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Physico-Chemical Properties of Biodiesel Produced from Safflower Oil (Isfahan Cultivar)

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ABSTRACT

Using oilseeds with high oil content can play a major role in biodiesel production. In this study, safflower oilseed (Isfahan cultivar) was evaluated and experimented as a biodiesel production feedstock because of its high oil content (30 %). The results showed that the Kinematic viscosity (4.27 mm^2/s) of the produced biodiesel from sfflower oil was in the approved range of D6751 ASTM standard. It was also close to the viscosity of soybean methyl ester, but it was better than palm. Its flash point (173˚C) was higher than petroleum diesel and the range of ASTM D6751 standard. In addition, its cold flow properties were similar to soybean methyl ester and better than palm. The cetan index of the produced fuel was lower than cetan index of palm oil methyl ester, but it was nearly as high as the cetan index of soybean methyl ester. The distillation range of the produced fuel was 303.4-391.2 ˚C.
KEYWORDS: biodiesel properties; safflower (Isfahan Cultivar) oil; Transestrification

1. INTRODUCTION

Biodiesel obtained from vegetable oil can be used as conventional diesel in diesel engines, because its properties are very close to petroleum diesel. For example, biodiesel has the proper viscosity; high flash point; high cetane number and no engine modification are required when using biodiesel [1,2].

Several biodiesel production methods have been developed, among which transestrification using alkali catalyst gives high level of conversion of triglycerides to their corresponding methyl ester in short reaction time. The process of transestrification is affected by the reaction condition, molar reaction of alcohol to oil, type of alcohol, type and amount of catalysts, reaction temperature and pressure, reaction time and contents of free fatty acids and water in oils or fats [3].

Biodiesel has a higher cetane number than petroleum diesel fuel, no aromatics, and contains 10-11 % oxygen by weight. These characteristics of biodiesel reduce the emissions of carbon monoxide, hydrocarbons, and particulate matter in the exhaust gas compared with diesel fuel. However, No_x emissions of biodiesel increase, because of combustion and some fuel characteristics [4].

Biodiesel has been mainly produced from edible vegetables oils all over the world. More than 95% of global biodiesel production is made from edible vegetable oils. The largest biodiesel producers were the European Union, the United States, Brazil, Indonesia, with a combined use of edible oil for biodiesel production of about 8.6 million tons in 2007 compared to global edible oil production of 132 million tons [5]. Rapeseed and sunflower oils are used in EU, palm oil predominates in biodiesel production in tropical countries, and soybean oil is the major feedstock in the United States [6].

Venkanna and Venkataramana [7], examined the production of biodiesel from hone oil (Calophyllum inophyllum). A three stage transestrification process has been studied which comprised of acid estrification, alkali transestrification and post treatment. The acid estrification with 0.5 ml anhydrous H_2SO_4 at 60 ± 1 °C for 120 min at 4:1 (methanol to oil) molar ratio gave the maximum conversion efficiency of FFA to triglycerides. The acid value of hone oil was reduced from 4.76 KOH/g during acid estrification reaction. The combination giving optimum reaction conditions foralkali transestrification of hone oil was found to be 8:1 M ratio of Methanol to oil, 1.25% water (30% v/v) of 60 °C.

The oilseed crop Camelina sativa (camelina) has lower production costs than oilseed rape in some climates. For this reason, the production of biodiesel from camelina oil was evaluated by Frohlich and Rice. The evaluation included quality assessment of esters produced in laboratory and pilot plant, an examination of methods of improving ester low-temperature properties, and vehicle trials. The results indicated that the methyl ester produced from camelina oil has properties similar to rape methyl ester, with the exception of its higher iodine value. The expected yield of methyl ester from camelina oil is similar to that from rapeseed oil. High free fatty acid levels reduce ester yields in a single stage process. Fuel consumption and general vehicle operation with camelina ester are similar to what one would expect from rape methyl ester [8]. Cottonseed oil was converted into biodiesel by alkali-catalyzed transesterification reaction at different catalyst concentration, catalyst type, temperature, methanol to oil molar ratio and agitation intensity designing an optimized protocol. It was found that optimum catalyst type was $NaOCH_3$, Catalyst concentration 0.75%, temperature 65 °C, methanol to oil molar ratio 6:1, and agitation intensity 600 rpm [9].

