BIODIESEL FUEL OBTAINED FROM SUNFLOWER OIL AS AN ALTERNATIVE FUEL FOR DIESEL ENGINES

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Abstract: In this study, an alternative diesel fuel, of which chemical modification was made by transesterification with short chain methyl alcohols, was produced from sunflower oil, a designated as B100. The modified products were then evaluated according to their fuel properties as compared to diesel fuel. The fuel properties considered were viscosity, pour point, calorific value, flash point, and cetane number in addition to some other properties. The effects of sunflower oil methyl ester (biodiesel) and diesel fuel on a direct injected, four strokes, single cylinder diesel engine performance were studied. The results showed that the performance of the engine using biodiesel fuel differed very little from the engine's using diesel fuel.

Keywords: diesel engine, alternative fuel, biodiesel fuel, performance.

Introduction

The prevalence of internal combustion engines and subsequent developments in engine technology have led to wide spread consumption of the petroleum fuels. Due to the shortage of petroleum products and its increasing cost, many efforts are put on the stage to develop alternative fuels, especially for fully or partial replacement of diesel oil. The high cost of petroleum and petroleum crises have brought much pressure on many countries to re-evaluate their national energy strategies. Thus energy conservation and alternative fuels research are given high priority in energy planning in some countries. Many studies have been performed in developed countries and elsewhere involving vegetable oils as a primary source of energy. Particularly, during the early 1980's, studies on the possibility of using unmodified vegetable oils as a diesel fuel were conducted.

Since the petroleum crises in 1970's and 1980's, rapidly increasing petroleum prices and uncertainties concerning petroleum availability, a growing concern of the environment, and the gases affecting global warming have attracted more interests in the use of vegetable oils as a substitute of diesel fuel. The acceptability of vegetable oils as diesel fuel has been evaluated for the first time in the 70th years because of the well known energy crises. Thus energy conservation and alternative fuel researches are given high priority in energy planning in some countries. Several studies conducted worldwide have shown that vegetable oil, without any modification on diesel engine, can give performances comparable with those of diesel fuels. The most important advantage of vegetable oils is that they are renewable energy sources compared to the limited resources of petroleum. Many of these studies are on vegetable oils to be used in diesel engines (Labeckas et al. 2005), (Ryu et al. 2004), (Rakopoulos et al 1992), (Lapuerta et al 2005), (Huzayyin et al 2004), (Hebbal et al 2006), (Geyer et al 1984), (Yoshimoto et al 2002). It has been found that the vegetable oils are promising fuels because their properties are similar to diesel and can be produced easily from the crops (Jung et al 2004), (Zou et al 2003), (Nagaraj et al 2002).

Vegetable oils are non-toxic renewable sources of energy, which do not contribute to the global CO_2 buildup. Vegetable fuels can be used as an emergency energy source in the event of any petroleum shortage. Extensive studies on alternative fuels for diesel engines have been carried out since the fossil based fuels are limited. Common vegetable oils are sunflower, cottonseed, olive, soybean, corn, nut, leenseed and sesame oils. The most produced ones in Turkey are sunflower, cottonseed, corn, soybean, olive and nut oils.

Sunflower and other vegetable seeds release oil on compression processes. During the processes of compression of these seeds and final storage, many fatty acids are formed (Gunstone et al 2003), (Bikou et al 2003), (Warner et al 1997), (Yücesu et al 2006). These are palmitic, stearic, oleic, lynoleic, arachidic and behenic acids. Sunflower oil also contains some fatty acids like other vegetable oils. The chemical formulations and the percentage of sunflower oil and some other oils fatty acids are given in Table 1.

Table 1. Fatty acid composition of sunflower oil in comparison with other vegetable oils

Component	Chemical Bond	Chemical equation	Sunflower oil	Cottonseed oil	Soybean oil	Corn oil
Palmitic acid	16:0	C16H32O2	23	22	17	12
Stearic acid	18:0	C18H36O2	3	2	3	2
Oleic acid	18:1	C18H34O2	24	25	26	25
Linoleic acid	18:2	C18H32O2	49	50	54	60
Linolenic acid	18:3	C19H32O2	1	1	3	1

The melting point of fatty acids rises with the length of the structural chain of acid. Some vegetable oil contains high concentrations of less common fatty acids. Physical properties of sunflower oil used in this study in comparison with other some vegetable oils are given in Table 2. These oils are almost entirely consumed in foods. The excess of these could be used as diesel fuel besides consuming in foods.

