Renewable Energy 68 (2014) 282–288

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Experimental study and empirical correlation development of fuel properties of waste cooking palm biodiesel and its diesel blends at elevated temperatures

M. Ebna Alam Fahd*, Poh-Seng Lee, Siaw Kiang Chou*, Yang Wenming, Christopher Yap

Department of Mechanical Engineering, National University of Singapore, 9 Engineering Drive 1, Singapore 117576, Singapore

ARTICLE INFO

Article history:
Received 4 August 2013
Accepted 7 February 2014
Available online 3 March 2014

Keywords:
Methyl ester based palm-biodiesel
Density
Dynamic viscosity
Higher heating value
Regression correlation

ABSTRACT

In this experimental work, the density, dynamic viscosity and higher heating value of methyl ester based waste cooking palm-biodiesel oil (WMEPB) was investigated under varying temperature and blend ratio condition with No. 2 diesel fuel. The transesterified fatty acid methyl ester of palm vegetable oil collected from local food and beverage shops was used as neat biodiesel. Four different fuel blends (20%, 40%, 60% and 80% by volume mixing with base diesel) were studied along with base No. 2 diesel fuel and pure biodiesel. Tests for dynamic viscosity and density were performed in the temperature range 0–130 °C for each fuel sample whereas the higher heating values were determined at 25 °C room temperature condition. It is found that pure biodiesel has the highest density and dynamic viscosity at a given temperature whereas it exhibits lowest combustion heating value among the six fuels. Moreover, the density for each fuel sample decreases linearly with the increase in temperature. On the other hand, the dynamic viscosity decreases exponentially with the temperature for each fuel sample. In addition, based on the experimental results, regression correlations have been proposed for the density, dynamic viscosity, and higher heating value of the fuels. Subsequently, comprehensive error analyses of these proposed correlations were performed. In particular, the correlation for density and dynamic viscosity were respectively compared with Kay's mixing rule and Grunberg-Nissan mixing rule theory in order to validate their applicability. It is found that density correlations predicted within ±0.3% average error band. And, as high as 72.2% of the dynamic viscosity data were in the range of ±5% average error while the remaining data fell within ±10% error range. And finally, through a comparative study with the available fuel property results of fresh methyl ester palm biodiesel, it is found that available existing correlations derived from fresh palm biodiesel studies can not accurately predict the fuel properties of same waste biodiesel and its blends with diesel.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Depletion of fossil fuels in the near future has become a burning issue in recent times. Moreover, the ever fluctuating volatile fuel pricing is another major concern. Therefore, the search for renewable fuels has stimulated an intense research thrust to the area of biofuel. Among the alternatives considered, biodiesel is currently gaining increasing attention because of its competitive advantages. These fuels are bio-degradable, non-toxic, contain trace amount of sulfur, and produce comparatively fewer engine exhaust emissions. However, despite the lower emission benefits, biodiesel fuels also have some inherent disadvantages. Biodiesel produced from vegetable and animal feed stock usually has higher density, viscosity, cloud point, and lower heating value and volatility [1]. The higher viscosity and density of biodiesel is an important concern to automotive manufacturers as viscosity and density has significant impact on fuel spray and subsequent combustion and pollutant formation. Higher viscosity tends to alter the injection spray characteristics, resulting in fuel impingement on the piston and other combustion chamber surfaces [2]. 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 [3].

* Corresponding authors. Tel.: +65 84518005; fax: +65 6779 1459.
E-mail addresses: fahd@nus.edu.sg, fahd1@outlook.com (M. Ebna Alam Fahd), skchou@nus.edu.sg (S.K. Chou).

http://dx.doi.org/10.1016/j.renene.2014.02.007
0960-1481/© 2014 Elsevier Ltd. All rights reserved.

Different types of biodiesel have been tested and reported as a renewable alternative fuel source; and out of this pool of biodiesel-cottonseed, rapeseed, soybean, linseed, peanut, sunflower, palm and coconut oils are the most investigated ones. Significant researches have already been put forward in investigating the performance of biodiesel in diesel engine application [4]. Experimental studies have revealed that selective amount of biodiesel blends with diesel fuel yielded comparable engine performance similar to diesel. Moreover, engine tailpipe emissions; particularly soot, particulate matter, hydrocarbon (HC) and carbon-monoxide (CO) are reduced significantly while oxides of nitrogen (NOx) emissions are still either comparative or higher [5,6]. In addition, multidimensional numerical studies [7,8] have been carried out to understand the basic combustion and emission mechanisms of biodiesel.

Yoon et al. [2] experimentally studied the fuel properties such as the specific gravity, dynamic viscosity, and density of methyl ester soybean oil and its different blends with fossil diesel for a temperature range 0–200 °C. In their two studies, Tate et al. [3,9] reported the viscosity and density of three different biodiesels (methyl esters of canola and soy oil, ethyl ester of fish oil) up to 300 °C using a modified Saybolt viscometer. From their experimental results, the authors proposed regression correlation for each of the fuels. Joshi et al. [10] investigated ethyl ester fish oil, and its blend with No. 2 diesel at lower temperature range. In an independent study, Alptekin et al. [11] also reported the experimental findings of basic fuel properties (density, viscosity) of six different vegetable oils with their respective blends with fossil diesel. In other studies, there were research endeavors to develop methods and empirical models to predict different biodiesel fuels properties [12–16]. In a comprehensive study, the authors agglomerated the experimental correlations for viscosity of different biodiesels [17]. In their experiments, Chhetri and co-workers [18] considered Canola, Jatropha and Soapnut biodiesel to determine the viscosity of these fuels at elevated temperature and pressure. It was observed that with temperature the viscosity of each fuel decreased exponentially whereas pressure had little effect on fuel viscosity. It should be noted that in almost every case, the researchers used fresh biodiesel as their sample, and prepared blends by mixing diesel fuel with it.

