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Study on the characteristics of palm oil–biodiesel–diesel fuel blend ☆

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ABSTRACT

Palm oil/palm oil methyl esters are blends with diesel fuel, the blends were characterized as an alternative fuels for diesel engines. Density, kinematic viscosity, and flash point were estimated according to ASTM as key fuel properties. Palm oil and palm oil biodiesel were blended with diesel. The properties of both blends were estimated. The results showed that the fuel properties of the blends were very close to that of diesel till 30% unless other characteristics are within the limits. The experimental data were correlated as a function of the volume fraction of oil/biodiesel in the blend. Different correlations were developed to predict the properties of the oil/bio-oil-diesel blends based on our experimental results. The developed correlations were validated by comparing the correlation prediction with experimental data in literature. A good agreement was found between modeled equations prediction and experimental data in literature. The developed equations can be used as a guide for determining the best blending mixture to be used for diesel engines.

1. Introduction

It is important to find an alternative fuels to replace fossil fuels based on renewable and natural sources like vegetable oil and fats [1]. Oil and fats are composed of 80–90% triglycerides with small portion of mono and di-glycerides, which contain oxygen in their structure. Diesel fuels from petroleum sources have chemical structure different from chemical structure of vegetable oils. A Diesel fuel has no oxygen compound, it contains carbon and hydrogen arranged in straight and/or branched chain structures. Further research is desired before substituting diesel fuels with vegetable oils [2,3]. Researchers recognized different complications related to the use of oil in diesel engine, due to their high viscosity and low volatility so they form deposits in the fuel injector of the engine [4–8]. These problems can be solved by dilution, micro emulsion, pyrolysis, and transesterification [9]. Transesterification is the reaction of oil with an alcohol in presence of catalyst to form ester and glycerol. The methyl esters produced by transesterification are called biodiesel, which has a low viscosity and high cetane number [10,11].

Dilution of diesel with vegetable oil is conducted by mixing and stirring. No negative effect has been observed because of short-term engine tests using diesel and biodiesel blends. The carbon deposits observed with diesel/vegetable oil mixture on combustion chamber parts are similar to that observed when operating with 100% diesel fuel [11–16].

Clark et al. [17]reported that rapeseed methyl esters of soybean and other seed oils showed a similar performance to diesel fuel in diesel engines. Peterson et al. [18] used rapeseed ethyl esters in truck's operation and reported that no difficulties or unusual behavior was observed. Peterson et al. [19] mentioned that the biodiesel can be used in a blend with diesel fuel in a diesel engines.

However, the properties of oil/biodiesel–diesel blends fuels are changing as a function of volume fraction of oil/biodieselin mixture. There are several key properties, which need to be characterized before using oil/biodiesel–diesel fuel blends in a diesel engine. These properties are kinematic viscosity, density, and flash point of the blend [2]. It is important to figure out if the properties of the blended fuel meet the standard properties of diesel fuel requirements. To better predict fuel properties, mixing rules are developed as a function of oil/biodiesel volume fraction in the blend [20].

This paper provides an experimental determination of density, viscosity and flash point for palm oil, palm oil biodiesel and their blends with diesel fuel. The aim of this work is to develop mixing rules to calculate the essential properties of palm oil, palm oil biodiesel and their blends with diesel fuel as a function of diesel content based on experimental values of blended fuel properties.

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2. Materials and methods

2.1. Materials

Palm oil and diesel were obtained from local market. All chemicals (methanol, potassium hydroxide and acetic acid) used in this study are analytical grade.

2.2. Biodiesel production

Experiments were done in a laboratory scale apparatus. Transesterification was carried out in 2000 ml flask equipped with reflux condenser, thermometer and magnetic stirrer. 1000 ml of oil was heated in the flask to 65 °C. Potassium hydroxide (12.75 gm) was dissolved in (255 ml) of methanol and was added to the heated oil. After 2 h, the mixture was transferred into separating funnel to separate the glycerol layer. Esters were washed twice using warm water with 5%acetic acid then with water and left to separate methyl esters. Then ester was dried at 100 °C to remove excess alcohol and water.

Table 1
Chemical composition of palm oil and palm oil methyl ester using GC-MS.

Palm oil methyl ester [21]	Palm oil	Fatty acid
0.64	0.190	Lauric (12:0)
1.02	1.01	Myristic (14:0)
40.2	38.88	Palmitic (16:0)
42.4	55.86	Oleic (18:1)
0.08	–	Arachidic (20:0)
0.36	–	Palmitoleic (16:1)
9.9	–	Linoleic (18:2)
0.47	–	Linolenic (18:3)
4.6	4.07	Stearic (18:0)
0.33	–	Gadolic (20:1)

2.3. Analysis

Palm oil/palm oil methyl ester blends with diesel fuel were analyzed using gas chromatograph/mass spectroscopy with flame ionization detector. The chromatographic analysis was made using Hewlett Packard Model 6890 Chromatograph. Detector temperature was 280 °C, injection temperature was 300 °C and the column temperature was increased from 100 to 240 °C using a ramp rate of 15 °C/min.