Table 2. Physical properties of sunflower oil in comparison with other some vegetable oils

Properties	Sunflower oil	Cottonseed oil	Soybean oil	Corn oil
Density @ 26ºC (Kg/lt)	0.918	0.912	0.92	0.91
Viscosity(mm^2/s) at 26°C	34	35	34	36
Flash point (°C)	220	210	230	280
Calorific value (kJ/kg)	39500	39450	39600	39550
Setan number	36	42	38	37
Acid value	0.15	0.11	0.20	0.16
Sulphur value (%)	0.01	0.01	0.01	0.01

It has been shown that pure vegetable oils have harmful effects on engine parts and cause a starting up problem (Engler et al 1983), (Schlick et al 1988), (Ramadhas et al 2005), (Muñoz et al 2004), (Bari et al 2002), (Goodrum et al 2005), (Dorado et al 2002), (Krishna et al 2004). The problems due to the viscosity and density of the vegetable oils having different physical and chemical properties from the diesel fuel should be eliminated by making them less viscous. High viscosity of the vegetable oils and its tendency to polymerise within the cylinder are major chemical and physical problems encountered. With this aim, it is necessary to obtain either esters or emulsions of vegetable oils (Bhattacharyya et al 1994), (Agarwal et al 2001), (Barnwal et al 2005), (Schwab et al 1987). Vegetable oils can be used as material to produce methyl or ethyl ester. There are several methods for producing of ester; and the best method is known as transesterification (Freedman et al 1986), (Mittelbach et al 1999), (Schuchardt et al 1998), (Ramadhas et al 2005), (İlkılıç et al 2005), (Megahed et al 2004), (Dorado et al 2004), (Encinar et al 2002), (Noureddini et al 1997), (Ma et al 1999), (Harrington et al 1985).

Experimental procedure

Transesterification is the most frequently applied method of industrial ester production. A strong acid can be used in transesterification process. Vegetable oils' methyl or ethyl ester is considered as a promising alternative fuel for the reduction of pollutant from diesel engines. Biodiesel can be used in any diesel engine in pure form or blended with diesel fuel at any rate. Even a blend of 20% biodiesel and 80% diesel fuel will significantly reduce carcinogenic emissions by 27% and gases that may contribute to global warming up (Petrowski, 2002). Biodiesel fuel production from sunflower oil has been studied as an alternative fuel for compression ignition engines. Detailed reviews about biodiesel fuel production processes are available in the literature. In this study, crude sunflower oil was obtained from the oil processing factory of Karadeniz Birlik, Elazığ, Turkey. Diesel fuel was obtained from a commercial gas station in Elazığ, Turkey. The biodiesel fuel produced by a transesterification technique was further reacted by using a peroxidation process. Physical properties of crude sunflower oil (CSO), Biodiesel (B100) fuel, and diesel fuel are given Table 3.

Table 3. Physical properties of crude sunflower oil (CSO), biodiesel fuel (B100) and diesel fuel

Properties	CSO	Biodiesel	Diesel fuel
Density @ 26°C (Kg/lt)	0.918	0.89	0.84
Viscosity (mm^2/s)@ 26 °C	34	4.5	3.2
Flash point (°C)	220	85	59
Calorific value (kJ/kg)	39342	40565	42980
Setan number	36	74	56
Acid value	0.15	0.13	0.22
Percentage of H (%)	11.67	12.19	15.10
Percentage of C (%)	77.46	76.66	84.90
Percentage of O (%)	10.87	11.15	-

B100 fuel prepared in laboratory conditions was tested in an engine of which technical data is detailed in table 4.

Table 4. Lombardini Diesel Engine Details.

