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Design of a Small Scale Pilot Biodiesel Production Plant and Determination of the Fuel Properties of Biodiesel Produced with this Plant

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ABSTRACT

A small scale pilot biodiesel production plant that has a volume of 65 liters/day has been designed, constructed and tested. The plant was performed using oil mixture (OM) (50% wild mustard seed oil+50% refined canola oil) and methanol with sodium hydroxide (NaOH) catalyst. The fuel properties of biodiesel indicated as density at 15°C (889.64 kg m^{-3}), kinematic viscosity at 40°C (6.975 mm^2 s^{-1}), flash point (170°C), copper strip corrosion (1a), water content (499.87 mg kg^{-1}), and calorific value (39.555 MJ kg^{-1}), respectively.

Introduction

Energy sources are classified into seven groups, such as kinetic, physical, thermal, chemical, ray, nuclear, and fission energy. In addition, energy is separated into two groups: renewable and non-renewable energy (Haktanirlar Ulutas, 2005; Aksoy et al., 2010a; Kus, 2011). A significant part of the demand for energy, which has been increasing day by day, is met through fossil based fuels around the world. In parallel with the increase in energy consumption, an increase is observed in the amount of product of combustion, leading to environmental problems (Aydogan et al., 2011). Because of the effects resulting from traditional energy sources, such as the greenhouse effects, environmental pollution, reducing dependence on traditional energy sources, and the associated environmental damage, research on the development and application of renewable energy sources has become a matter of great importance recently (Aksoy et al., 2010b).

Renewable energy sources become the need of today and biodiesel is one of them. Biodiesel, being biodegradable and non-toxic, is also essentially free of sulfur and aromatics, producing lower exhaust emissions than diesel whilst providing similar properties in terms of fuel efficiency (Ozcanli and Serin, 2011). Biodiesel can be produced from vegetable, animal and algae oil. While there are various methods for biodiesel production, transesterification is the most commonly used method (Eryilmaz and Ogut, 2011). It is known as a chemical reaction of a vegetable oil or animal fat with an alcohol, such as methanol. The reaction requires a catalyst, usually a strong base, such as sodium or potassium hydroxide, and produces new chemical compounds called methyl esters (Ozcanli et al., 2013). Biodiesel can be used in compression ignition (diesel) engines with little or no engine modifications (Oseni et al., 2013).

Biodiesel production plants are either stirred by an electric motor driving an impeller or by a recirculation pump. Production is either done by batch or continuous method (Daniyan et al., 2013).

The principal aim of present study is to design and manufacture a small scale pilot biodiesel production plant for Bozok University Engineering-Architecture Faculty Biosystems Engineering Department Biofuel Laboratory and produce biodiesel from 50% wild mustard seed crude oil (WMO) and 50% refined canola oil (RCO) mixture in this plant. Then, the fuel properties of biodiesel were determined and compare with EN 14214 standards.

Materials and Methods

Design of a Small Scale Pilot Biodiesel Production Plant

The biodiesel pilot plant consists of oil tank, reactor with heater and stirrer, methoxide tank with circulation pump, pure water tank with heater and stirrer, washing/conditioning tank with heater and stirrer, pure biodiesel tank, waste water tank and glycerol tank. The capacities of oil tank, reactor, methoxide tank, pure water tank, washing/conditioning tank, pure biodiesel tank, waste water tank, glycerol tank are 65 liters, 105 liters, 23 liters, 65 liters, 105 liters, 65 liters, 65 liters and 65 liters, respectively. The small scale pilot biodiesel production plant project is shown in Fig. 1.

Preparing of oil mixture

Wild mustard (*Sinapis arvensis* L.) seed were purchased from local market in Konya, Turkey (Fig. 2). Wild mustard seed crude oil (WMO) was obtained from the seeds produced by using a screw press with Koprulu Machine brand 2.2 kW electrical motors and with oilcake output of 6 mm. Wild mustard seed was pressed at 50-55°C head temperature and 6.97% humidity (Fig. 3).

Refined canola oil was taken from a local oil plant. WMO (50%)-RCO (50%) oil mixture were used for biodiesel production. When mixing WMO and RCO, first 50% WMO was put in, than 50% RCO has been added. The mixture was tried to be made homogenous first with laboratory type IKA brand Yellow line OST basic model mixer at 1500 min^{-1}, then with Yellow line brand DI 18 basic model homogenizer at 24000 min^{-1}, for 7.5 minutes each, for a total of 15 minutes. Following this, WMO (50%)-RCO (50%) oil mixture has been acquired (Fig. 4) (Eryilmaz, 2009).

Biodiesel Production in a Small Scale Pilot Biodiesel Production Plant

To produce biodiesel, 20 liters of oil mixture (50% WMO-50% RCO) was put into oil tank in a small scale pilot biodiesel production plant (Fig. 5). From this tank oil was transferred to reactor tank with helping gravity effect. In the reactor, the oil was heated up to 65°C. Temperatures of tanks were kept stable by thermostat controlled units during reaction. 4 liters of methyl alcohol (CH_3OH) which equals to 20% of the total volume of the oil mixture was used and 70 gram sodium hydroxide (NaOH) was used as a catalyst at rate of 3.5 g l^{-1}. For reaction, methyl alcohol and sodium hydroxide were resolved in methoxide tank and methoxide was obtained. It was mixed with oil at 100 min^{-1} for 90 minutes. After that, mixer and heater were stopped. We waited for 60 minutes for precipitation of glycerol and glycerol was taken approximately 15%. The temperature of crude biodiesel was heated up to 75°C and 0.5 liters of methyl alcohol was regained with the help of heat exchanger. Crude biodiesel in the reactor was transferred to washing/conditioning tank and was kept there for 10 hours so that the remaining glycerol can deposit and the end of 10 hours, glycerol was taken. During washing up, the temperature of biodiesel was 50^{o}C and 4 liters of pure water at 50°C was used for washing as well. After washing process, we waited for 10 hours for the sedimentation of the water. Depositing water was taken to waste water tank. Drying was performed at 120°C under vacuum for 2 hours. Thus, biodiesel was produced from oil mixtures (50% WMO-50% RCO).