2.4. Blend preparation

Palm oil/palm oil methyl ester was added to diesel at low stirring rate. The mixture was stirred for 20 min and left to reach equilibrium before analysis. Palm oil/palm oil methyl ester was added in volume percentages of 5%, 10%, 15%, 20%, and 30%. In order to measure the properties of the oil diesel fuels, the test methods were used as follows; Density (ASTM D941), Viscosity (ASTM D445) and Flash point (ASTM D93).

3. Results and discussion

Fatty acid profileof palm oil biodiesel islisted in Table 1. Chemical composition of diesel is shown in Fig. 1.

Properties of palm oil, palm oil biodiesel and diesel fuel as measured experimentally are presented in Table 3. Properties of palm oil and palm oil biodiesel are not close to diesel fuel properties, so mixing is the only way to use palm oil or palm oil biodiesel. As shown in Table 4, blends properties up to 30% volume fraction of palm oil meet the requirement for diesel fuel.

In case of transesterification to convert palm oil to palm oil methyl ester, it was found that the properties of the palm methyl ester satisfy the ASTM standards for biodiesel as shown in Tables 2 and 3. Table 5 showed the properties of palm oil biodiesel.

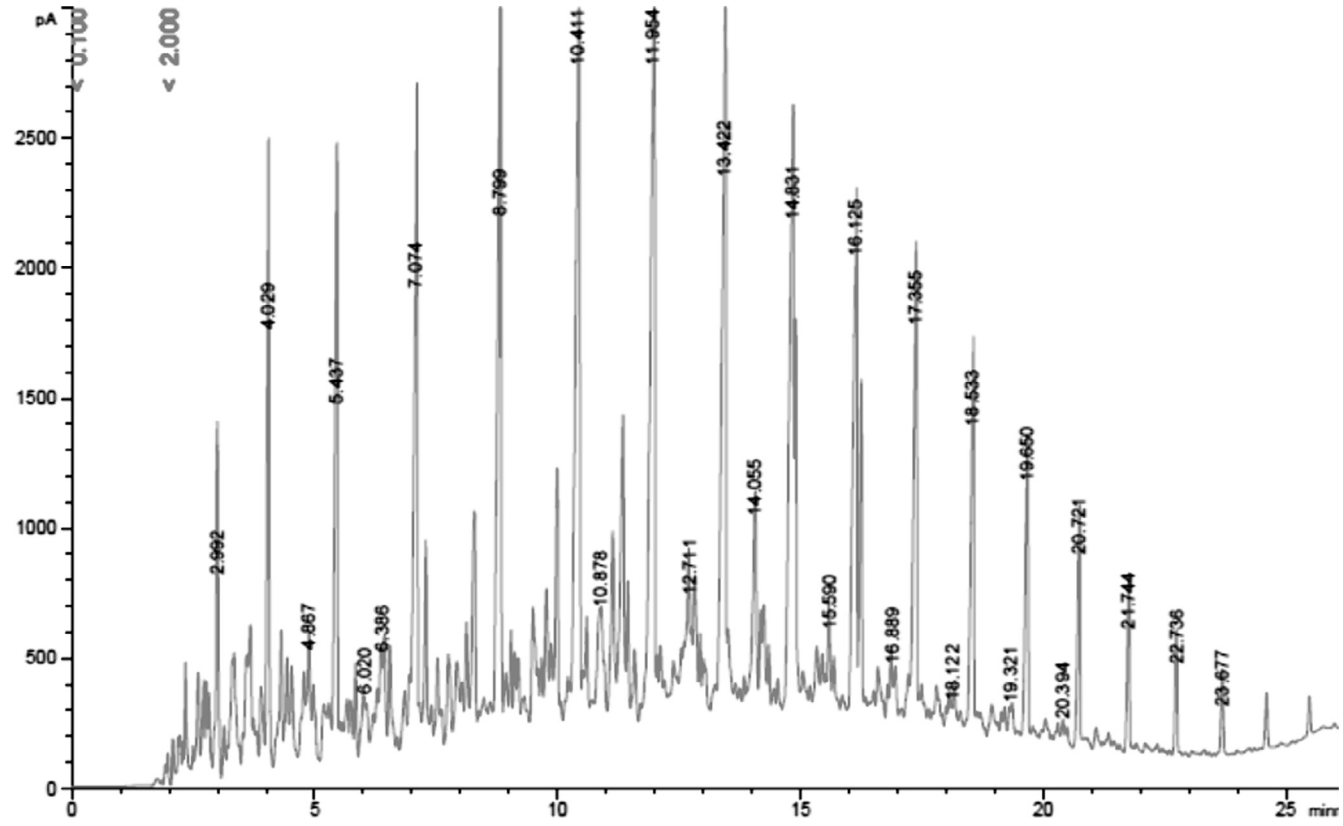

Fig. 1. Chemical composition of diesel.