Type	6LD 400 Lombardini
Number of cylinder	1
Cylinder diameter	86 mm
Stroke	68 mm
Clearance volume	395 cm^3
Compression ratio	18:1
Maximum speed	3600 l/min
Maximum power	6.2 kW @ 3600 l/min
Maximum torque	20 N.m @ 2200 l/min
Fuel tank capacity	4.3 lt
Oil consumption	0.0115 kg/h
Cooling	air
Injection timing	30 BTDC
Injection opening pressure	200 kg/cm^2
Starting	by dynamometer
Dry weight	45 kg

Tests were held on a laboratory test bed which consisted of an electrical dynamometer, an exhaust gas analyzer, a data acquisition system and engine mounting elements, as shown in Fig. 1. Diesel fuel and biodiesel fuel were compared for their fuel properties and their engine performance.

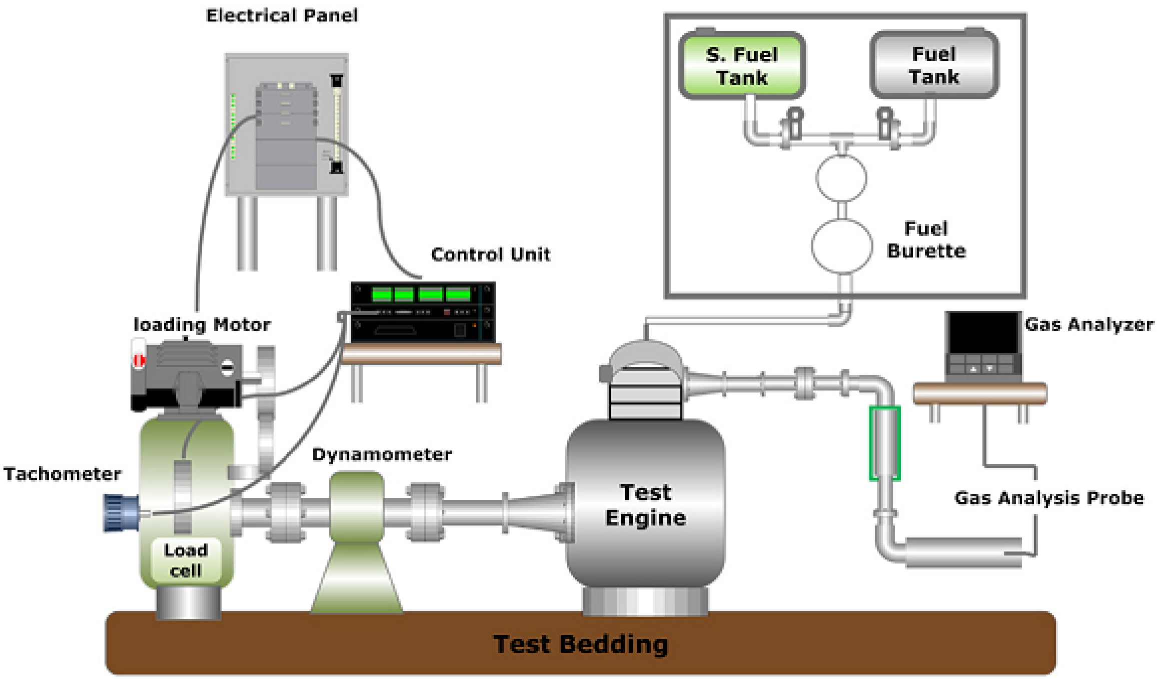

Figure 1. Schematic layout of the engine test system

Results and discussions

The engine power

During the injection period, the injection conditions such as injection pressure, nozzle size, and injection rate may vary. The droplet size distribution in the spray may also change with time during the injection period. The effect of injection pressure has been studied. The injected diesel fuel and B100 fuel are atomised into small drops near the nozzle exit to form a spray. Good atomisation requires high fuel injection pressure small injector nozzle size, optimum fuel viscosity and high cylinder air pressure at the time of injection. The variations of engine power values in relation with the various injection pressures are shown in Fig. 2. The maximum power for diesel fuel and B100 fuel occurred at 200 bar pressure injection. The power output of diesel engine using B100 fuel was lower than the power output using diesel fuel.

