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Evaluation of Biodiesel from Rice Bran Oil as a Fuel for Automotive Applications

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Abstract

Due to increased environmental pollution and gradual depletion of the fossil fuels, it becomes necessary to develop viable alternative fuels from renewable sources for industrial as well as automotive applications. Vegetable oils seem to be a potential alternative fuel but because of some detrimental properties like high viscosity and low volatility, it causes several problems during their long duration usage in diesel (CI) engines. The most commonly used method to make vegetable oil suitable for use in diesel engines is to convert it into biodiesel i.e. vegetable oil esters using transesterification process. Rice Bran oil is an underutilized, edible vegetable oil, which is available in large quantities in rice cultivating countries and very little research on it, has been done to utilize this oil as a proper substitute to mineral diesel fuel. In this work, the transesterification process for the production of rice bran oil methyl ester has been investigated. The optimum conditions to achieve maximum yield of biodiesel has been investigated at different catalyst weight % of oil and with different molar ratio of Rice Bran oil and methanol. The most expected result has been investigated at 6:1 molar ratio of methanol and Rice Bran oil at the reaction temperature 60°C, 1h heating and stirring time, and for 1% (w/w) catalyst for high biodiesel production rate. The fuel properties, economic analysis and comparison with other edible and non-edible sources showed that the biodiesel from rice bran oil has comparable properties to substitute mineral diesel fuel in CI engines, hence, rice bran oil methyl ester can be recommended as mineral diesel fuel substitute for diesel engines especially in automotive engines.

Keywords: Biodiesel, Rice Bran oil, Transesterification, Catalyst.

1. Introduction

During the past decades worldwide petroleum consumption has permanently increased due to rapid growth of human population and industrialization, which has caused depletion of the fossil fuel reserves and increased their prize. On the other hand, combustion of the petroleum fuels emits greenhouse gases and contributes to environmental pollution and global warming [1]. Since most of the road vehicles are utterly dependent on these fossil fuels, thus there has been happening a severe instability of the environment and climate of the whole planet. Therefore, there is a great awareness in diesel fuel substitution with a clean, renewable fuel such as biodiesel. It facilitates 75% cleaner burning phenomena than diesel fuel, reduces the CO emission by 48%, particulate matter emission by 47%, and ozone formation probability by 67% [2]. It can be made from vegetable oils, animal fats or recycled restaurant greases. Out of these, rice bran oil is one of the most promising alternative fuels for diesel engine. It is a non conventional, inexpensive and low grade vegetable oil. Its acid value, FFA content and saponification value dignifies its approbation in biodiesel production [3]. Though various works had been pursued on biodiesel but most of them are on elementary analysis of different parts of the biodiesel production. But, many of them lacks the clarification of the RBO biodiesel usability as a fuel in automotive applications considering its overall production feasibility, fuel characteristics compared to diesel and economic perspective. So, the main purpose of this work is to produce biodiesel in an economical and effective way, to investigate the fuel properties of biodiesel from RBO, to compare it with the conventional Diesel fuel, make a standard comparison of different biodiesels made from variety of oil and finally proposes RBO biodiesel prospective as a fuel in automotive vehicles with respect of its characteristics and financial consideration.

2. Methodology

2.1 Transesterification Process

Transesterification is a chemical reaction in which alcohol reacts with triglycerides of fatty acids of vegetable oil in presence of catalyst. It is such a reversible process in which an ester is transformed into another through interchange of the alkoxy moiety [4]. The reaction is as follows:

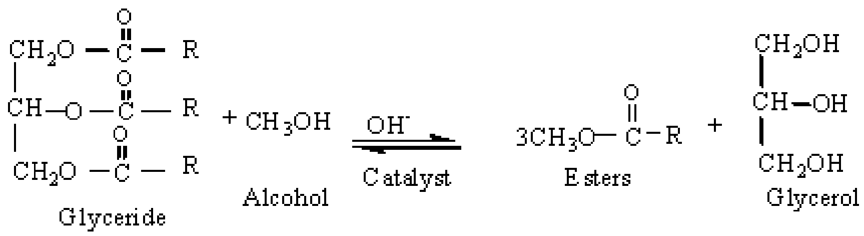


Fig. 1. Transesterification reaction

There are three types of transesterification process are available including acid-catalyzed, base-catalyzed and enzyme-catalyzed transesterification. Depending upon the FFA content, reaction time and temperature all these processes have their own certain benefits [5-10]. There are also some other processes like Heterogeneously Catalyzed process, Non-ionic Base-Catalyzed process. The above figure shows the chemical process for methyl ester biodiesel.

