz Registered Variety Crude Oil in Diesel Engines

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HIGHLIGHTS

- Natural Growth in Anatolia: Although native to Mediterranean countries and the Middle East, coriander naturally grows in Anatolia, making it an accessible resource for biodiesel production.
- Extraction and Production: The study obtained coriander crude oil from the Gürbüz registered variety of coriander seeds using a screw press. Biodiesel production was achieved through a single-stage transesterification method, known as CGBD.
- Fuel Properties Assessment: Various fuel properties of the coriander biodiesel, including density, kinematic viscosity, flash point, water content, copper strip corrosion, calorific value, color, cloud point, cold filter plugging point, and pour point were examined.
- Conformance to Standards: The study assessed the conformity of coriander biodiesel to the EN 14214 standard, ensuring its suitability for use as a biodiesel fuel.

Abstract

In recent years, the use of biodiesel has become increasingly important. One of the potential plants that can be used in biodiesel production is coriander (*Coriandrum sativum L.*). Coriander *(Coriandrum sativum L.)*, a member of the Apiaceae family, is a medicinal, spice and essential oil plant. Although the homeland of coriander is the Mediterranean countries and the Middle East region, it grows naturally in Anatolia. In this study, coriander crude oil was obtained from coriander (*Coriandrum sativum L.)* (Gürbüz registered variety) seeds using a screw press. Biodiesel production was obtained from coriander crude oil by transesterification method in a single stage (CGBD). Fuel properties of coriander (Gürbüz registered variety) (CGBD); density (kg m^{-3}) (at 15 °C), kinematic viscosity (mm^2 s^{-1}) (at 40 ºC), flash point (°C), water content (mg kg^{-1}), copper strip corrosion (3h at 50 °C), calorific value (MJ kg^{-1}), color (ASTM D1500), cloud point (°C), cold filter plugging point (°C), pour point (°C). The conformity of coriander biodiesel according to EN 14214 standard was examined.

Keywords: Biodiesel; *Coriandrum sativum L.*; Gürbüz registered variety; fuel properties

Citation: Şahin S, Coşke Şenkal B, Eryılmaz E, Uskutoğlu T, (2023). Investigation Of The Usability Of Biodiesel Produced From Coriander (Coriandrum Sativum L.) Gürbüz Registered Variety Crude Oil In Diesel Engines. *Selcuk Journal of Agriculture and Food Sciences*, 37(3), 505-514. https://doi.org/10. 15316/SJAFS.2023.048

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Received date: 03/03/2023

Accepted date: 20/07/2023

1. Introduction

Coriander (*Coriandrum sativum L.,* 2=22), a member of the Apiaceae family, is a medicinal, spice and essential oil plant. Although the origin of coriander is the Mediterranean countries and the Middle East region, it grows naturally in Anatolia. In the Flora of Turkey, two species, C. sativum L. and Coriandrum tordylium (Fenzl) Bornm. have a natural distribution (Menemen, 2012). The plant, which is about 25-60 cm long, has an annual herbaceous structure, has small pinkish white flowers. Its fruits are schizocarp and rounded. According to the fruit size of the cultivated *C. sativum*, large fruit (*C. sativum var. macrocarpum*, 1000 fruit weight: more than 10 g, fruit diameter: 3-5 mm) and small fruit (*C. sativum var. microcarpum*, 1000 fruit weight: less than 10 g, fruit diameter: 1.5-3 mm) has two varieties (Tunçtürk, 2011). Fruit color turns from green to brown with ripening (Ulutaş Deniz et al., 2018). All parts of the plant can be used for food, but mostly fresh leaves and dried fruits are used as spices to add flavor and flavor to various food products (Singh and Verma, 2015; Kumar et al., 2017). Its fruits contain essential oil (0.15-1.40%) and fixed oil (18-22%). Linalool (69-91%) is the main component of essential oil (Farooq et al., 2011, Abou El-Nasr et al., 2013; Saxene et al., 2014; Beyzi et al., 2017; Gökduman and Telci,2018; Wahba et al., 2020). Essential oil is used in the food, beverage and perfumery industries (Yalçın, 2016). However, coriander essential oil is also used in folk medicine and pharmaceutical industry due to its pharmacological properties (antioxidant, hypoglycemic, anti-inflammatory, hypolipidemic, analgesic, sedative, antimutogenic, diuretic, antimicrobial, etc.) (Yalçın, 2016; Al-Khayri et al., 2023). Petrocelinic acid constitutes 72-75% of the fixed oil obtained from coriander fruits, while linoleic acid (13-14%) and oleic acid (5-6%) are other important fatty acids (Uitterhaegen et al., 2006; Sriti et al., 2009).