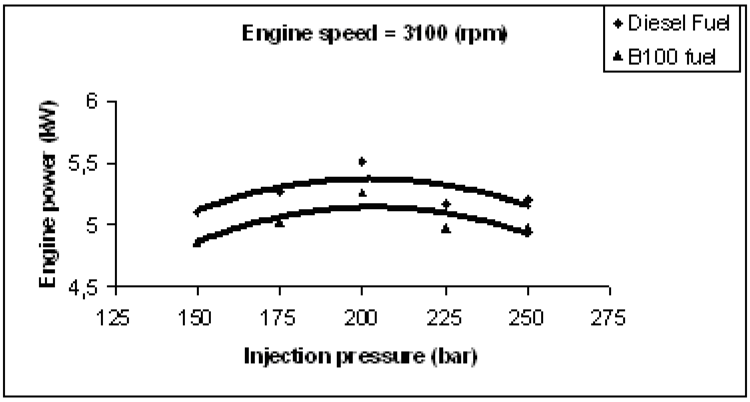

Figure 2. The variation of the engine power at the various injection pressure.

The maximum power obtained by diesel fuel was 5.51 kW while 5.26 kW by B100 fuel at 200 bar injection pressure. This was due to an increase in fuel consumption with an increase of injection pressure. The difference in power outputs was caused by the difference between the calorific values of the fuels. The power increases from 5.11 kW to about 5.51 kW when the injection pressure is increased from 150 bar to 200 bar for diesel fuel. From injection pressure of 150 to 200 bar the power increases from 4.86 kW to about 5.26 kW and then decreases slowly the other injection pressures for B100 fuel. From injection pressure of 200 to 250 bar the power decreases from 5.51 kW to 5.21 kW for diesel fuel and from injection pressure of 200 to 250 bar the power increases from 5.26 kW to 4.97 kW for B100 fuel. The maximum power between diesel fuel and B100 fuel represents a difference of 5% of the 200 bar injection pressure. The small difference was mainly a result of reduction at heating value of diesel fuel due to the lower heating value of B100 fuel.

3.2. Engine torque

The variation of engine torque by injection pressure for the two fuels was shown in Fig. 3.

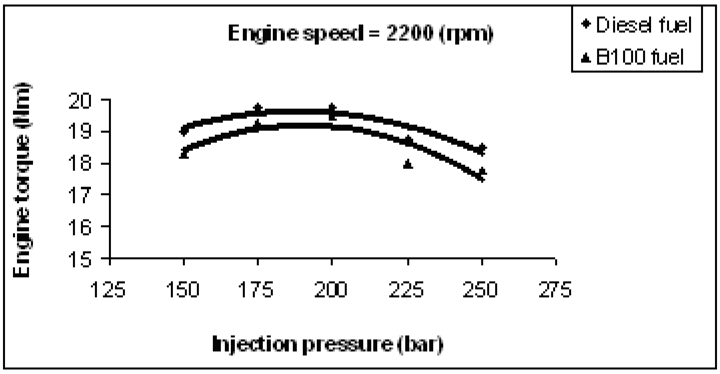

Figure 3. The variation of the engine torque at the various injection pressure

The torque decreased with increase of injection pressure for the two fuels. Up to a pressure of 200 bar the engine torque is about constant and then it is decrease slowly for diesel fuel and B100 fuel. The torque increases from 19 Nm to about 19.75 Nm when the injection pressure is increased from 150 bar to 200 bar for diesel fuel. From injection pressure of 150 bar to 200 bar the torque increases from 18.25 Nm to about 19.50 Nm and then decreases the other high injection pressures for B100 fuel. From injection pressure of 200 bar to 250 bar the power decreases from 19.75 Nm to 18.50 Nm for diesel fuel and from injection pressure 200 bar to 250 bar the power increases from 19.50 Nm to 17.50 Nm for B100 fuel.

Specific fuel consumption

Figure 4 showed the specific fuel consumption (SFC) for the two fuels. Specific fuel consumption increased with increase of injection pressure. The specific fuel consumption of B100 fuel was higher than of diesel fuel. This was due to the calorific value of B100 fuel being lower than that of diesel fuel. But the density of the B100 fuel was higher than that of diesel fuel so their calorific value by volume was relatively close. In addition, B100 fuel contains a certain amount of oxygen and the high viscosity. B100 fuel may also provide a good sealant between the piston rings and cylinder wall. The utilization ratio of energy can be raised so the fuel consumption rate was higher than diesel fuel. Because of the lower calorific value, with an increase in B100 fuel, the specific fuel consumption of B100 fuel was a little higher than that of diesel fuel.

