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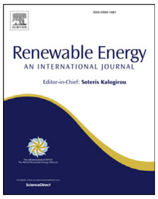

Influence of blending ratio on the physicochemical properties of safflower oil methyl ester-safflower oil, safflower oil methyl ester-diesel and safflower oil-diesel

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ABSTRACT

In this study, the methyl ester production and characterization from safflower oil (SO) was examined. The seed were collected from Yozgat-Turkey and SO was obtained from safflower seeds using screw press. SO was transesterified with methanol and NaOH to obtain safflower oil methyl ester (SOME). SO and SOME show high amounts of linoleic acid of 62.29 and 61.17%, respectively. This result in better low temperature properties of SOME like cloud point (CP) of −5 °C, pour point (PP) of −14 °C, freezing point (FP) of −16 °C and cold filter plugging point (CFPP) of −9 °C. Cold flow properties of SOME demonstrate its operational viability during the cold weather conditions and also it exhibited excellent transportation safety with flash point of 171 °C. It has been found that fuel properties of SOME indicate that SO can be considered as a future biodiesel source. Furthermore, viscosity, density, higher heating value (HHV), flash point, water content, pH, copper strip corrosion, CP, PP, FP and CFPP of SOME-SO, SOME-Euro Diesel(ED) and SO-ED blends have been investigated and discussed in the light of biodiesel standards. The effects of temperature and fraction on density and viscosity of blends were studied and constants of these correlations vary depending on the type of blend.

1. Introduction

Limited energy resources in the energy group, seems insufficient and their reserves come closer to the end point as a result of the growing population. In addition, the damages to the environment caused from the energy derived from fossil fuels cannot be ignored. This situation has led to search for alternative energy sources worldwide [1].

One of the alternative energy sources for vehicles is vegetable oils used especially in compression-ignition engines [2]. They have high viscosity causing some problems, such as engine deposit, piston ring sticking, injector coking and thickening of the lubricating oil because of their high viscosity, low volatility, and poor cold flow [3,4]. Methods like blending with diesel, emulsification, pyrolysis, and transesterification are used to reduce the viscosity of vegetable oils. Among these, transesterification is the most commonly used commercial process to produce clean and environmental friendly biodiesel fuel [5]. The purpose of the transesterification of vegetable oils to their methyl esters (biodiesels) process is to lower the viscosity of the oil. The main factors affecting transesterification are molar ratio of glycerides to alcohol, catalyst, reaction temperature and pressure, reaction time and the contents of free fatty acids and water in oils. The commonly accepted molar ratios of alcohol to glycerides are 6:1–30:1 [6].

Biodiesel, defined as the mono alkyl esters (methyl and ethyl esters) of long chain fatty acids, is produced from triglycerides or free fatty acids with short chain alcohols, primarily methanol or ethanol [7,8]. Biodiesel is a biodegradable, outstanding lubricity, non-toxic, superior combustion efficiency and clean burning fuel. A lot of researches have been done to investigate the effect of the biodiesel and its blends on emissions as compared to diesel fuel. In compression engine, use of biodiesel can reduce hydrocarbons (HC) [9–18], carbon monoxide (CO) [9–14,19–26], carbon dioxide (CO_2) [21,24,27–29], sulfur dioxide (SO_2) [21], and particulate matter (PM) [11,14,19,20], however nitrogen oxide (NOx) [9,13,15,19,20,22,24,25] emission can increase. Addition to these knowledge, the percentages of increased or decreased emissions for biodiesel and their blends as compared to those in diesel fuel are

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Abbreviations

SO	Safflower oil
SOME	Safflower oil methyl ester
ED	Euro diesel
SuO	Sunflower oil
CO	Canola oil
CoO	Cotton oil
SoO	Soybean oil
PO	Palm oil
CP	Cloud point
PP	Pour point
CFPP	Cold filter plugging point
FP	Freezing point
PAH	Poly-aromatic hydrocarbons
SO_2	Sulfur dioxide
CO	Carbon monoxide
VI	Viscosity index
CoOME	Cottonseed oil methyl ester
SoOME	Soybean oil methyl ester
SuOME	Sunflower oil methyl ester
GO	Groundnut oil
SN	Saponification number
IV	Iodine value
CN	Cetane number
JO	Jatropha oil
SeO	Sesame oil
CrO	Corn oil
PM	Particulate matter
nPAH	Nitrated poly-aromatic hydrocarbons
HC	Hydrocarbons
CO_2	Carbon dioxide
HHV	Higher heating value

dissimilar for different experiments [30]. A life cycle analysis of biodiesel showed that overall CO_2 emissions were reduced by 78% compared with diesel fuel [31]. Biodiesel can be used in all conventional diesel engines, delivers similar performance and engine durability as diesel fuel, and requires no modifications in fuel handling and delivery systems [32]. In addition, the production costs of biodiesel are still higher than normal diesels and are often tax-favored for promotional purposes. Moreover, the quality of biodiesel depends on feed stock, climate and geographical conditions, soil type, plant health and plant maturity upon harvest [33].

