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ORIGINAL PAPER

Effect of FFA of Crude Rice Bran Oil on the Properties of Diesel Blends

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Abstract Crude rice bran oil (CRBO) with high free fatty acid (FFA) content is not suitable for eating purposes, however, it can be used as a fuel to partially replace or fully replace No.2 diesel. The main objective of the present work was to analyse the effect of FFA content of CRBO on the combustion properties such as viscosity, calorific value, volatility and aniline point. CRBO with different FFAs were collected and mixed with No.2 diesel to prepare CRBO-diesel blends. It was observed that the viscosity of the blends increased with increase in FFA while the calorific value decreased. Significant variations were observed in the distillation curve for the CRBO blends with different FFA. Aniline point of the blends was 10–15% lower than that of diesel and it is indirectly proportional to the FFA of CRBO in the blend. Experimental results showed that the combustion properties of CRBO are the function of the FFA in the oil. As a dilute blend with diesel, CRBO with high FFA content showed comparable combustion properties to that of diesel. The properties differed in magnitude by 10–15% when compared with diesel. From the present investigation it is concluded that in blended form, CRBO with high FFA can be a potential resource to utilize it as an alternative fuel for CI (compression ignition) engines.

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Introduction

Increasing the availability of energy resources of their countries and meeting updated emission standards will be the biggest challenge over the next decade for researchers all over the world. As the petroleum resources are being depleted it is important to have renewable sources of energy with the potential for reduced environmental impact to achieve the above objectives. As compression ignition (CI) engines have gained significant and well-deserved attention for their wide range of applications in the energy sector, attention is focussed on determining an alternative fuel for CI engine fuel. Vegetable oils, a renewable material have the potential to replace petroleum diesel in their pure and modified form. Even though some neat vegetable oils have been tested in CI engines their higher viscosity restrict their direct use in the diesel engines combustion chamber [1]. To overcome this problem the vegetable oil chemical structure needs to be modified. This can be done by modification techniques such as transesterification, pyrolysis and emulsification [2]. However, these processes demand a lot of work and are time consuming. Hence blending vegetable oils with No.2 diesel can be done to minimize the viscosity of the vegetable oils and make them suitable for the CI engines. CI engine fuel blends of vegetable oils with diesel show similar combustion characteristics and reduced emissions when compared with diesel with minor power loss [3–5].

Every nation, worldwide has the potential to produce different kinds of edible and non-edible vegetable oil, based on their climate and geographic conditions and over the last two decades much attention was given to use these non-edible oils as engine fuels. Rice bran oil, a renewable vegetable oil, is produced during the rice milling process, has the ability to replace diesel as a CI engine fuel in its pure and blended forms [6]. As the second largest producer of rice in the world India has a great potential to produce rice bran oil and it does not require any special cultivation since it is a bi-product of the rice milling process [7].

Only a small quantity (6.5%) of the extracted crude rice bran oil (CRBO) is subjected to any further refining process to make it suitable for edible purpose [8]. The higher free fatty acid (FFA) content of the remaining CRBO restricts its utility as an edible oil. Hence CRBO with high FFA is a potential resource to utilize as an alternative to diesel oil.

In the present investigation an attempt was made to analyse the suitability of high-FFA content CRBO as a CI engine fuel in its blended form by observing its combustion properties. Earlier research work concluded that direct use of vegetable oils is not a favourable one [9]. Hence a dilute CRBO blend was prepared by mixing 20% CRBO with 80% of petroleum diesel on a volume basis and the combustion properties of the blend were determined. To analyse the effect of FFA on the properties, CRBO with different FFA were chosen and three CRBO blends were prepared. The properties under investigation were viscosity, calorific value, volatility and aniline point which examines the suitability of oil as a CI engine fuel. Since CRBO present in the blends is equal in volume and different in FFA any variation predicted in the properties of the blends will be the indication of its FFA content.