The primary objective of this research was to generate biodiesel from coriander seed oil, specifically sourced from the Gürbüz registered variety. Coriander, a plant of significant importance in both our nation and global trade, is renowned for its applications in medicinal and culinary contexts. The study sought to employ the transesterification method within a single stage, aiming to produce biodiesel efficiently. Additionally, the investigation aimed to assess the compliance of coriander crude oil (CGCO) and the resulting biodiesel (CGBD) with the EN 14214 standard, a critical benchmark for evaluating the suitability of biodiesel as a fuel. This evaluation was conducted through a comprehensive analysis of fuel properties, thereby offering insights into the potential of coriander-derived biodiesel for meeting established quality standards in accordance with EN 14214.

2. Materials and Methods

2.1. Obtaining the seed

Coriander (Gürbüz registered variety) seeds used in the study were obtained from Ankara University, Faculty of Agriculture (Figure 1.) and coriander (Gürbüz registered variety) crude oil was obtained with the help of a screw press in Oğuzhan Farm located in Gövdecili/Yozgat village. Methyl alcohol (CH_3OH) required for biodiesel production and sodium hydroxide (NaOH) as a catalyst were used as materials.

Figure 1. Coriander (*Coriandrum sativum L.)* Seeds

2.2. Obtaining the Crude Oil from Coriander (Coriandrum sativum L.) Seeds via Screw Press

Coriander (Gürbüz registered variety) seed oil was obtained from coriander seed crude oil with the help of an American KERN&KRAFT brand, 3.5 kW electric motor, screw press with a pulp outlet opening of 12 mm (Figure 2).

Figure 2. Extraction of oil from Coriander (*Coriandrum sativum L*). seeds via screw press

2.3. Biodiesel Production

Biodiesel production from coriander *(Coriandrum sativum L*). (Gürbüz registered variety) seeds crude oil was carried out by transesterification method in a single stage with a temperature regulated magnetic stirrer with probe heater according to the flow diagram given in Figure 3. Coriander (Gürbüz registered variety) seed crude oil was filtered to remove impurities before biodiesel production (Figure 4). To obtain methoxide, methyl alcohol (CH_3OH) was used as alcohol and NaOH as catalyst.

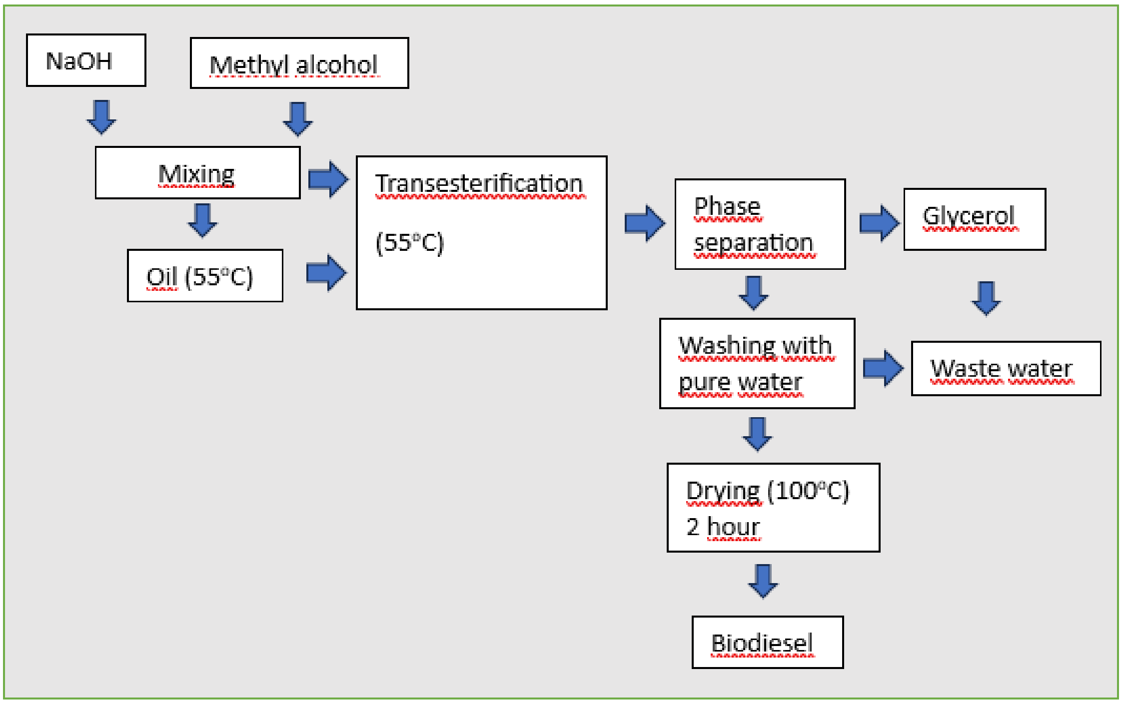

Figure 3. Process flow diagram for biodiesel production

Figure 4. Filtering of coriander *(Coriandrum sativum L).* (Gürbüz registered variety) crude oil

