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Determining the performance, emission and combustion properties of camelina biodiesel blends

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ABSTRACT

In the present study, the effects of two different camelina biodiesel fuels obtained through transesterification on engine power and torque performance and emissions and fuel combustion characteristics of these fuels compared to diesel fuel were determined particularly focusing on new blend ratios of B7 and B100, which the European Union has been specifically studying on.

Heat release rate calculations, which are an important parameter for the engine characterizing the combustion process that occurs depending on cylinder pressure and crank angle, and mass fraction burned (MFB) in each individual engine cycle, which describes the process of chemical energy release as a function of crank angle, were determined in the study. Maximum HRR (Heat Release Rate) at 2500 rpm and 4000 rpm was found as 35 J/Crank Angle Degree.

MFB values at 2500 rpm and in blends were found as 100% after 30° (ATDC), at 4000 rpm as 100% after 34° (ATDC). Temperature variation depending on crank angle and blends was found to be a maximum of 1900 K after 18° (ATDC).

1. Introduction

Conventional transportation fuels from petroleum are one of the primary sources of greenhouse gas (GHG) emissions that promote global warming. Renewable fuels including ethanol, biodiesel, and jet fuel are practical and effective alternative energy sources.

Biodiesel production is an important area of research due to the increasing petroleum prices and the environmental advantages of biofuels. Biodiesel, a low-emission renewable fuel made from biomass resources, has recently attracted great interest as one of the best substitutes for diesel fuel [1].

The distinct advantages of Biodiesel include its derivation from renewable and waste feedstock's, a higher cetane number, biodegradability, lower sulfur and aromatic content, and lower emissions of carbon monoxide, unburned hydrocarbons and particulate matter. Soy, rapeseed, sunflower and palm oil have a significant place in global vegetable oil production [2]. Sunflower, soy, safflower, sesame, peanut and poppy are cultivated in Turkey. However, it is inevitable to diversify the cultivation of oil crop plants for sustainable production. Camelina plant (Camelina sativa (L.) Crantz) is also among these vegetable oil sources. Today, it is called with different names as "False Flax", "German Sesame" and "Siberian Oil Seed". In recent years, there has been a revival in the cultivation of this plant as oil crop because of the positive agricultural sustainability observed due to its planting process carried out in spring. At present, the oily seed obtained from camelina plant still cannot be sufficiently utilized [3–11].

In comparison with common oilseed crops, camelina has lower agriculture input, such as lower water, pesticide and fertilizer requirements, and higher cold-weather tolerance. Furthermore, camelina seeds have oil content as high as 28–40%, which makes camelina a high oil-bearing crop [12–22].

Therefore, the use of camelina oil as feedstock for biodiesel production can greatly reduce the production cost of biodiesel and offer some environmental benefits. Camelina is an old cultigen belonging to Brassicaceae family and is an alternative oil plant that can utilize the marginal areas in Turkey [20,23]. Unsaturated fatty acids ratio of camelina oil is higher than that of other widely used vegetable oils such as soy, sunflower and safflower oil. Furthermore, similar to flaxseed oil (which includes 50–55% of α-linoleic acid), camelina oil has high ratios of polyunsaturated fatty acids. Camelina is an important biofuel source owing to its distinctive fatty acid composition [24–27].

Camelina sativa oil is a good base for the production of esters that fulfill high standards of second generation renewable fuels. The camelina methyl ester has properties similar to the rapeseed

