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Emission Characteristics of Tea Seed/Soybean/Cotton Seed Biodiesel Blends

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Abstract. This study examines fuel properties and emission characteristics of diesel engine fueled with three different biodiesel mixtures (tea seed, soybean, cotton seed oils) and their blends with diesel fuel. The fuel properties of biodiesel blends were measured according to ASTM and EN standards. Cetane number and pour point of tea seed-soybean-cotton seed (T-S-C) biodiesel blends were found out of standard ranges. Blend with tea seed (20%) - soybean (20%) – cotton seed (20%) - diesel (40%) reached acceptable fuel properties (kinematic viscosity 3.9 mm^2/s, cetane number 52.8, pour point -6 ℃). While CO and CO_2 emissions were reduced, NO_x emissions were increased with increasing biodiesel contents in blends. As a result, diesel usage was minimized to 40% by blending it with trio biodiesel.

Keywords: Biodiesel, diesel, fuel blend, trasnesterification, emission.

1. Introduction

Biodiesel, renewable clean bio-energy, can be produced from vegetable oils, animal fats or used cooking oil which is reacted with alcohol to form esters (biodiesel) and glycerol [1], [2]. Biodiesel, being biodegradable and non-toxic, is also essentially free of sulfur and aromatics, producing lower exhaust emissions than conventional gasoline whilst providing similar properties in terms of fuel efficiency [3], [4].

Biodiesel can be produced via the transesterification method. Biodiesel can be blended with diesel fuels and used in diesel engines with no or little modifications [5]-[8]. Various studies on biodiesel production and also its usage in internal combustion engines are available in the literature [9]-[17]. Required fuel specifications of biodiesel are announced with ASTM D 6751 and EN 14214 standards. Density effects directly on engine performance characteristics. Cetane number and heating value are related with density [9]-[11]. Fuel properties influence efficiency of fuel atomization [15]. So, change of fuel density will influence engine output power due to a different mass injected fuel [12]-[14].

Biodiesel can be produced by various feedstokes; while soybean biodiesel getting first place in America continent, tea seed and cotton seed oils are preferential in Turkey. In general, soybean and tea seed biodiesels have good quality of fuel specifications. But, cotton seed oil biodiesel has a cold weather operation disadvantage. Its pour point (8 ℃) is critical to use in internal combustion (IC) engine injection systems especially in winter conditions. On the other hand, tea seed oil, as well as different vegetable oils, has lower pour point [16]-[19] and it is one of the cheapest vegetable oil feedstocks with average price, 514 US$/ton [16].

This study examines fuel properties of blend of tea seed, soybean, and cotton seed (T-S-C) biodiesels to improve fuel properties of biodiesel blends with diesel at different ratios and their emission effects on usage in diesel engine.

2. Experimental Section

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Experimental study was conducted in Petroleum Research and Automotive Engineering Laboratories of Department of Mechanical Engineering in Cukurova University. Soybean and cotton seed oils were supplied from Turkish oil sources and used for biodiesel production. The samples of tea seed were supplied from Trabzon, a north region city of Turkey, and used as a raw material for tea seed biodiesel production [19].

Biodiesels were produced with transesterification using methyl alcohol and sodium hydroxide (NaOH) as a reactant and catalyst. Chemicals used during experiments were purchased from Merck and methanol was purified prior to use. Transesterification was carried out in a spherical glass reactor equipped with reflux condenser, stirrer and thermometer. Molar ratio of alcohol to oil was 6:1 for all sample oils. The first transesterification process was carried out at the following optimized conditions: methanol, 20 wt %; sodium hydroxide, 0.4 wt %; reaction temperature, 60 ℃; and reaction time, 60 min. Same steps were used for soybean and cotton seed oils. Two step reactions were performed for transesterification of tea seed oil because of high free fatty acid content (2.7%). The second process conditions: methanol, 10 wt %; sodium hydroxide, 0.25 wt %; reaction temperature, 60 ℃; and reaction time, 60 min. Diesel fuel within EN 590 forms was purchased and used.