In the reaction, 20% (100 mL) methyl alcohol (CH_3OH) (Merck, d=0.791-0.793 kg m^{-3}) to be used for 500 mL coriander crude oil. 1.75g NaOH (Merck) to be used for each 500 mL oil was dissolved in a magnetic stirrer with heater and methoxide was obtained. This methoxide was added to the coriander crude oil which was heated at 55^0C. The stirrer speed was adjusted to 1000 min^{-1} and the mixture was reacted for 90 minutes. Then the mixer and heater were switched off. The temperature of the coriander crude biodiesel was raised to 75^0C and the methyl alcohol (CH_3OH) remaining in the crude biodiesel was removed. Glycerol was allowed to precipitate for 24 hours and glycerol was removed.

Then, the pH value of coriander oil biodiesel was checked, and since the reaction was basic, it was subjected to washing using pure water by misting method until it reached a neutral state (Eryılmaz et al., 2014; Cesur et al., 2021).

The purpose of washing is to remove unreacted alcohol, residual fatty acids, Na+, K+ ions, catalyzing agent and glycerol that may remain in the biodiesel during decomposition (Eryılmaz, 2009). During washing, the temperature of the biodiesel was 50⁰C and the temperature of the pure water used in washing was 50ᵒC and the pH of the biodiesel was washed by using pure water by mist method until the pH of the biodiesel was neutralized. After the washing process, 12 hours were waited for the precipitation of the water and the precipitated waste water was taken. The crude biodiesel from which the precipitated water was removed was subjected to drying at 120⁰C for 120 minutes and thus coriander (*Coriandrum sativum L*). (Gürbüz registered variety) crude oil biodiesel was produced (Özgün and Eryılmaz 2018; Cesur et al., 2021). Figure 5 shows the coriander (Gürbüz registered variety) biodiesel (CGBD) produced.

Figure 5. Coriander (*Coriandrum sativum L*). (Gürbüz registered variety) biodiesel

2.4. Fuel analysis

In this study, some fuel properties of coriander (*Coriandrum sativum L*) (Gürbüz registered variety) oil biodiesel; density, kinematic viscosity, flash point, water content, copper strip corrosion, calorific value, color, cloud point, cold filter plugging point, pour point) were determined according to the devices and working methods given in Table 1. Some fuel analyses of the obtained biodiesel were carried out in the Fuel Analysis Laboratory of Selçuk University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering.

Table 1. Properties of test devices

Fuel Property	Devices	Measurement Range	Unit	Measurement Accuracy	Manufacturer	Standard
Density	Kem Kyoto DA-130N	0.0000 - 2.0000	g cm^{-3}	±0.0001	Kem Kyoto Elektronik, Japonya	EN ISO 3675 EN ISO 12185
Kinematic viscosity	Koehler K23377	Ambient temperature – 150	⁰C	±0.01	Koehler Instrument Company, US	EN ISO 3104
Flash point	Koehler K16270	Ambient temperature - 370	⁰C	±0.01	Koehler Instrument Company, USA	EN ISO 2719 EN ISO 3679
Water content	Kem Kyoto MKC-501	10μg-100mg	μg	±0.01	Kem Kyoto Electronic, 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 a coolant down to -60⁰C	⁰C	±0.01	Tanaka Scientific Limited, Japan	ASTMD6379
Cloud and pour point	Koehler	-	⁰C	-	-	ASTM D97
Copper strip corrosion	Koehler K 25330	0-190	⁰C	±0.01	Koehler Instrument Company, USA	EN ISO 2160

3. Results

Coriander (Gürbüz registered variety) crude oil (CGCO), Coriander (Gürbüz registered variety) crude oil biodiesel (CGBD) analysis results are given in Table 5.

Table 5. Fuel properties of the crude oil of the registered coriander (*Coriandrum sativum L.)* variety and the biodiesel produced from this oil.