2.2 Production of Biodiesel (BD) from Rice Bran Oil

The refined and neutralized rice bran oil collected from the market contains the following substances per liter of oil:

[Moisture-0.11%, Ether insoluable matters-0.12%, Per-oxide value-4.41, Iodine value-101.42, Refractive index-1.4658, FFA content-0.25%, Acid value-0.44, Saponification value-188.61, Unsaponifiable value- 0.75%, Density at room temperature(30°C) -0.913]* All data are collected for white gold rice bran oil (From Rashid Oil Mills Ltd [11]).

Now the selection of appropriate and economical transesterification process is the first priority for biodiesel production. Since the FFA content of the collected rice bran oil is less than 2% thus base-catalyzed transesterification is applicable. In transesterification reaction since three moles of alcohol reacts with one mole of triglycerides thus the molar ratio of oil to methanol should be 3:1. But transesterification is a reversible reaction. In order to keep the reaction always forward it is necessary to add excess alcohol. Different studies showed that a molar ratio of 5:1 to 7:1 is required for better reaction purposes. Bradshow and Meuly (1944) showed that molar ratios greater than 5.25:1 are effective for better separation of ester and glycerol phases [10]. In such case, 3:1, 4:1, 5:1, 6:1 molar ratios had been tested, but for of 6:1 molar ratio the results were satisfactory. Much oil was extracted, soap was easily separable and glycerin settled down comfortably.

The raw materials for biodiesel production are: Methyl alcohol having 99.5% purity, density of 0.792 gm./ml and the molar mass is 32.04 gm./mole; Sodium hydroxide pellets having 99.98% purity; Rice bran oil having average molecular weight 867.90 gm./mole (source: Ying Xia Li 2011[13]). By the molar ratio 6:1 of methanol to oil, it is required 255.2 ml of methyl alcohol for 1 liter RBO (from molar ratio to volume ratio calculation). For this amount of oil to methanol, catalyst amount is 9.13 gm (for 1% catalyst) for RBO density 0.913 gm./ml. For small scale production, 250 ml RBO, 63.8 ml CH_3OH and 2.283 gm. NaOH (for 1% catalyst) has been taken.

