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FULL LENGTH ARTICLE

Performance evaluation of diesel engine using rice bran biodiesel

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Abstract The consumption of fuels in the world is increasing rapidly and it affects the global economy of all the countries so this factor forced all the countries to find the alternative fuel to reduce and even replace the usage of petroleum. Thus use of biodiesel from non-edible oil sources serves as an alternative to this problem. The present study focuses on impact assessment of rice bran and crude rice bran biodiesel and its blends with diesel on diesel engine performance. The experimental investigation provides in depth detail of the biodiesel production process, evaluation of fuel properties and impact on engine performance. The study also investigates the optimization of the Compression ratio (CR) of a compression ignition engine fueled with blends of biodiesel. In order to find out the optimum CR of the engine, experiments were conducted at different CRs ranging from 12 to 18. Then the experiments were conducted using B_{10}, B_{20} and B_{40} blends of crude rice bran bio-diesel and diesel at CR of 12 and 14 and these results were compared with the results obtained when the same engine was tested on conventional diesel fuel. Similarly the experimental results of B_{10}, B_{20} and B_{40} blends of rice bran bio-diesel at CR 14 were investigated and analyzed. Based on the experimental investigation the blends of crude rice bran bio-diesel can be used as fuel in diesel engine without making any modification to the diesel engine.

1. Introduction

Bio-diesel is an alternative to petroleum-based fuels derived from vegetable oils, animal fats, and used waste cooking oil including triglycerides. Increasing environmental concern, diminishing petroleum reserves and agriculture based economy of our country are the driving forces to promote bio-diesel as an alternate fuel [1,2]. Biodiesel can be produced from a great variety of feedstock's which includes most common vegetable oils (e.g., soybean, cottonseed, palm, peanut, rapeseed/canola, sunflower, coconut) and animal fats (usually tallow) as well as waste oils (e.g., used frying oils). The choice of feedstock depends largely on availability. Biodiesel has a higher cetane number than diesel fuel, no aromatics, no sulfur, and contains 10–11% oxygen by weight [3,4]. The lower sulfur in the blend helps in the reduction in the sulfur dioxide emissions which generates sulfuric acid in our atmosphere and this results in the formation of acid rain. The absence of toxic and carcinogenic aromatics (benzene and xylene) in bio-diesel

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means the gases produced due to combustion will have reduced impact on human health and the environment. The high cetane rating of bio-diesel (ranges from 49 to 62) is another measure of the additive's ability to improve combustion efficiency. Due to environmental concern about pollution coming from automobile emission, biodiesel is emerging as a developing area of high concern [5–9].Generally the direct use of vegetable oils in the diesel engine is not recommended due to their high viscosity, which affects combustion. So in order to reduce its viscosity so that it can be used in common diesel engines without making any modification in the engine the transesterification method is used to reduce the high viscosity of oil [10–13].

Rice bran oil ranks first among the non-conventional, inexpensive, low-grade vegetable oils. Furthermore, crude rice bran oil is a rich source of high value-added byproduct. Therefore, use of rice bran oil as raw material for the production of biodiesel not only makes the process economical but also generates value added bio-active compounds. Isolation and purification of these byproducts make the process attractive and remunerative. Thus, if the by-products are derived from crude rice bran oil and the resultant oil is used as feedstock for biodiesel, the resulting biodiesel could be quite economical and affordable. In the present study, crude rice bran oil and refined rice bran oil are chosen as potential alternatives for producing biodiesel and use as fuel in four stroke compression ignition engines.

The kinematic viscosity of crude rice bran oil and refined rice bran oil is however several times higher than that of diesel oil [8] and this leads to problems in pumping and atomization in the injection system of a diesel engine so their viscosity must be lowered. The combined effect of high viscosity and low volatility causes poor cold engine start up, misfire and ignition delay. Hence, it is necessary to bring their combustion related properties closer to those of diesel oil [4]. The free fatty acid (FFA) content of crude rice bran oil is high depending on the quality of rice bran from which the oil has been extracted. Because of the high FFA content for crude rice bran oil a 2-stage transesterification process is carried out which includes an acid catalyzed transesterification followed by a base catalyzed transesterification. For refined rice bran oil a single stage base catalyzed transesterification was carried out. The present study focuses on production and performance evaluation of rice bran biodiesel as an alternative source of fuel.

2. Biodiesel production methodology

Due to high FFA (15%) for crude rice bran oil transesterification was carried out in two stages. First stage is called acid catalyzed transesterification in which transesterification reaction was carried out in a water bath shaker and some quantity of crude rice bran oil was taken in a conical flask and it was preheated to the temperature of 60 °C for 30 min. Then a mixture of known quantity of sulfuric acid (H_2SO_4) as acid catalyst and methanol was then mixed with the preheated crude oil. The preheated oil mixture was then subjected to 1 h constant stirring at a constant temperature of 60 °C inside a water bath shaker. After 1 h of constant stirring the mixture was poured into a separating funnel for impurities to settle down. After 4–5 h the settled down impurities are separated from the remaining oil. After this second stage of transesterification (base catalyzed) starts in which remaining oil quantity was measured and again heated up to 60 °C. Potassium hydroxide (KOH) as base catalyst and methanol was then mixed with the remaining preheated oil. The preheated oil mixture was then again subjected to 1 h constant stirring at a constant temperature of 60 °C inside a water bath shaker. After 1 h of constant stirring the mixture was poured into a separating funnel for glycerol to settle down. After 2–3 h settled down glycerol is separated and removed. The remaining portion is methyl ester (biodiesel) of crude rice bran oil (yield 82%) which is further purified through washing and drying for removal of excess KOH, methanol and water. The biodiesel yield of 90% is obtained using same procedure for rice bran oil.

3. Measurement of fuel properties

The properties of crude rice bran oil biodiesel and refined rice bran oil biodiesel were evaluated using the standard test methods given in Table 1. Table 1 shows the apparatus and standards used for evaluating the fuel properties.

4. Impact on engine performance

The specification of the engine used for experimentation is given in Table 2. The set-up enables the study of engine brake power, fuel consumption, air consumption, heat balance, thermal efficiency, volumetric efficiency etc. The performance tests were carried out on the variable CR single cylinder four stroke

Table 1 Different apparatus and standards used for fuel characterization.

Fuel property	Test method/standard	Crude rice bran biodiesel	Rice bran biodiesel
Density, g/cc	Hydrometer, IS: 1448 [P: 32]: 1992	0.897	0.876
Viscosity at 40 °C, mm^2/s	Redwood viscometer, IS: 1448 [P: 25]	3.59	3.24
Flash point, °C	Closed cup flash and fire point apparatus, IS: 1448 [P: 32]: 1992	205	152
Fire point, °C	Closed cup flash and fire point apparatus, IS: 1448 [P: 32]: 1992	210	159
Cloud point, °C	Cloud and pour point apparatus, IS: 1448 [P:10] 1970	−1	3
Pour point, °C	Cloud and pour point apparatus, IS: 1448 [P:10] 1970	−3	−1
Calorific value, kJ	Bomb calorimeter, IS: 1448 [P: 6] 1984	9814	9920
FFA content, %	Titration with 0.1 N NaOH	0.28	0.07
Carbon residue, % by mass	Carbon residue apparatus, ASTM D189-IP 13 of IIP	0.251	1.15
Ash content, % by mass	Electric muffle furnace, ASTM D482-IP 4 of IIP	0.27	0.22

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