Experimental Procedure

Crude rice bran oil with three different FFA was collected from a solvent Extraction Company. Before determination of the properties of the CRBO blends the FFA content of these three CRBOs was determined [10].

The titration method was used to determine the FFA content of the CRBO. Isopropyl alcohol (IPA) was used in this method since it does not react with vegetable oil [10]. A known mass of CRBO was dissolved in 10 mL of IPA. Two drops of phenolphthalein were added to this solution as an indicator and titrated against an NaOH solution of 0.1 N till the pink color had just appeared. This process was repeated several times to ensure the reliability of the results and no change in the results was found. From the volume of NaOH solution consumed the FFA of CRBO was determined using the formulae.

$$\%\ \mathrm{FFA} = \frac{\text{Volume of NaOH consumed (mL)} \times \text{normality of NaOH} \times (282/1000)}{\text{Mass of oil taken (gm)}} \times 100$$

In the above formulae molecular weight of FFA of CRBO was assumed as 282 [8].

The viscosity of the CRBO blends was measured by using redwood viscometer apparatus. A total of 60 mL of oil was taken and heat was applied gradually. When the thermometer reads 40 °C the oil was made to flow through an orifice and the time taken to collect 60 mL of oil was recorded from which the kinematic viscosity was calculated.

The calorific value of the CRBO blends was determined as per the standard test method ASTM D 240-02. The calorific value was determined by burning a weighed sample in an oxygen bomb calorimeter. After placing the sample in the bomb, the calorimeter was assembled in the jacket and stirrer was started. A duration of 5 min was allowed to attain the equilibrium temperature and the charge was fired at the sixth minute. Temperatures were recorded at every minute until the difference between successive readings had been constant for 5 min. The calorific value in kJ/kg was computed from the recorded maximum rise in temperature of the calorimeter cooling water (°C) and the energy equivalent of the calorimeter (kJ/°C).

The volatility of diesel and CRBO blends was determined by conducting a manual distillation test in ASTM D86 distillation apparatus. A total of 100 mL of the oil sample was heated in a distillation flask and the resulting vapors were made to pass through a condenser and the condensed liquid was collected in a receiving cylinder. Temperatures were recorded from the instant the first drop of condensate fell from the lower end of the condenser tube (initial boiling point) and also at regular intervals for every 5% collection of condensed liquid. This was repeated till the maximum thermometer reading was obtained which is the end point temperature. The distillation curve was plotted between the percentage of distillation and the corresponding temperature.

The aniline point is defined as the minimum equilibrium solution temperature for equal volumes of aniline and sample. The aniline point of the fuels was determined by testing the samples in the ASTM D611 aniline point apparatus. Specified volumes of aniline and sample oil were placed in a tube and mixed mechanically. The mixture was heated at a controlled rate until the two phases become miscible. The mixture was then cooled at a controlled rate and the temperature at which two phases separate was recorded as the aniline point of the sample oil.

Results and Discussions

From the experiments conducted the percentage FFA content of the three CRBO samples was determined as 5.4, 7.8 and 14.7. Three CRBO blends were prepared by mixing 20% of these oils with 80% of No.2 petroleum diesel on volume basis. These blends were specified according to the FFA content of CRBO such as 5.4% FFA blend (B1), 7.8% FFA blend (B2) and 14.7% FFA blend (B3) and the investigation was focussed to determine the various properties of these blends. The results of this investigation are compared with that of diesel by taking its FFA content as zero.