The experiments were performed on a commercial four-cylinder, four stroke and direct injection diesel engine (Table 1). Before the tests, the engine was operated for 15 minutes with diesel fuel to reach the steady state operation condition temperature. In order to measure the exhaust emissions (CO, NO_x and CO_2), a Testo 350-S flue gas analyzer was used. Measurement accuracy of the gas analyzer is ±1 ppm for CO, 0.1% for CO_2 and ±1 ppm for NO_x. Measurement capacity of the device is 0-10000 ppm for CO, 0-3000 ppm for NO_x and 0-50% for CO_2 emission.

Table 1: Engine specifications

Engine	
Brand	Mitsubishi Canter
Model	4D34-2A
Configuration	In line 4
Type	Direct injection diesel with glow plug
Displacement	3907 cc
Bore	104 mm
Stroke	115 mm
Power	89 kW @ 3200 rpm
Torque	295 Nm @ 1800 rpm
Oil Cooler	Water cooled
Weight	325 kg

Instruments used for analyzing the product are; Zeltex ZX 440 NIR petroleum analyzer with an accuracy of ±0.5 for determining cetane number; ISL CPP 97-2 with an accuracy of ±0.5 ^oC for pour point; Koehler Saybolt viscosity test for determining the viscosity; Kyoto electronics DA-130 for density measurement, Tanaka flash point control unit FC-7 for flash point determination and IKA Werke C2000 bomb calorimeter for determination of heating value.

3. Results and Discussions

3.1. Fuel Properties

While cetane numbers of tea seed and cotton seed biodiesels are acceptable, soybean biodiesel has a lower cetane number according to ASTM and EN standards (Table 2). Pour point values of soybean and especially cotton seed biodiesel is another problem for pure usage of these biodiesels in diesel engines at low temperature conditions. To minimize diesel fuel usage, either blending with diesel or using additives for biodiesel fuels may be initial ways to enhance characteristics of biodiesels. Different biodiesels are blended within different ratios to compensate specifications, which are out of standards (Table 3). At first, a blend without diesel fuel was prepared for fuel specification examination. Cetane number of Blend No.1 is out of

EN 14214 biodiesel standards but it is so close to the limits (Table 4). Main subject is to use lowest rate of diesel fuel; Blend No.2 is outside of this objective with its 70% of diesel fuel. When Blends No. 3 is examined, all fuel specifications are seen avaliable within ASTM and EN standards.

Table 2: Fuel specifications of biodiesels

Properties	Tea seed biodiesel	Soybean biodiesel	Cotton seed biodiesel	ASTM D 6751	EN 14214	Diesel	EN 590
Density, g/cm^3	0.884	0.884	0.886	-	860–900	0.831	820-845
Cetane Number	51.1	45.1	54.8	Min. 47	Min 51	55.7	Min. 51
Flash Point, ℃	165	210	160	Min.130	Min. 101	67.5	Min. 55
Pour Point, ℃	-5	1	8	-	-	-17	
Higher heating value, kJ/kg	37502	39195	39520	-	-	44524	
Kinematic viscosity, mm^2/s	4.9	4.2	4.6	1.9–6.0	3.5 - 5.0	2.8	2-4.5

Table 3: Blend variations

Blends Fuels	Blend No.1 Contents (%)	Blend No.2 Contents (%)	Blend No.3 Contents (%)
Tea seed biodiesel	33.3	10	20
Soybean biodiesel	33.3	10	20
Cotton seed biodiesel	33.4	10	20
Diesel	-	70	40

Table 4: Fuel specifications of blends

Properties	Blend No.1	Blend No.2	Blend No.3	ASTM D 6751	EN 14214
Density, g/cm^3	0.885	0.848	0.863	-	860–900
Cetane Number	50.4	54.2	52.8	Min. 47	Min 51
Flash Point, ℃	167.5	68.5	68.5	Min.130	Min. 101
Pour Point, ℃	1	-12	-6	-	-
Higher heating value, kJ/kg	38840	42970	41524	-	-
Kinematic viscosity, mm^2/s	4.6	3.4	3.9	1.9–6.0	3.5 - 5.0

3.2. Emissions

The variation of CO emission with the test fuels are presented in Figure 1. In comparison with diesel fuels, CO emissions showed a trend of decreasing with the increase in biodiesel blend ratios. Average rates of decreases in CO emission were 7% with Blend No 2, 11% with Blend No 3 and 17% with Blend No 1, respectively. CO emission decreased, due to fuel properties of biodiesel such as higher oxygen content which promote the complete combustion [20]. Similar reductions on CO emissions were also reported by researchers [1], [19] while testing different biodiesels.