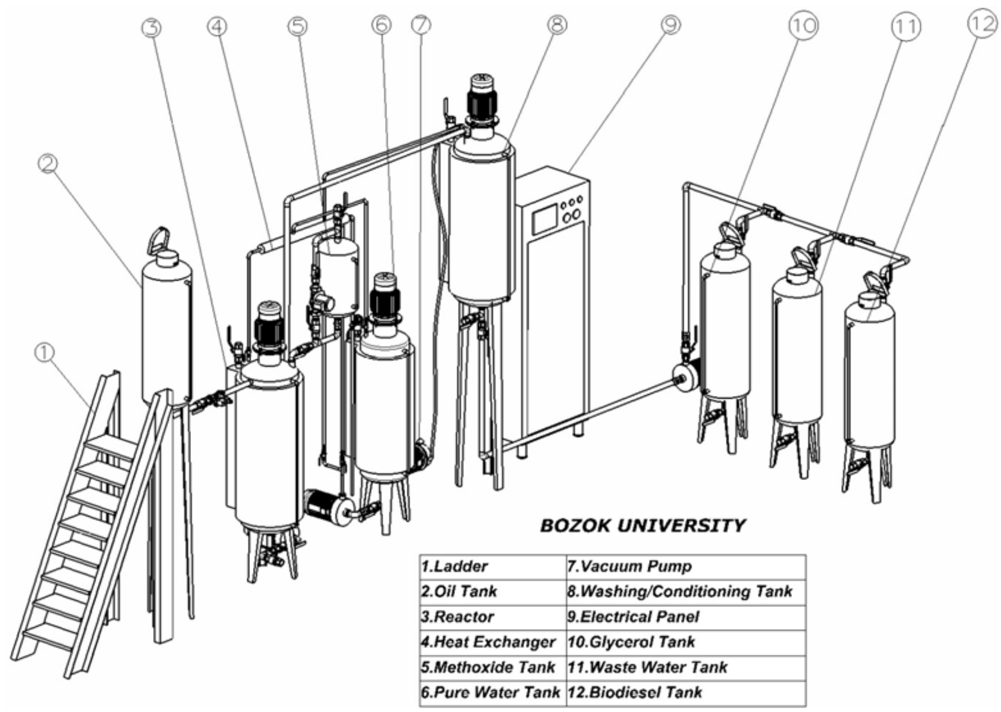

Figure 1 A small scale biodiesel production plant project

Figure 2 Wild mustard (*Sinapis arvensis* L.) seeds

Figure 3 A screw press

a b c

Figure 4 a)Wild mustard seed oil (WMO) b)Refined canola oil (RCO) c)Oil mixture (OM) (50%WMO+50%RCO)

Figure 5 A small scale pilot biodiesel production plant

Results and Discussion

In this study which was carried out using wild mustard (*Sinapis arvensis* L.) seed, 25.5% of oil was obtained from a screw press. The moisture content of seeds was measured as 6.97%. 6 mm of oil cake output was used and the calorific value of wild mustard seed oil cake was measured as 22.909 MJ kg^{-1}. After that, WMO and RCO were mixed and used for biodiesel production. The fuel properties of oil mixture, B100 and of the diesel used as reference were given in Table 1.

As a result of the analysis of the oil mixture, its density was found to be 917.86 kg m^{-3}, flash point was 219^{o}C, copper strip corrosion was 1a, water content was 357.90 mg kg^{-1}, heating value was 39.924 MJ kg^{-1}, and kinematic viscosity was 39.631 mm^2 s^{-1}, respectively. As a result of the analysis of the biodiesel from oil mixture, its density was found to be 889.64 kg m^{-3}, flash point was 170^{o}C, copper strip corrosion was 1a, water content was 499.87 mg kg^{-1}, heating value was 39.555 MJ kg^{-1}, and kinematic viscosity was 6.975 mm^2 s^{-1}, respectively. As can be seen in the results only kinematic viscosity is higher than EN 14214 standard and the other fuel properties of oil mixture (50% WMO+50% RCO) biodiesel is within the limiting values specified in EN 14214.

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Table 1 Fuel properties of diesel, B100 and oil mixture

Property	Unit	OM	B100	EN 14214	Diesel
Density at 15°C	kg m^{-3}	917.86	889.64	860-900	823.41
Kinematic viscosity at 40°C	mm^2 s^{-1}	39.631	6.975	3.5-5.0	2.641
Flash point	°C	219	170	>101	59
Water content	mg kg^{-1}	357.90	499.87	<500	36.757
Copper strip corrosion (3h at 50°C)	-	1a	1a	1	1a
Calorific Value	MJ kg^{-1}	39.924	39.555	>35*	45.082

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