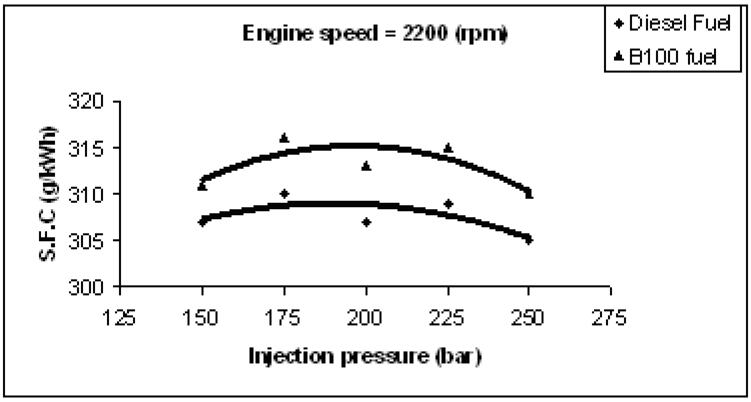

Figure 4. The variation of the engine specific fuel consumption (SFC) at the various injection pressure

Up to a pressure of 225 bar SFC is increased and then it is decreased slowly for diesel fuel. The SFC increases from 307 g/kWh to about 309 g/kWh when the injection pressure is increased from 150 bar to 225 bar for diesel fuel. From injection pressure of 150 bar to 200 bar the SFC increases from 311 g/kWh to about 313 g/kWh and then decreases the other high injection pressures for B100 fuel. From injection pressure of 225 bar to 250 bar the SFC decreases from 309 g/kWh to 305 g/kWh for diesel fuel and from injection pressure 200 bar to 250 bar the specific fuel consumption decreases from 313 g/kWh to 310 g/kWh for B100 fuel. The largest effect of high injection pressure is the state of the fuel as it passes through the nozzle. The injection pressure can be reduced slightly leave the fuel emerging from the nozzle in mostly vapour state. The question that remains is the increase in the specific fuel consumption at the high engine injection pressure due to the deacrease in drop size and the calorific value or some other factors.

Conclusions

Engine tests have been conducted with the aim of obtaining comparative measures of torque, engine power, specific fuel consumption to evaluate and compare the behaviors of the direct injected diesel engine running by diesel fuel and B100 fuel. Diesel fuel and B100 fuel was compared and its physical and chemical characteristics were determined. Fuel characterization data showed some similarities and differences between diesel fuel and B100 fuel. From the results obtained in this study it can be concluded that;

- The physical properties of diesel and B100 fuel are not very different. While the density and viscosity of B100 fuel decreased from 0.92 kg/lt to 0.88 kg/lt and from 33.98 mm^2/s to 4.5 mm^2/s respectively at 26^{o}C, the heat capacity increased from 39342 kJ/kg up to 40565 kJ/kg. Viscosity considerably decreased as a result of esterification.
- Flash point, density, cetane number and viscosity of B100 fuel were higher than those of diesel fuel. Calorific value of B100 fuel was lower about 6% than diesel fuel. Engine performance and exhaust gas emission of B100 fuel are comparable with diesel fuel. When the engine performance is considered, there are slight decreases in the engine torque and power with respect to diesel fuel. Thus B100 fuel is technically feasible in diesel engine.
- The high fuel consumption of B100 fuel at all injection pressure will compensate for the lower heating values such that the engine consumes equal amount energy.
- B100 fuel doesn't affect engine and bearing components seriously. It doesn't degrade lubricating oil and produces comparable amount of carbon deposit.
- Vegetable oils and biodiesel hold great promise as substitutes of diesel in existing diesel engines without any modification. Edible and non-edible oil and animal fats can be used to produce biodiesel. Non-edible or crude oils offer great promise as biodiesel, and hence there is a need to grow high yielding non-edible oil seed crops.
- Vegetable oils are renewable in nature and can be produced locally and environmentally friendly as well. They have no sulfur content and have excellent lubrication properties. Moreover, trees yielding vegetable oils absorb carbon dioxide from the atmosphere during their photosynthesis. Vegetable oil plants that produce oils used for making biodiesel draw CO_2 from the atmosphere to build stems, leaves, seeds and roots.

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