Features	CGCO	CGBD	EN 14214	
			Min.	Max.
Density (at 15°C) (kg m^{-3})	907,5	869,9	860	900
Kinematic Viscosity (at 40°C) (mm^2 s^{-1})	34,19	4,95	3,5	5,0
Flash Point, ºC	-	140	120	
Water Content, (mg kg^{-1})	368,2	75		500
Copper Strip Corrosion (3h/50°C)	1a	1a	1	
Calorific value, MJ kg^{-1}	39,910	39,322		
Colour (ASTM D1500)	3,2	1,9	-	-
Cloud Point, ^{0}C	4	-13,8	-	-
Cold Filter Plugging Point ^{0}C	0	-16		
Pour Point, ^{0}C	-5	-16,8	-	-

3.1. Kinematic Viscosity

First, it is important to note that the kinematic viscosity of CGBD, measured at 40°C, was found to be 4.95 mm^2 s^{-1}, a value that is indicative of its flow characteristics. The importance of kinematic viscosity in biodiesel lies in its direct correlation with the fluid's flow behavior. Lower kinematic viscosity values signify enhanced fluidity, indicating that the biodiesel is more adept at flowing through conduits and atomizing during combustion. This characteristic is especially significant in optimizing the performance of engines and fuel delivery systems. The fact that the result we obtained is within the standards plays an important role in the usability of biodiesel.

3.2. Density

Defined as the mass per unit volume, biodiesel density is a fundamental property that contributes to the overall understanding of the fuel's physical characteristics and behavior. The density at 15°C was recorded at 869.9 kg m^{-3}, which is significant for assessing the fuel's mass properties. The specified value aids in formulating biodiesel blends with conventional diesel fuel, ensuring that the resultant mixture maintains an appropriate density for seamless integration with existing distribution systems and combustion engines.

3.3. Water content

The water content, an important consideration in fuel quality, was measured at 75 mg kg^{-1}, indicating a low moisture level in the CGBD sample. In the realm of biodiesel, the water content assumes particular importance due to its potential implications for both the fuel's immediate performance and its long-term stability. The reported water content value of 75 mg kg^{-1} in the CGBD sample signifies a relatively low moisture level. This observation is noteworthy as excessive water content in biodiesel can have detrimental effects on combustion efficiency and engine performance. Water, when present in biodiesel, may lead to issues such as corrosion, microbial growth, and reduced lubricity, all of which can adversely impact the overall quality and functionality of the fuel.

3.4. Calorific value

One of the most critical parameters, the calorific value of CGBD, was measured at 39.32 MJ kg^{-1}, which is remarkably close to traditional diesel fuel. This high calorific value suggests that CGBD can provide a substantial amount of energy when combusted, making it a promising alternative. Calorific value, indicative of the energy content per unit mass, stands as a pivotal metric in determining the combustibility and overall utility of biodiesel. The measured calorific value of 39.32 MJ kg^{-1} for CGBD is noteworthy for its proximity to that of traditional diesel fuel. This close resemblance suggests that CGBD possesses a comparable energy content to conventional diesel, a crucial factor in assessing its suitability as a substitute fuel. The high calorific value implies that CGBD can release a substantial amount of energy upon combustion, positioning it as a promising and energetically efficient alternative within the realm of renewable fuels.

3.5. Flash point

A flash point of 140°C indicates a relatively high resistance to ignition, suggesting that the biodiesel sample, in this case, Coriander Biodiesel (CGBD), requires elevated temperatures before vapor concentrations reach the flammable threshold. This property is particularly advantageous in terms of safety during storage and transportation, as it reduces the risk of inadvertent ignition under normal operating conditions.

3.6. Colour

In biodiesel analysis, the ASTM D1500 color measurement serves as an important quality control parameter. A color value of 1.9 indicates a relatively low degree of coloration, suggesting a pale or clear appearance. This is typically desirable in biodiesel, as it implies a cleaner and more refined product with fewer impurities or contaminants. The ASTM D1500 color measurement is particularly valuable in assessing the effectiveness of production processes and ensuring compliance with industry standards.

3.7. Flow characteristics in cold

The cloud point, cold filter plugging point, and pour point, -13.8°C, -16°C, and -16.8°C, respectively. These results imply that CGBD exhibits properties conducive to efficient combustion and operation even in cold weather conditions. The cloud point, cold filter plugging point, and pour point represent key indicators of the low-temperature operability of biodiesel. The recorded values for these cold flow properties, i.e., -13.8°C, -16°C, and -16.8°C, suggest that CGBD exhibits favorable characteristics for operation in cold weather conditions. The relatively low values indicate that the biodiesel remains in a liquid state at temperatures lower than those specified, mitigating concerns related to the formation of wax crystals and filter plugging. This is particularly crucial in regions or seasons where low temperatures are prevalent.