Although there exists handful of experimental studies and empirical correlations for different biodiesels, it is interesting to note that methyl ester palm biodiesel has got less attention compared to other biodiesels despite its availability [4]. Moreover, methyl ester palm-biodiesel is also used as cooking oil. In general, any leftover cooking oil in hotels and restaurants after cooking is eventually disposed for dumping. However, this remaining cooking oil can be further reused as a diesel engine fuel and heat exchanger fluid media after recollection and necessary processing [13]. As of now, different studies has taken initiative to explore the fuel properties of waste cooking biodiesel [19–23]. It should be noted that in majority of these studies the temperature was fixed and the blending ratio was varied to obtain the fuel properties. However, both the blending ratio and temperature has significant ramification of fuel properties. Therefore, the primary motivation of this study is to investigate the fuel properties like the density, viscosity and higher heating value of transesterified methyl ester based waste palm biodiesel and their blends with No. 2 diesel considering the duel effect of working temperature (0–130 °C) and blending ratio (0–100%). A secondary objective of this study is to evaluate the applicability of existing fresh biodiesel results to simulate the fuel properties of waste recollected same biodiesel. Moreover, to understand the blending effect on fuel properties, six different fuel samples including No. 2 diesel and pure biodiesel were tested. In addition, based on the experimental results, regression correlations are proposed for the density, dynamic viscosity and the higher heating value; and an error analysis had been reported accordingly. And finally, comparisons were made with well known Kays and Grunberg-Nissan mixing rule to verify the applicability of the proposed density and dynamic viscosity correlations.

2. Experimental details

2.1. Test fuels

The biodiesel used in this experimental work was transesterified fatty acid methyl ester of palm vegetable oil and was supplied by Alpha Bio-fuel Singapore Limited. Prior to the transesterification, the fuels were collected from the local food and beverage shops. The transesterification process was conducted in base-catalyzed environment with potassium hydroxide (KOH). The details of the adopted transesterification process can be found in Ref. [24].

Palm oil biodiesel yields mostly palmitic and oleic acid methyl ester [4]. In this study, we termed pure biodiesel as BD100 and were mixed with the No 2 diesel which was denoted as BD 0 or D100. Blend ratio changed from 0.0 (neat diesel) to 1.0 (pure biodiesel) in step of 0.2 (20% v/v ratio). Therefore, the other four fuel samples were termed as BD20, BD40, BD60 and BD80.

2.2. Sample preparation

Sufficient amount of test fuel (100 ml) for each sample was prepared prior to the test using a calibrated burette (±0.1 ml). Subsequently, to confirm the homogeneous mixing of No 2 diesel and biodiesel, samples were stirred with a magnetic stirrer at 400 rpm for 5 min. Finally, each fuel sample was filtered through laboratory filter paper (pore size 20 microns) and was kept for two weeks in fluorinated polyethylene bottle in a dark room for observation. It was found that none of the samples had any physically visible alteration in this quarantine period.

2.3. Test procedure

2.3.1. Density

The density of the various fuels at different temperature was measured with fixed volume calibrated conical-shaped pyrex glass bottle and appropriate heating arrangement. First, the weight of the empty calibrated glass bottle was measured with 'OHAUS explorer' weight scale (accuracy ±0.001 g). The cap of the pyrex glass bottle had a converging entrance with a mark at its neck indicating a total inside volume of 26.703 ml (±0.005 ml). Then, the bottle was filled with the sample fuel up to the neck mark to ensure that inside fluid was 26.703 ml. To measure the temperature, two K-type thermocouples (accuracy ±0.1 °C) were inserted inside the glass bottle from a clamp stand, one reaching one-third and another reaching two-third of the fluid height. Then the fuel was slowly heated from 0 °C to 130 °C at a step of 10 °C and heated expanded fuel leaked through the hole of the converging cap. For a particular temperature set point, the glass bottle was carefully removed and allowed to cool down. The exterior surface was cleaned with acetone to ensure no additional sample fuel trace on the bottle surface. Finally, the weight was again measured and the density of the sample was calculated. For each reading, measurement was performed three times and then the average was reported.

2.3.2. Dynamic viscosity

A TA instrument AR-G2 viscometer [25] was used to measure the dynamic viscosity of different test fuels. A predefined amount of fluid was trapped between one rotating and one stationary surface. The fluid was first put over the flat plate (volume ~1.1 ml) and the rotating cone type plate was placed over the fluid. The highly

Download English Version:

https://daneshyari.com/en/article/300134

Download Persian Version:

https://daneshyari.com/article/300134

Daneshyari.com