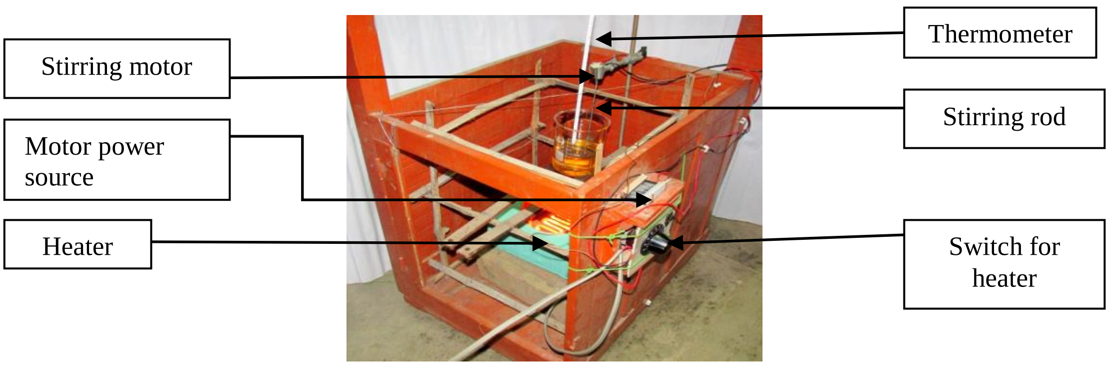
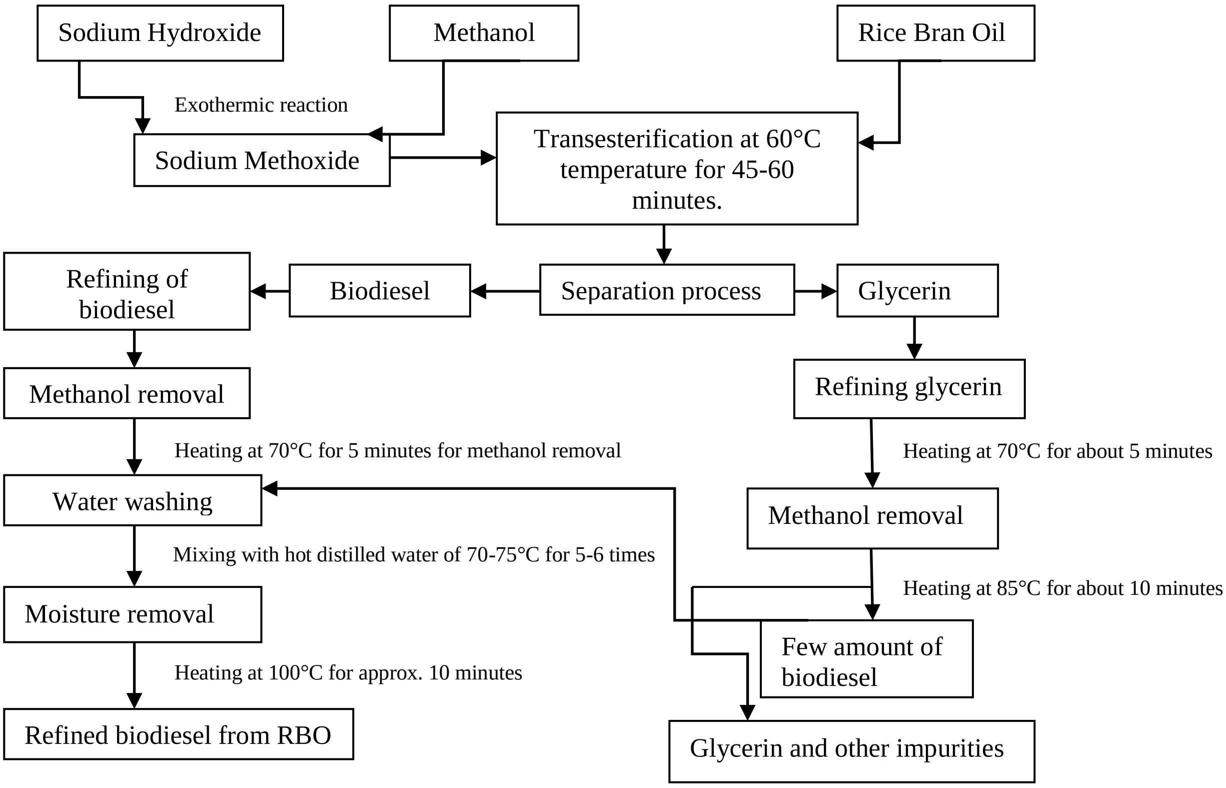