Viscosity

Viscosity is an important property of a CI engine fuel and it determines the rate of atomization of the fuel. Poor atomization may lead to an increase in ignition retardation, incomplete combustion and ultimately power loss [1]. Variation of viscosity of the blends at 40 °C with FFA is given in Fig. 1. It can be seen that as the FFA content increases the viscosity of the blends also increases. When CRBO undergoes oxidative degradation it results in an increase in its FFA, which was identified by its acid number. This oxidation can lead to high viscosity for the CRBO [11]. Rice bran oil contains a range of fats, with 47% of its fats mono-unsaturated, 33% poly-unsaturated, and 20% saturated [12]. It is of scientific interest to note that different countries have their own stipulated biodiesel standards. According to those standards, the maximum limit allowed in the amounts of chemically bound glycerol (mono-, di- and triglycerides) in biodiesel varies from country to country. Due to these existing differences in standards among the countries, the vegetable oil blends used in this experiment may be prohibited for use in these countries.

Calorific Value

Since the power developed by the engine is directly proportional to the heat energy liberated as a result of combustion, the heating value of a fuel will be a promising property, which decides the ability of a fuel to be used in an IC engine. Figure 2 shows the calorific value of the blends as a function of FFA content in the blends. It is very clear that with increase in FFA content of the blends the calorific value decreases. A marginal reduction was observed in the calorific value of the blends with increase in FFA since the molecular weight of CRBO is slightly reduced with increase in its FFA.

Volatility

Distillation is a simple test for determining the volatility of a fuel. CI engine fuels should have low T50 and T90 which are interim points on the distillation curve, which shows the temperature at which 50 and 90% of the fuel has vaporized, respectively [14]. The T50 temperature has to be low to prevent smoke and low T90 and end point temperatures to ensure low carbon residuals. An end point temperature of less than 372 °C is desirable for CI engine fuels [13]. Figure 3 shows the distillation curve for the three blends and the same is compared with that of diesel. It can be observed that the distillation temperatures for the CRBO blends are higher than that of diesel since the boiling points of fatty acids present in the CRBO were higher than the boiling point of hydrocarbons present in the diesel fuel. It can also be observed that, by increasing FFA,