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Nomenclature

ASTM	American Standards for Testing Materials
ATDC	after top dead center
BSFC	Brake Specific Fuel Consumption (g/kW h)
CO	carbon monoxide
CO_2	carbon dioxide
D	100% diesel fuel
B7	7% biodiesel, 93% diesel by volume
B100	100% biodiesel
HC	hydrocarbon
NOx	nitrogen oxides
LHV	lower heating value (MJ/kg)
MFB	mass fraction burned
PM	particulate matter
ppm	particulate per million
rpm	revolution per minute
HRR	heat release rate

methyl ester with the exception of its high iodine value and is stable in airtight containers with periodic openings for at least 18 months, even without natural antioxidants [28–36]. Because of the excessive use of petroleum derivative fuels and environmental concerns, the US searched for alternative and renewable energy sources. Gas fuel jet diffusion flame is extensively used in the application industry owing to its wide combustion stability. However, high pollutant emission levels are an important deficiency of this type of flame [37]. Jet fuel obtained from camelina oil was subjected to detailed tests in commercial airlines and military flights by the USA. Compared to petroleum-based jet fuels, camelina-based "hydro treated" jet fuel met the expectations for all jet engine performances and significantly decreased the greenhouse gas emissions [2,38–42].

When previous studies were examined, it was seen that there were no studies on the use of camelina biodiesel in a diesel engine with a common rail injection system. In the present study, the effects of two different camelina biodiesel fuel ratios obtained through transesterification on engine power and torque performance and emissions and fuel combustion characteristics of these fuels compared to diesel fuel were examined particularly focusing on new blend ratios of B7 and B100, which the European Union has been specifically studying on.

Heat release calculations were performed in order to better observe the combustion characteristics associated with cylinder pressure and crank angle of the engine and the combustion process.

2. Material and method

2.1. Fuel

Diesel fuel and camelina oil were used as material in this study. The properties of raw camelina oil and diesel fuel are presented in Table 1. Camelina seeds obtained after the harvest were subjected to hot press at 85 °C to produce raw oil. The raw oil was filtered and biodiesel was obtained through transesterification by using methanol as alcohol and NaOH as catalyzer. EN 14214 standard test methods were taken as reference in measuring the obtained values [43–45].

The raw oil values obtained for camelina oil show similarities with small deviations with the findings obtained in previously-conducted studies on this topic [28,29].

2.2. Density measurement

The density measurement experiment was conducted by using the KEM Density/Specific Gravity Meter DA-505. The device operates through resonant frequency measuring method. The measuring range is 0–3 g/cm^3, operating temperature is 4–90 °C, margin of error in density measurements is ±0.00005 g/cm^3, manual measuring time is 1–4 min and 2–10 min in programming code.

Table 1
Comparison of the properties of raw camelina oil and diesel fuel.

Properties	Raw camelina oil	Diesel
Density 15 °C (kg/m^3)	918	838
Kinematic viscosity 40 °C (mm^2/s)	24	2.92
Flash point (°C)	>220	102
Lower heating value (MJ/kg)	38	42.3
Ash (% mass)	0.0025	0.01
Sulfur (mg/kg)	13.85	9
Water content (mg/kg)	710	43.8
Acid value (mg KOH/g)	1.39	–
Iodine number (g · I_2/100 g)	151.5	–

2.3. Measuring calorie value

IKA Calorimeters C200 device was used to measure the upper heating values of the experimental fuels. The technical specifications of the calorimeter are presented in Table 2.

2.4. Kinematic viscosity measurement

The device used for kinematic viscosity measurement was Koehler K23377 model with operating temperature range between 25 and 150 °C and a temperature sensitivity of ±0.01. Viscosity measurement can be performed according to ASTM D 445, DIN 51550 and ISO 3104 standards.

2.5. Engine tests

A 1.9 multijet diesel engine was used in engine tests (Table 3). The tests were carried out on the hydraulic engine dynamometer with the specifications presented in Table 4.

All the tests were conducted at full-throttle opening. Before starting the tests, the engine was operated until it reached a stable condition. Afterward, the experiments were started. Engine power, engine torque, specific fuel consumption and engine cylinder inner pressure values were measured simultaneously. Cylinder inner

Table 2
Technical specifications of IKA Calorimeters C200 device.

Measuring range	40.000 J (max)
Dynamic measuring time	8 min
Isoperibolic measuring time	17 min
Operating temperature	20–25 °C
Operating environment humidity	%80 (max)
Oxygen pressure max.	30 bar
Printer connection	Parallel
Computer connection	RS232