The oil content of crops is one of the essential properties in deciding on the suitability of a certain crops as biodiesel feedstock. Oilseeds with high oil content, are always favored, due to their lower production cost (the raw material cost is usually 70-80 percent of the total cost) [10].Safflower is an oilseed crop which is mainly grown in semiarid regions. It is used as vegetable and industrial oil, for spice processing and birdfeed. Safflower is a strongly top rooted annual plant to the Asteraceae family and is native to the Middle East. It is resistance to saline conditions, to water stress, and can reach the deep-lying water. In addition the importance of oil seed crops such as safflower has increased in recent years, especially with growing interest in production of biofuels [11].

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One of the safflower cultivars with high oil content is the Isfahan cultivar. In this cultivar the 1000 seed weight is 29 (gr). Its oil content is 32 percent and its seed yield is about 4 (tons/hectar). The main purpose of this study is to evaluate and assess the physiochemical properties of the biodiesel produced from this crop.

2. METHODS & MATERIALS

2.1. Fuel production

After extraction of oil from safflower (Isfahan cultivar) seeds, by solvent extractor (soxhlet). The extracted oil was converted to methyl ester via transestrification reaction (Fig 1) as following conditions: preheating the oil for 0.5 h in 65°C; NaOH as catalyst (1 % wt/wt); alcohol (methanol) to oil molar ratio (6:1); stirring speed (600 rpm); reaction temperature(65°C); reaction time (1.5 h).

The reaction result was two phases. The upper and lower layers were methyl ester and glycerin respectively. In the next step the produced methyl ester (biodiesel) was heated to 100 °C, and then dried with anhydrous Na_2SO_4 to get rid of any water [1,12]. Then the final product was transferred to fuel laboratory for characterization.

2.2. Determination of fuel properties

The properties of produced biodiesel were determined by using ASTM standards: Kinematic viscosity (ASTM D445); Flash point (ASTM D93); Cetane Index (ASTM D97); Cloud point (ASTM D2500); Pour point(ASTM D97); Distillation range (ASTM D1160)[13].

