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Cold flow properties improvement of Jatropha curcas biodiesel and waste cooking oil biodiesel using winterization and blending

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ABSTRACT

The objective of this study was to study the cold flow properties of JCB (Jatropha curcas biodiesel) and WCB (Waste cooking oil biodiesel). For the purpose two methods were examined experimentally viz. winterization and blending of biodiesel samples with petro diesel and kerosene. Winterization was found to be effective as it improved the cold flow properties of biodiesel samples but at the same time decreased the yield and stability due to partially removal of saturated fatty acids. Blending was found to be more favorable for improvement in cold flow properties of biodiesel without any effect on yield, however, the biodiesel become more stable after blending. The CP and PP (pour point) for JCB for B20 blends with petro diesel were reported as 14.9 °C and 14 °C respectively, however, for WCB it was 12 °C and 11.5 °C respectively. Kerosene K20 samples was showing best result as the reported CP and PP were −1 °C and −2.2 °C respectively for JCB. However in case of WCB blends with kerosene, the reported CP and PP for K20 blends are −10.5 °C and −12 °C respectively.

1. Introduction

Depletion of fossil fuels and increased pollution caused by the burning of fossil is leading factor to think about alternate sources of energy and biodiesel is found to be an alternate for the petro-diesel. Biodiesel is emerging as one of the most prominent fuels in the near future. Biodiesel is obtained from lipid materials such as vegetable oils and animal fats. It is defined as the fatty acid alkyl esters of edible oils, non-edible oils, animal fats or waste oils. The main process for producing biodiesel is the transesterification reaction, which consists of an alcoholysis of triglycerides to obtain methyl esters and glycerol as a by-product. The composition largely influences the critical parameters of the biodiesel. It is renewable, biodegradable and nontoxic, has low emission profiles and so is environmentally advantageous [1]. Biodiesel possesses inherent lubricity property and a relatively high flash point, and reduces most of the exhaust emissions in comparison to petro-diesel. Therefore it is a technically competitive and environmentally friendly alternative to conventional fossil-derived diesel fuel for use in compression-ignition engines [2].

Biodiesel with its advantages suffers a major drawback in the cold flow properties. So during winters, crystallization of saturated FAME (fatty acid methyl esters) may lead to the plugging of filters and tubes [3]. This could further result in the start-up and performance problems when vehicles and fuel system are subjected to the cold temperatures. Cold flow properties of diesel fuel are generally determined by the following parameters viz CP (cloud point), PP (pour point), CFPP (cold filter plugging point) and LTFT (low temperature filterability test). When biodiesel is subjected to lower temperatures there is the formation of solid wax crystal nuclei. Further decrease in temperature causes the crystal nuclei to grow [4] and become visible, and this temperature is termed as CP (cloud point). When the temperature is further decreased, the crystal nuclei aggrandizes and thus prevent free pouring of fluid, this temperature is termed as PP (pour point). Therefore CP (cloud point) and PP (pour point) are the essential parameters, which defines the cold flow property. There is an on-going effort to improve the cold flow properties of

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biodiesel [5–7]. To overcome the disadvantages arising at the low temperature, certain techniques are used to lower the CP (cloud point) and PP (pour point). These are: Use of cold flow improvers, winterization and blending.

Various authors have done work on improving the cold flow properties of biodiesel from edible oil sources. The first technique is the use of cold flow improvers or cold flow additives to reduce the PP (pour point) of the biodiesel. There is a decrease of 8 °C in PP of soybean (edible) biodiesel is seen using OECP (olefin-ester copolymer) as CFI [8]. Commercial DEP (trade name) and PGE (polyglycerol ester), and self-made PA (given name by author's laboratory researchers), were used as cold flow improvers for PME (Palm Methyl ester) [9]. From the experiment it was found that when the ratio of DEP: PGE: PA was 3:1:1 or 2:2:1, the CFPP of PME was decreased by 7 °C. A mixture of 0.2% additive, 79.8% soybean biodiesel, and 20% kerosene reduced the PP of B100 by 27 °C [10]. 2-butyl ester of palm oil is able to reduce the PP by 6 °C [11]. The above researches shows that use of CFI decreases PP up to much extent but the only problem with CFI is its high cost.

Winterization may be a useful technique for decreasing CP by reducing the saturated alkyl ester content. It involves the separation of the components of lipids (vegetable oils, fats, fatty acids, fatty acid esters, mono-di-glycerides and other derivatives) based on differences in crystallization temperatures [12]. Winterization is a two-step process: (a) – Under controlled rate of cooling, nucleation and crystal growth occurs. This is the crystallization stage of the biodiesel. (b) – Second stage is the filtration. Resulting slurry is filtered to separate solid and liquid fractions [13]. To achieve significant reductions in PP, several winterization steps are required to achieve a yield of higher than 25–26% and thereby render this technique viable [12].