Oil for biodiesel production can be extracted from almost any oilseed crop [34]. Globally, the most common feedstocks are rapeseed [35,36], corn [37,38], hazelnut [39,40], jatropha [41–43], palm [44,45], soybean [46,47], sunflower [48,49], cottonseed [50,51], karanja [43,52], sesame [53], etc. Also, there is a growing interest in biodiesel production from SO in the world, however few researchers have worked with the SO [36,54–57].

Although there exists various studies about fuel properties of biodiesel derived from different vegetable oils such as *Sterculia foetida* [58], *Moringa oleifera* [59], *Croton megalocarpus* [60], palm [61], *Calophyllum inophyllum* [58], *Jatropha curcas* [58,62,63], *Elaeis guineensis* [63], *Cocos nucifera* [63], jojoba [64] etc., SOME-ED, SOME-SO, and SO-ED have not been researched in detailed before. The aim of this experimental study is to investigate how the physicochemical properties such as density, kinematic viscosity, water content, HHV, flash point, color, pH, CP, CFPP, PP, FP and copper strip corrosion change when the SOME, SO and ED are blended with each other. Thus, safflower seed was pressed to obtain SO and it was chemically processed by the transesterification reaction under methanol in the presence of NaOH as a catalyst. The fatty acid composition profiles of SO and SOME was examined. Afterwards, SOME-ED, SOME-SO, and SO-ED fuel blends were prepared and before these blends being used in engine or in liquid fuel heating devices, it is necessary to know the important physicochemical characterization such as density, kinematic viscosity, HHV, flash point, water content, copper strip corrosion, color, CP, PP, CFPP, FP, and pH of these fuels as compared to ED before using them in engine and in liquid burning systems. Furthermore, all of the properties were correlated with respect to blending ratio and predicting equations were proposed, and also the kinematic viscosities and densities of test fuels were measured at different temperature to evaluate the effect of temperature.

2. Experimental procedures

2.1. Materials and chemicals

The seeds of safflower were supplied from Yozgat, Turkey. Distribution of the safflower plant growing region in Turkey and Yozgat, the place of collection and the appearances of plant and seeds are shown in Figs. 1 and 2. All chemicals used in this experimental work such as methanol (99.9%) and NaOH (99%) were purchased form Merck. ED was supplied from a local market in Yozgat.

2.2. Crude oil extraction

The seeds of the safflower obtained manually and cleaned before being dried in sunlight for a week and the moisture ratio of the dried seeds was detected as 5.1%. The crude oil was extracted by screw press and heating.

2.3. Methyl ester production

In the present study, methyl ester was produced from SO in the Biofuel Laboratory of Department of Biosystems Engineering in Bozok University. To produce methyl ester from the oil, a small-scale (105 L) pilot biodiesel production plant (Fig. 3) was used in the laboratory condition.

In order to produce methyl ester, 20 L of SO was put into the oil tank and the oil was transferred to the reactor with helping gravity effect. In the reactor, the oil was heated up to 55 °C and temperature was kept stable by thermostat controlled units during the transesterification reaction. Methyl ester was prepared using methanol to oil ratio of 6:1 with NaOH as catalyst (0.35% of oil by weight). The catalyst and methanol were put in the methoxide tank and they were mixed by circulation pump for 30 min. When the temperature of oil was reached to the reaction temperature, the valve was opened and the methoxide was poured in the oil. It was mixed with the oil at 100 rpm for 60 min. Then, mechanical stirrer and heater were stopped and the mixture was waited approximately 2 h for precipitation of glycerol and it was separated from the mixture. The temperature of crude ester was raised up to 75 °C and 0.5 L of methanol was regained with the help of a heat exchanger. Crude ester in the reactor was pumped the washing/conditioning tank for decreasing temperature at 50 °C. During the washing up process,