3. RESULTS AND DISCUSSIONS

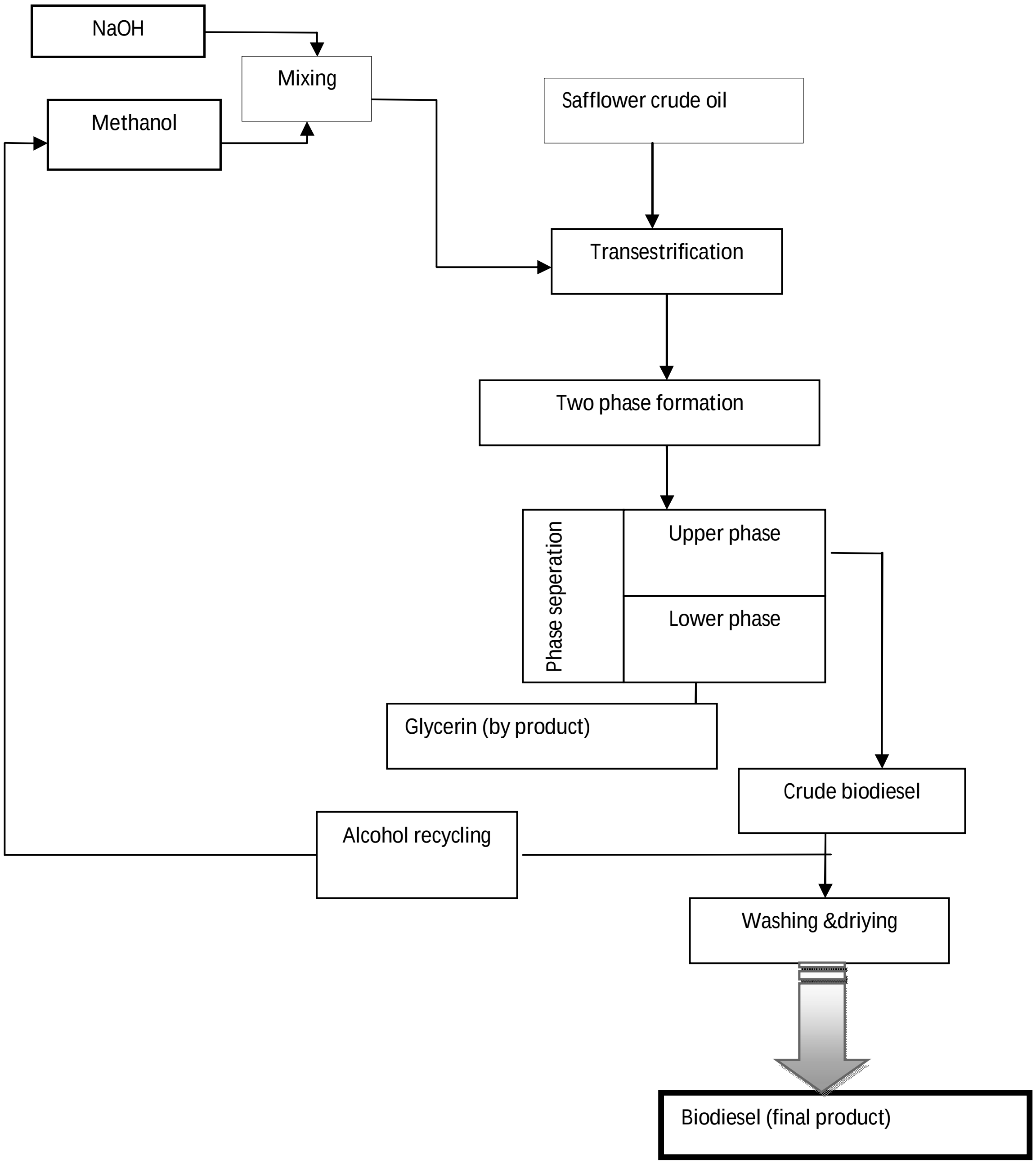

Fig 1- Biodisel production flow chart

The properties of the produced biodiesel were compared with soybean and palm biodiesel properties and the standards set by ASTM D 6751 and petroleum diesel. All he tests were conducted in triplicate and the data reported as mean.

3.1 Kinematic viscosity

The vegetable oils, as alternative engine fuels, are all extremely viscous with viscosities ranging from 9 to 17 times greater than that of petroleum- derived diesel fuel. Modern diesel engines have a fuel-injection system that is sensitive to viscosity change. Transesrification is the most common way to lower this high viscosities [14]. Fig.2 shows that the kinematic viscosity of safflower (Isfahan cultivar) methyl ester is 4.27 (mm^2/s) at 40 degrees centigrade, which is similar to soybean methyl ester viscosity and better than palm with its kinematic viscosity of 4.71 (mm^2/s). The acquired quantities were in accordance with American (1.9-6) and petroleum diesel (2-4.5) standards.

3.2. Flash point

The flash points needed for diesel grade 1 and 2 , are 38 and 52 degrees centigrade respectively [15].The flash point of the biodiesel is usually higher than 150 degrees centigrade. Of course, there are some exceptions. For instance, the flash point of the biodiesel produced from coconut oil is 110 degrees centigrade. This low flash point, is because of the presence of esters of carbon chain length 12. Methyl esters with such chain lengths, have lower flash points than chain lengths of 16 and 18 carbons. According to ASTM D 6751 standard, the flash point of a biodiesel has to be 130 degrees centigrade. Fig. 3 shows that the flash point of safflower (Isfahan cultivator) methyl ester, is 173 degrees centigrade, which is higher than American standard and the flash point of palm methyl ester, but lower than soybean methyl ester flash point.

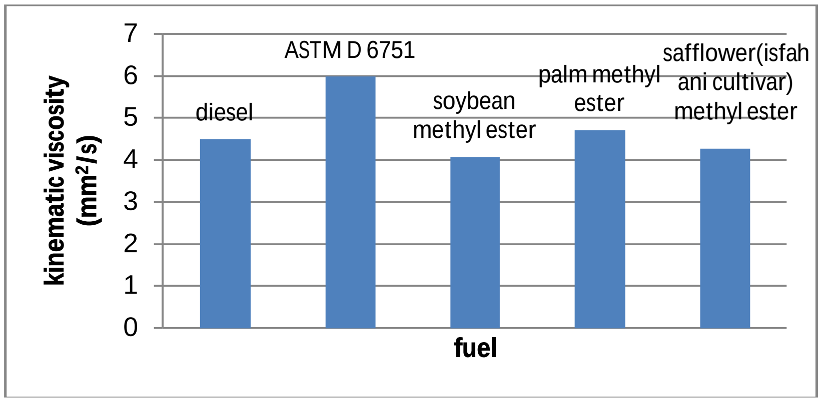

Fig 2-. Kinematic viscosity of safflower (Isfahani cultivar) methyl ester (this study) in comparison with the other fuels (Lin et al., 2011).