Fig. 2. Experimental setup for biodiesel production

2.3 Flow diagram for biodiesel production from rice bran oil



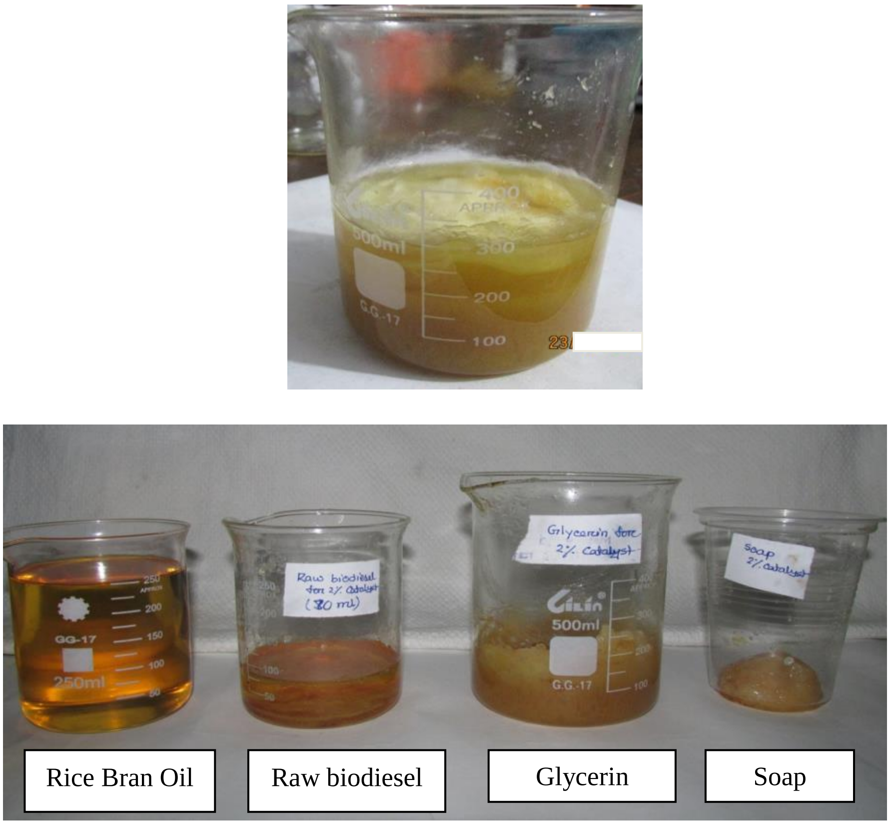


Fig. 3. Different stages of biodiesel production

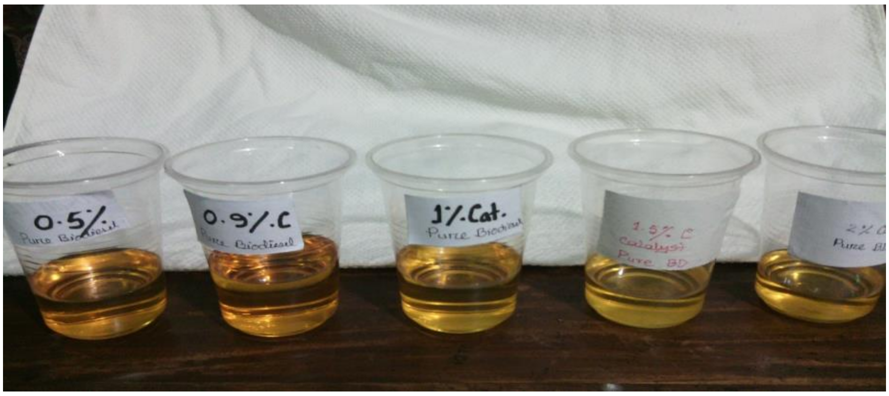


Fig. 4. Pure usable biodiesel with different percentages of catalyst

3. Results and Discussion

Table 1. Comparison between fuel properties of RBO, biodiesel (BD), RBO methyl ester

Serial no.	Properties	RBO	Biodiesel (for 1% catalyst)	Diesel*
1	Density(gm./ml)	0.913**	0.7561	0.82
2	Flash point(°C)	327**	Above 150°C	55
3	Boiling point(°C)	320**	334.5	248
4	Calorific value (MJ/kg)	36.99**	37.84	44.5
5	Kinematic viscosity at 30°C(mm^2/s)	67.7	5.274	1.6-2.9
6	Kinematic viscosity at 40°C(mm^2/s)	42.87	4.63	2.5-3.5

*Properties are taken as standard value (source: http://www.dieselnet.com/standards/fuels.php)
**Source: www.rashidgroup/whitegoldricebranoil.com

Table 2. Comparison between fuel properties of different biodiesels from different vegetable oils

Properties	Sunflower Oil BD_1	Soyabean Oil BD_1	Peanut Oil BD_2	Rapeseed Oil BD_2	Palm Oil BD_2	Mahua Oil BD_3	Jatropha Oil BD_3	Castor Oil BD_4	RBO BD
Density (gm./ml)	0.880	0.884	0.883	0.893	0.880	0.880	0.880	0.68	0.7561
Viscosity at 40°C (mm^2/s)	4.2	4.08	4.9^a	4.8	5.7^a	3.98	4.84	4.8	4.63
Calorific value (MJ/kg)	40.1	39.8	33.6	40.0	33.5	37	37.2	37.37	37.84
Flash point(°C)	164	141	176	153	164	208	192	183	Above 150°C

^{a} at37.8°C
$_1$Srivastava et al. [14], $_2$Ghadge and Rehman [15], $_3$Encinar et al. [16]
$_4$Dept. of ME, KUET, June 2012 [17]

Biodiesel production cost: Biodiesel produced from 1 Liter RBO= 0.780 liter, Cost of 0.780 liter biodiesel= 322.132 BDT. Cost of 1 liter of biodiesel= 443 BDT. Prize of De-oiled rice cake, wax and gum, soap and glycerin were found= 81.48 BDT. Therefore, the neat Biodiesel production cost without methanol recovery= 361 BDT.

