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FULL LENGTH ARTICLE

Esters of ricebran oil with short chain alcohols as alternative fuel for diesel engines

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Abstract The potential of ricebran oil as a feedstock for the production of a fuel for diesel engines alternative to regular diesel fuel has been assessed. Esterification rate of crude ricebran oil with methyl alcohol was studied using different volumetric ratios of alcohol to oil, different catalyst loads and catalyst types. Catalysts used were sulfuric acid at a concentration of 2% of the oil/alcohol mixture in addition to hydrochloric acid and Amberlite IR-120 cation exchange resin at the same molar concentration of H^+ as in case of sulfuric acid. The reaction was fastest using sulfuric acid which has been then used to prepare esters of ricebran oil with methyl, ethyl, propyl and butyl alcohols. The four products have been evaluated as a fuel for diesel engines according to their fuel properties compared to regular diesel fuel. These properties include the calorific value, flash point, viscosity, pour point, cetane number, sulfur content and ASTM distillation characteristics. The results have shown that the methyl as well as the ethyl esters have the closest properties to those of regular diesel fuel. Diesel engine performance using blends of regular diesel fuel with methyl and ethyl esters of ricebran oil have been tested and compared to that using regular diesel fuel. The results have shown that the engine performance using a blend of 50% regular diesel fuel and 50% methyl esters of ricebran oil is better than that using regular diesel fuel. The brake thermal efficiency at full load was 30.2% using the fuel blend compared to 27.5% in case of regular fuel.

1. Introduction

Petroleum natural resources are expected to be depleted within few years in the future. Therefore, it becomes quite important to find alternatives to all products that are obtained from petroleum such as diesel fuel used to operate the engines of most vehicles. Biodiesel fuel which is chemically a blend of the esters of fatty acids with short chain alcohols is considered the most promising fuel substitute for diesel fuel obtained from petroleum. It is advantageous over regular diesel fuel as being renewable, free of sulfur and it is biodegradable [1–10]. More over biodiesel has the potential to cut down carbon dioxide emissions and hence reduces the problem of global warming. This is due to the fact that carbon dioxide released in burning plant biomass such as plant oils equals the carbon dioxide tied

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up by the plant during photosynthesis and thus, it does not increase the net carbon dioxide concentration in the atmosphere. It is thus more environmentally friendly compared to regular diesel fuel (petro-diesel). In addition, it has more lubricity which means smooth running of the engine.

Biodiesel fuel can be prepared by transesterification of vegetable oils with alcohols in presence of an alkaline or acidic catalyst. Alkaline catalysts are preferred over acidic catalysts as the reaction is usually faster. However, acidic catalysts are rather preferred when the acidity of oil feed stock is high.

Since Egypt imports huge quantities of edible oils annually to cover more than 90% of the consumption needs, it is completely unacceptable to produce this fuel in Egypt using vegetable oils that can be used for human consumption. Therefore, most previous studies carried out in Egypt in scope of biodiesel production were based on non edible oils. Examples of these oils are, jatropha oil [2], rapeseed oil [3] and used cooking oil [4].

Rice milling industry in Egypt could provide huge quantities of ricebran oil each year. That oil is usually highly acidic due to hydrolysis of triglycerides during the process of rice milling by action of lipase enzyme which makes the oil unsuitable for edible purposes. This work is proposed to assess the potential of the utilization of ricebran oil that can be obtained as a byproduct from the rice milling industry in Egypt as a feedstock for the production of biodiesel fuel.

2. Experimental

2.1. Materials

Crude ricebran oil used in this study has been supplied by Damanhour Factory, Damanhour, which belongs to the company of extracted oils and their derivatives, Egypt. The percentage of free fatty acids in the oil was 50% which is quite unsuitable for edible purposes. The fatty acid composition of the oil as reported by Megahed [6] was as follows:

Myristic acid	0.4%
Palmitic acid	20%
Stearic acid	1.1%
Palmitoleic acid	0.9%
Oleic acid	44.7%
Linoleic acid	32.6%
Linolenic acid	0.3%

Four types of short chain alcohols of analytical grade were used being methyl, ethyl, propyl and butyl alcohols

Three types of catalysts were used being sulfuric acid, hydrochloric acid and Amberlite IR-120 cation exchange resin. Basic catalysts were not recommended due to the high acidity of the oil (50%).

3. Experimental procedure

The reaction was carried out at the boiling point of each alcohol using each of the three catalysts used in this study. The three catalysts were used in quantities so that the molar concentration of H^+ in the reaction mixture was the same as that achieved using 2% sulfuric acid (based on the weight of the reaction mixture.). The weight of each catalyst used varied according to the number of moles of H^+ that can be provided by each gram of the catalyst. The volumetric ratio of the alcohol to oil was two. The reaction progress was followed up during the esterification process by thin layer chromatographic analysis of samples drawn over definite time intervals following the procedures of Megahed [6] until the reaction was completed. At the end of the reaction, the upper layer containing the ester was washed with distilled water till neutralization, dried over anhydrous sodium sulfate and the residual alcohol was completely evaporated. Three other similar experiments were also carried out using 2%, 3% and 4% sulfuric acid using one volume of alcohol to each volume of oil as to study the effect of catalyst load. In order to study the effect of alcohol to oil volumetric ratio on the process rate, some other experiments were carried out using 1, 1.25 and 2 volumes of alcohol to each volume of oil and the conversion rate measured each time.

The prepared esters were tested for their fuel properties using the ASTM standard methods for petroleum products [11]. These include the kinematic viscosity (D-445), heat of combustion (D-224), pour point (D-97), distillation characteristics (D-86), flash point (D-92), carbon residue (D-189), sulfur percentage (D-4294), API gravity (D-1298) and, ash % (D-482). The cetane number has been determined according to the equation used by Megahed [6].

The prepared biodiesel fuel has been also evaluated according to the performance of a diesel engine running using blends of biodiesel with regular diesel fuel in comparison to that using regular diesel fuel. Four blends were tested being two blends of diesel fuel with the methyl esters of ricebran oil and two other blends of diesel fuel with the ethyl esters of ricebran oil. The concentration of the esters of ricebran oil, (biodiesel fuel) in those blends was 25% and 50%. Engine testing has been conducted on an air cooled single cylinder four stroke direct injection diesel engine (Robur). A schematic layout of the experimental set-up used for testing the fuels on the engine is described in Fig. 1. The experiments were carried out at a constant speed of 1250 rpm and the flow rate of air, A, was 29.8 kg/h. Four experimental runs were made using each fuel at different loads where the break power was increased each time to be 4.36 kW at full engine loading The rate of fuel consumption, F, kg/h as well as the break power, kW was recorded each time. Accordingly, the brake specific fuel consumption, BSFC as well as the brake thermal efficiency was estimated. Brake thermal efficiency% = 100 × (Brake Power, kW × 3600)/(Fuel consumption rate, gm/h × calorific value, kJ/gm), Megahed [6].

4. Results and discussion

4.1. a-Effect of the process conditions on the esterification rate

The results listed in Table 1 shows the effects of catalyst type, catalyst load and volumetric ratio of alcohol to oil on the esterification rate of ricebran oil. The three catalysts used and compared in this Table include Amberlite IR-120 cation exchange resin, HCl and H_2SO_4. All catalysts were used at a concentration adjusted so that the concentration of H^+ in the reaction mixture was the same as that using 2% H_2SO_4 based on the