3.3. Cold flow properties

These properties (cloud point and pour point) determine the suitability or unsuitability of biodiesels in cold weather. Oils with high percentage of unsaturated fatty acids, have better cold flow properties, and reversely, oils with high percentage of saturated fatty acids, have inadequate cold flow properties. For instance, biodiesels made from corn and soybean oil, have lower or nearly zero degrees centigrade cloud points, which is due to their low

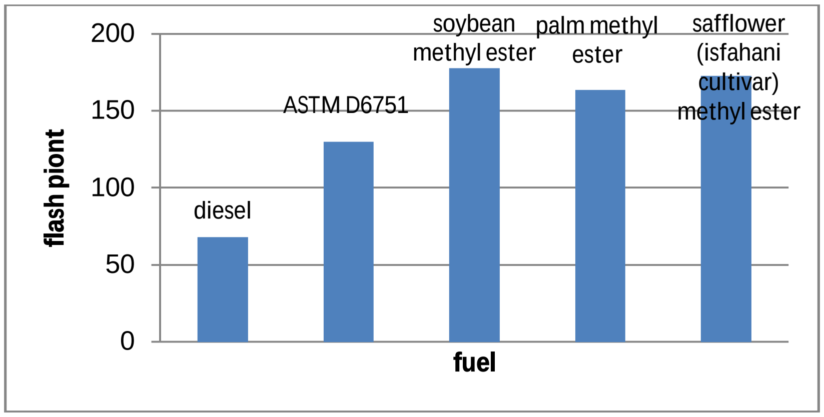

Fig 3- Flash point of safflower (Isfahani cultivar) methyl ester (this study) in comparison with the other fuels (Singh and Singh, 2010).

Percentage of fatty acids such as palmitic and stearic. But, palm oil methyl ester shows low pour point, due to its high percentage (50 %) of fatty acids. Because of climate diversity in different places, the American and European standard, haven't set any limitations for flow properties. The cold flow properties of the methyl ester produced from safflower (Isfahan cultivar), along with soybean and palm biodiesel, diesel petroleum, and ASTM D 6751 standard, are illustrated in figure 4. As illustrated in figure 4, the cloud point of diesel (-18 °C) is much lower than biodiesel. The cloud point of biodiesel produced from safflower (Isfahan cultivar) is (-2°C), which is similar to soy bean biodiesel and in cold climates, it is better than palm biodiesel, the cloud point of which is (16°C). Figure 4 also shows that the pour point of safflower (Isfahan cultivar) methyl ester is (-8°C), which is lower than diesel petroleum (-25°C). But it is better than palm and soybean methyl ester, the pour points of which are 20°C and 4 °C respectively.

3.4. Cetane Index

Cetane number is one of the very important quality indexes of diesel fuels. According to Ramos et al [16], cetane number depends on the oil type which is used to produce the biodiesel. Compounds which have high degrees of saturation of fatty acid esters such as linoleic and linolenic, have lower cetane numbers. Figure 5 indicates that the cetane index in methyl ester of safflower (Isfahan cultivar) oil, is the least necessary amount according to American standard (47), which is higher than diesel petroleum.