Table 3. Comparison between the different biodiesel production costs

Serial no.	Vegetable oil	Cost per liter(BDT)	Cost of BD without recovery (soap & glycerin) BDT	Amount of BD (liter)	Total cost of BD per liter(BDT)
1.	Castor[1]	74	2264	0.9	2515.55
2.	Neem[2]	82.5	1753.5	0.95	1845.78
3.	Jatropha[3]	80.5	2385	0.9	2650.5
4.	Sunflower[4]	167.56	305.56	0.7	436.51
5.	Coconut[4]	168	333.6	0.75	444.8
6.	Rice Bran	120	322.132	0.728	443

[1]Biodiesel from castor oil as an alternative fuel for diesel engine, Dept. of ME, KUET, June 2012
[2]Biodiesel from Neem oil as an alternative fuel for diesel engine, Dept. of ME, KUET, June 2012
[3]Biodiesel from Jatropha oil as an alternative fuel for diesel engine, Dept. of ME, KUET, March 2009
[4]Production of biodiesel from vegetable oil as an alternative fuel for diesel engine, Dept. of ME, KUET, March 2013

The high kinematic viscosities of the vegetable oils are generally 30-40 mm^2/s at 40°C [18-19]. It is due to their large molecular weight in the range of 600-900, which is about 20 times higher than that of diesel fuel. The presence of chemically bound oxygen also lowers their heating value by about 10%. The high viscosity of vegetable oils leads to unfavorable pumping, atomization and spray characteristics [12]. Therefore, the basic part of this project was to reduce the kinematic viscosity of RBO and bring down it in the range of 1.9-6 mm^2/s (ASTM standard). For this reason, transesterification method was applied to reduce the viscosity. At first, volumetric ratio of 1:5, 1:6, 1:7 of RBO to methanol were applied with the varied percentage (0.5%, 0,7%, 0.9%, 1%, 1.5%, 2%) of catalyst but the reactions were inappropriate and undesired results were observed. Then, the molar ratios of 1:5, 1:6 and 1:7 of oil to methanol were applied with the identical percentages of catalyst mentioned as before. The most promising result was observed for 1:6 molar ratio of oil to methanol with the varied percentages of catalyst. For 0.5% catalyst the amount of production was high with less amount of soap and glycerol but that required water washing 8-10 times. The kinematic viscosity was about 6.567 mm^2/s, which exceeded ASTM standard for 40°C. But, for 0.9%, 1%, 1.5% and 2% catalyst use the kinematic viscosities are 5.668, 4.63, 4.3, and 4.1 mm^2/s. With the increasing amount of catalyst the soap formation also increased together with the increase in glycerin formation rate. But in this case, the water washing time got decreased. The most satisfactory result was obtained for 1% catalyst use. For this percentage of catalyst use, the biodiesel production rate was high with decreased soap and glycerin formation and decreased water washing time compared to 0.5% and 0.9% catalyst use. The kinematic viscosity was observed 4.63 mm^2/s, which was within the range of ASTM standard kinematic viscosity. The other fuel properties like calorific value was measured 37.84 MJ/kg, boiling point temperature 334.5°C for 1% catalyst, which shows quite better result to substitute diesel fuel use (Table.1) and other biodiesels e.g. sunflower, peanut, palm, jatropha and castor oil methyl ester (Table. 2). These fuel properties showed that rice bran oil methyl ester exhibits very close characteristics to diesel fuel and in comparison to other edible and non-edible oil methyl esters it can be suggested as one of the best substitute for diesel fuel in diesel engine. In addition, RBO biodiesel has showed a better consequence in case of financial affordability in comparison to coconut, sunflower, neem and castor oil methyl ester (Table. 3).

4. Conclusion

Today biodiesel is am increasingly attractive, non-toxic, biodegradable fossil fuel alternative that can be produced from a variety of renewable sources like vegetable oils, waste cooking oils, animal fats etc. Therefore, in this project, an effort has been made to produce biodiesel from rice bran oil. The primary of this work was to evaluate the biodiesel obtained from rice bran oil as a fuel in the automotive applications. To implement this a detail study on biodiesel and its importance was carried out. In the second stage, biodiesel was produced by the application of the most appropriate and economical transesterification process. The production rate of biodiesel varied for different catalyst percentages use. But highest the production rate was obtained for 1% (w/w) catalyst use. By the fuel properties of the usable biodiesel at this percentage, it was observed that it has closer properties to petroleum diesel also has better fuel characteristics in comparison to peanut, palm, jatropha, castor, mahua oil methyl esters. Through the economic analysis, it evident that the RBO methyl ester has better economic prospect compared to other biodiesels. In addition to this, rice bran oil is such an oil which is extracted from a byproduct called rice bran obtained after rice husk. Therefore, without any extra cultivation effort and without affecting the human food needs, rice bran oil is the only vegetable oil which shows a better resource and high priority in biodiesel production in mass rice cultivating countries.

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