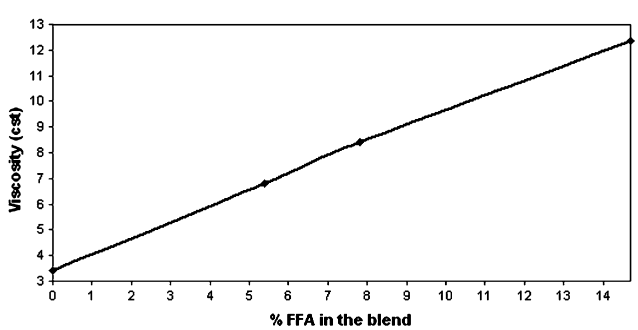

Fig. 1 Variation of viscosity of blends with FFA

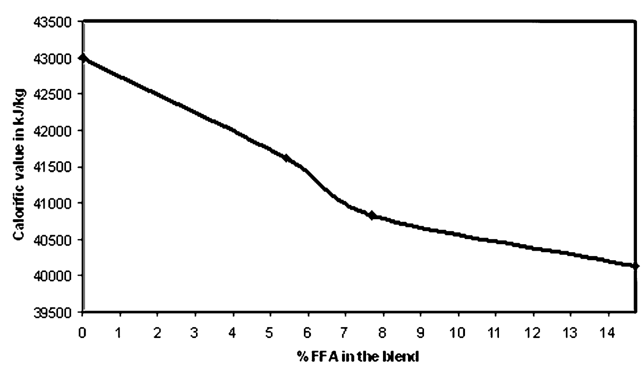

Fig. 2 Variation of calorific value of blends with FFA

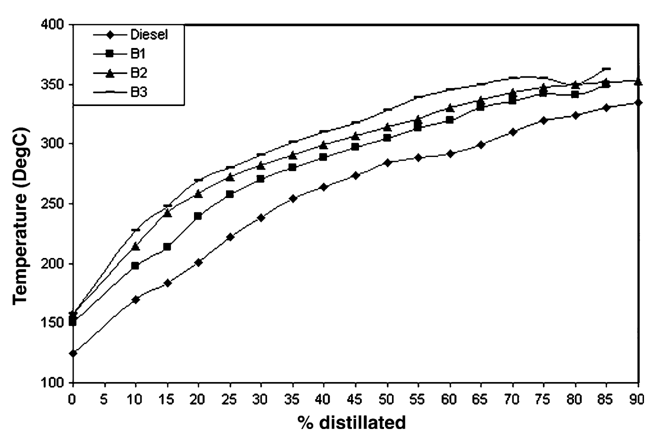

Fig. 3 Distillation curve for blends for different FFA

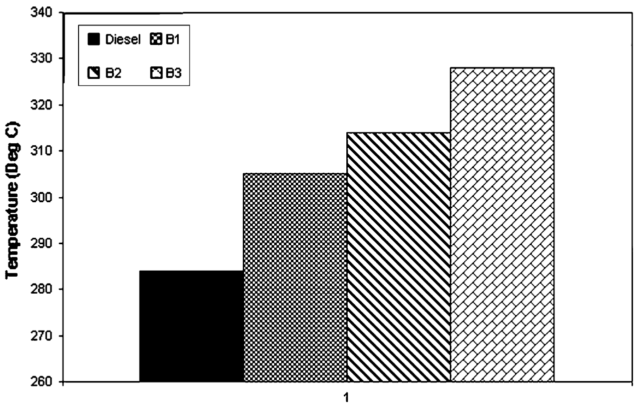

Fig. 4 Variation of 50% temperature of blends with FFA

the volatility of the fuel is reduced. This is due to the increase in viscosity of the CRBO with FFA. The end point temperature of the CRBO blends is less than 372 °C which indicates the suitability of the blend as a CI engine fuel.

Temperature (50%)

Smoke and exhaust odor are most directly affected by volatility because volatile fuels vaporize rapidly and therefore give better mixtures on combustion. For this reason the T50 is a better index of the overall mixing problem than the T90. Figure 4 shows the variation of T50 of the CRBO blends with FFA content in the blend and the same is compared with that of diesel. It can be observed that the T50 increases with an increase in FFA content in the blend. This is due to the increase in viscosity of CRBO with FFA. It can also be noted that the CRBO blends have a higher T50 than that of diesel and the variation is within 15%. Hence high FFA CRBO blends will not cause any mixing problem, which is the major requirement for any CI engine fuel.

Aniline Point

The ignition quality of a CI-engine fuel is measured in terms of its auto ignition ability. Since paraffin fuels have

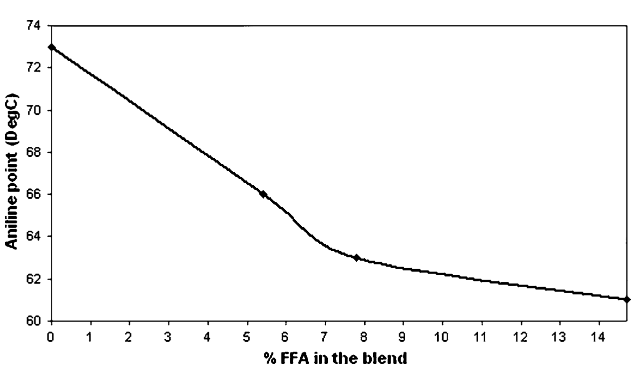

Fig. 5 Variation of aniline point of blends with FFA

higher Cetane ratings, the amount of paraffin compounds in the fuel will be related to ignition quality. It is evaluated by measuring the aniline point. It is simply the temperature at which the fuel and aniline are completely miscible. For paraffinic fuels, the solubility temperature is high and for aromatic fuels it is relatively low. Figure 5 compares the aniline point of the blends with that of diesel. It can be observed that the aniline point of the blends is lower than that of diesel due to the higher boiling point compounds present in the CRBO. It can also be observed that the aniline point of the CRBO blends decreases with increases in FFA content and the variation of aniline points of the blends with that of diesel is within the range of 10–15%.

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