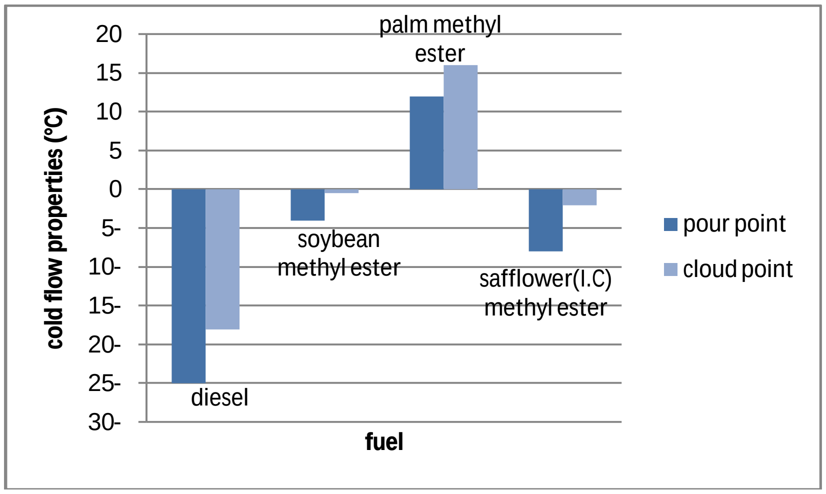

Fig 4- Cold flow properties of safflower (isfahani cultivar) methyl ester (this study) in comparison with the other fuels (Lin et al., 2011).

3.5. Distillation range

Fuels must be vaporized in the ignition chamber prior to ignition. Distillation range is the vaporization quality of the fuels. Fuels which can be vaporized easily in low temperature, have higher distillation ranges than Fuels which need higher temperatures for vaporization. The distillation curve shows both the distillation range and tendency to make soot. American and European standards have set no limitations for T_{10} and $T_{50,}$ but the highest temperature limit determined for T_{90} is 360°C. According to figure 6, safflower (Isfahan cultivar) oil methyl ester T_{90} (357°C) is lower than this limit.

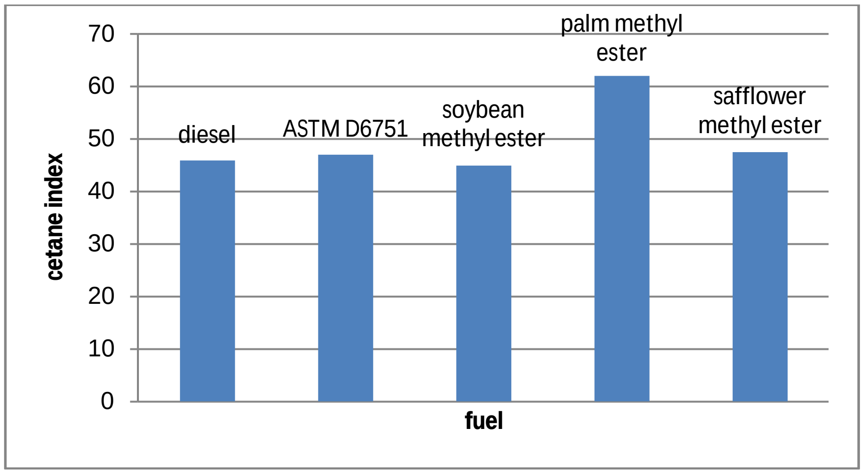

Fig 5- cetane index of safflower (isfahani cultivar) methyl (this study) ester in comparison with the other fuels (Gerpen et al., 2004; Singh and Sigh, 2010; Lin et al., 2011).

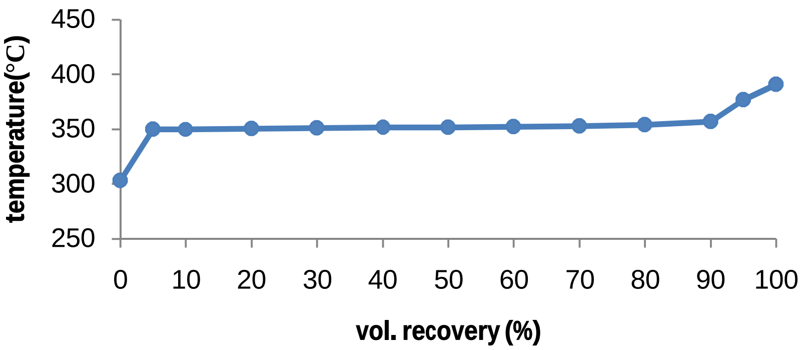

Fig 6.- Distillation curve of safflower (Isfahan Cultivar) methyl ester

4. conclusion

Considering the similarities between the properties of safflower (Isfahan cultivar) oil methyl ester and soybean methyl ester, and its accordance with ASTM D6751 standard, this oil can be introduced and used as a proper biodiesel feedstock.

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