Third technique is Blending of biodiesel with other petrochemicals. With increase in biodiesel concentration the CP and PP also increases. Biodiesel blend up to B30 shows good cold flow behavior [14]. At the end Blending is found out to be the best and economical way to improve cold flow behavior. However, an unfavorable impact on ignition quality and stability of Biodiesel are observed.

Based on the above it is found that researchers mainly worked on biodiesel from edible oils and very few report has been found on biodiesel from non-edible resources. Since Indian Government is giving much emphasis on non-edible oils seeds for biodiesel production therefore the aim of the present paper is to report the cold flow properties of JCB (Jatropha curcas biodiesel) and WCB (waste cooking oil biodiesel). Since the CFI are quite costly and due to this increases the cost of fuel therefore the present paper aims to report the results of winterization and blending on cold flow properties and suggesting the best between the two.

2. Materials and methods

2.1. Materials

The biodiesels used in this study were derived from the most preferred feedstocks for biodiesel in India, i.e. JCO (Jatropha Curcas oil) and WCO (waste cooking oil). JCO was purchased from Jatropha Vikas Sansthan, New Delhi, India and WCO was collected from various hotels and food junctions of Haridwar city. Transesterification process was used for the conversion of oil into biodiesel. A detailed methodology is already given in the author's previous publications [15,16].

2.2. Methods

2.2.1. Test fuel preparation

Petro diesel and kerosene was used as blending fuels in the present study. Different blends of JCB and WCB were prepared with diesel and kerosene to better understand the effect of blending on cold flow properties. The blends were named as B100, B80, B60, B40, and B20 for biodiesel and petro-diesel blends and as K100, K80, K60, K40, and K20 for biodiesel and kerosene blends.

2.2.2. Winterization process

The biodiesel was agitated at 200 rpm during the winterization. The winterization of the biodiesel begun from CP temperature and reduced by about 0.5 °C intervals at a cooling rate of 0.5 °C/min. The resulting crystals were then separated by vacuumed filtration at the same temperature. Samples obtained from each filtration were analyzed in terms of cold flow properties, viscosity and fatty acid composition. Filtered liquid phase was also used for the next crystallization stage. This process was continued until whole biodiesel sample was crystallized. In addition, the amount of crystallized biodiesel was determined after each experiment in weight basis.

2.2.3. Analytical methods

2.2.3.1. CP (cloud point) and PP (pour point) measurement. CP (cloud point) and PP (pour point) tests are used to define the low-temperature operating limits for diesel fuel. In order to minimize the potential effect of human error on the experimental data, automated fuel testing equipment was used to perform the tests. The CP and PP were measured using a Tanaka MPC-102L CP/PP tester which determines both the cloud point (in accordance with ASTM D2500) and the pour point.

2.2.3.2. Gas chromatography analysis. The JCB and WCB samples were analyzed for ME formation at a predetermined interval of time by Gas Chromatograph (Netal make) equipped with a flame ionization detector and a capillary column for injecting the sample [17]. The GC oven was kept at 230 °C (5 °C/min). Nitrogen was used as carrier gas. Quantitative analysis of % ME was done using European standard EN 14,103:2003 (DIN EN, 1410). The% ME yield was calculated using Eq. (1).

$$\%\ of\ ME = \frac{\sum A - A_{EI}}{A_{EI}} \times \frac{C_{EI} - V_{EI}}{m} \times 100 \tag{1}$$

$\sum A$ = Total peak area from the methyl ester in C14 to that in C24:1;
A_{EI} = Peak area corresponding to methyl heptadecanoate;
C_{EI} = Concentration of the methyl heptadecanoate solution (mg/ml);
V_{EI} = Volume of the methyl heptadecanoate solution (ml);
m = Mass of the sample (mg).

For the purpose of error analysis, 2 tests were conducted for single sample and then the average of the 2 reading was taken for further investigation purpose. After each experiment, pour point (D 97-11) and cloud point (D 2500-11) were analyzed according to related EN standards.

2.2.3.3. Oxidation stability measurement. Oxidation stability of JCB and WCB and their blends was quantified by the IP (induction period). The IP was measured as per EN 14112 for pure biodiesel and EN 15751 for the biodiesel blends. In the modified Rancimat method, a number of parameters were changed, mainly because of