The copper strip corrosion test, which is indicative of the fuel's corrosive potential, showed a rating of 1a, indicating minimal corrosion risk. A rating of 1a in the copper strip corrosion test is indicative of a low corrosive impact, implying that Coriander Biodiesel (CGBD) poses minimal risk to copper surfaces. This result is noteworthy for several reasons, most notably in terms of engine and fuel system integrity. Corrosion can lead to the degradation of metallic components, negatively impacting the overall efficiency and lifespan of engines and associated infrastructure.

4. Discussion

In CGBD fuel; kinematic viscosity (mm^2 s^{-1}) (at 40 ^{0}C), density (kg m^{-3}) (at 15 ^{0}C), water content (mg kg^{-1}), calorific value (Mj kg^{-1}), flash point (^{0}C), copper strip corrosion (3h at 50^{0}C) were within the standards (Table 5). These values were similar to those reported in other studies for B100 biodiesel (Moser and Steven, 2010; Kumar, M. et al., 2023; Tibesigwa, T. et al., 2023). The copper strip corrosion values were found to be 1a in KGBD fuel and were similar to Ciubota-Rosieet et al., 2013. The cold filter plugging point was determined at the dates specified in the standard (16 April to 30 September: 0^{0}C; 1 March to 15 April and 1 October to 15 November: -10^{0}C; from 16 November until the end of February: -20^{0}C). From 16 November to the end of February: -20^{0}C in CGBD fuel, but not in other dates (Table 5). In the study conducted by Moser and Steven (2010), a CFPP of -15 was reported, which was found to be close to the result obtained in our research (-16).

The results of this study provide valuable insights into the fuel quality of biodiesel (CGBD) derived from coriander (Gürbüz registered variety) crude oil and its potential adherence to the EN 14214 standard. A comprehensive analysis of various physicochemical properties was conducted, and the findings are crucial in evaluating the suitability of CGBD as a viable alternative fuel source for diesel engines.

Overall, the results of this study demonstrate that CGBD exhibits fuel quality characteristics remarkably close to conventional diesel fuel. The similarities in key parameters, such as calorific value and viscosity, suggest that CGBD could serve as a suitable substitute for diesel fuel in various applications, particularly in diesel engines. These findings are promising and support the feasibility of utilizing CGBD as a renewable and environmentally friendly fuel source, contributing to the reduction of greenhouse gas emissions and promoting sustainable energy solutions. Further research and field testing may be necessary to fully validate the practical use of CGBD in diesel engines.

5. Conclusions

In this study, the parameters related to the fuel quality of biodiesel (CGBD) produced from coriander (Gürbüz registered variety) crude oil were investigated. CGBD biodiesel was examined whether it meets the requirements specified in (EN 14214) standard.

The physicochemical properties analyzed for the KGBD fuel sample were kinematic viscosity ($mm^2\ s^{-1}$) (at 40 ^{0}C) 4.95, density ($kg\ m^{-3}$) (at 15 ^{0}C) 869.9, water content ($mg\ kg^{-1}$) 75, calorific value ($Mj\ kg^{-1}$) 39. 32, flash point (^{0}C) 140, cloud point (^{0}C) (-13.8), cold filter plugging point (^{0}C) (-16), pour point (^{0}C) (-16.8), copper strip corrosion (3h at 50^{0}C) 1a and color (ASTM D1500) 1.9. According to the results obtained, the fuel quality of biodiesel produced from coriander (Gürbüz registered variety) crude oil showed values close to the fuel quality of diesel. According to these results, it can be said that CGBD fuel can be used in diesel engines.

Author Contributions: "Conceptualization, S.Ş. and T.E.; methodology, S.Ş., T.E., B.C.Ş. and T.U.; validation, S.Ş., T.E., B.C.Ş. and T.U.; formal analysis, S.Ş. and T.E; investigation, B.C.Ş. and T.U.; resources, S.Ş., T.E., B.C.Ş. and T.U; data curation, S.Ş., T.E., B.C.Ş. and T.U; writing—original draft preparation, S.Ş., T.E., B.C.Ş. and T.U.; writing—review and editing, S.Ş., T.E., B.C.Ş. and T.U.; visualization, S.Ş.; supervision, S.Ş.; All authors have read and agreed to the published version of the manuscript."

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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