NO_x emissions of the test fuels are shown in Figure 2. Compared to diesel fuel, NO_x emissions for Blend No 2 did not changed significantly. However, NO_x emissions with Blend No 3 and Blend No 1 showed a trend of increasing. The reason for the increase of NO_x emissions is the higher oxygen content of biodiesel which provides better combustion, and as a consequence, the combustion temperature increases and provides additional oxygen for NO_x formation [8], [17].

CO_2 emissions of test fuels are presented in Figure 3. In comparison with diesel fuel, usually CO_2 emissions are decreased depending on the rate of biodiesel in test fuels, because of lower elemental carbon to hydrogen ratio of biodiesel against to diesel fuel. The lowest value of CO_2 emission obtained was 4.30% with Blend No 1 at 2800 rpm.

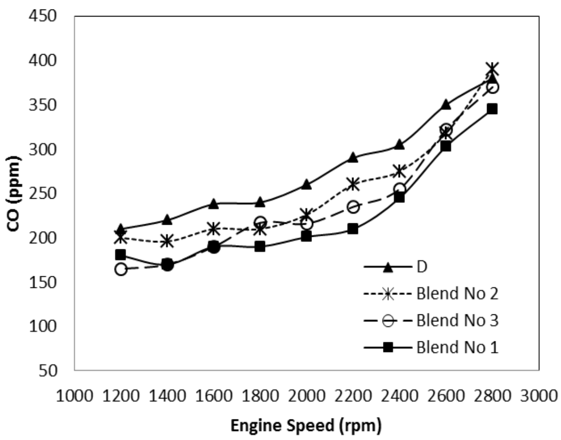

Fig. 1: CO emissions values at full load condition

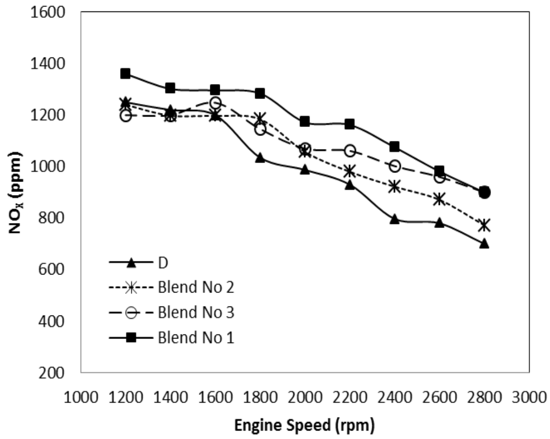

Fig. 2: NO_x emissions values at full load condition

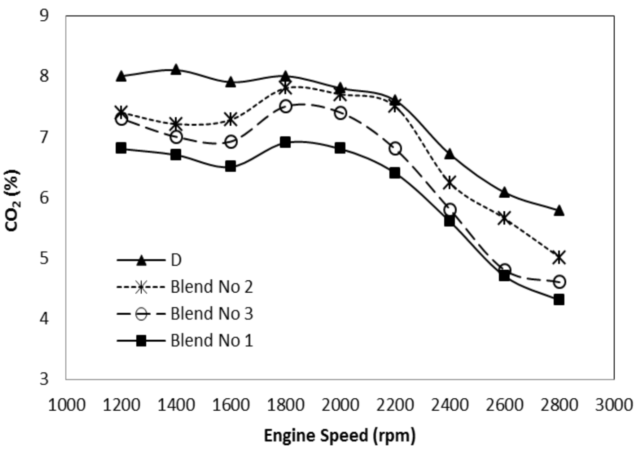

Fig. 3: CO_2 emissions values at full load condition

4. Conclusions

The following conclusions can be drawn from the experimental results:

Fuel properties tests showed that, density, cetane number, flash point, pour point, heating value, kinematic viscosity values of Blend No.3 were found suitable for ASTM and EN standards.

According to the emission test results; CO and CO_2 emissions showed a trend of decrease with the increase in biodiesel blend ratios; whereas, NO_x emissions showed a trend of increase.

Therefore it can be concluded that diesel fuel usage minimized to 40% by blending it with tea seed/soybean/cotton seed biodiesels together.

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