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Prospect of rice bran for biodiesel production in Bangladesh

Ahmed Probudha Hasan[a,*], Md. Abdul Wakil[a], Md. Abdullahil Kafy[a]

[a]*Department of Mechanical Engineering, Khulna University of Engineering and Technology, Khulna-9203, Bangladesh.*

Abstract

This paper investigates the prospect of biodiesel from rice bran in Bangladesh. Rice bran is the non-edible portion of paddy. It can be easily collected from the rice husk of the paddy. The estimated production of paddy in Bangladesh in year 2010-11 is about 33.54 million metric ton (source: BBS). If 18-20 wt% rice is rice husk then the amount of rice husk becomes 6.71 million metric ton. This rice husk contains about 16 to 20% of crude rice bran oil of its weight. An estimate of about 1.34 million metric ton of crude rice bran oil can be obtained annually. The current consumption of Petroleum Products in Bangladesh is 3.7 MT/annum and annual growth rate is 4% (source: BPC). Diesel consumption in Bangladesh is about 2.4 MT/annum. If the estimated amount of rice bran oil (RBO) is converted into biodiesel, this can satisfy 60-70% of our diesel need. This study involves the investigation of oil properties collected from rice bran to ensure the production of biodiesel by the well-known transesterification process. In order to inveterate the clarity of cost of biodiesel production, the aim fix with the determination of fuel properties, economic analysis and comparison with other non-edible sources.

Keywords: Non-edible source; rice bran oil; biodiesel; transesterification process.

1. Introduction

Human history for energy uses started with utilization of sun for light and heat. The first natural gas well was dug in 1821 [1]. Coal mines were initiated at the same time, oil was also discovered. In the New World, the first commercial oil well was dug in 1858 [2]. In New York, Thomas Edison built the first power plant in 1882 [3]. As

* Ahmed Probudha Hasan. Phone: +8801710264348
E-mail address: ninad009@yahoo.com

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civilization is moving towards the era of utilizing different modern technology the hunger for energy is increasing rapidly and fossil fuel is diminishing at a very fast rate. So it is the right time to invent a newer source of energy to replace the demand of the fossil fuel and meet the scarcity for energy. The term biodiesel cannot be defined definitely or clearly. It stands for neat vegetable oils used as Diesel Fuel as well as neat methyl esters prepared from vegetable oils or animal fats and blends of conventional diesel fuel with vegetable oils or methyl esters [4]. Biodiesel can be prepared from vegetables, animal fates or other agricultural products all around our environment. The variability of biodiesel can differ on various agricultural products depending on the production of that vegetable in that area. But comparing to fossil fuel most of the cases biodiesel burn up to 75% cleaner [5]. The ozone-forming potential of biodiesel emissions is nearly 50% less than conventional diesel fuel [6]. In diesel engine the use of vegetable oils was first started at the very beginning of diesel engine invention. Rudolf Diesel the inventor of the diesel engine used vegetable oil (peanut oil) as an engine fuel for demonstration purposes in 1900 [7]. In the 1930's and 1940's vegetable oils was slowly started to use in some of the engines of automobiles. Now a day's vegetable oil has created a new aspect to replace diesel fuel and a new dimension in research to improve the existing vegetable oils and invent new source of renewable energy. Rice bran oil can be defined as natural oil that is produced using the rice bran inside the hull of the paddy [8].

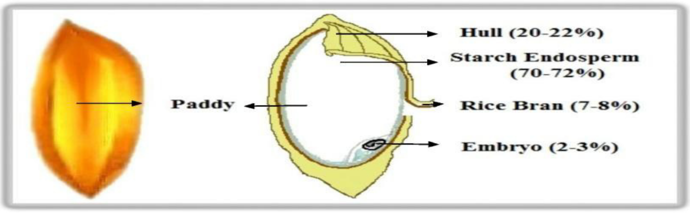


Fig. 1. Structure of a Rice Kernel.

It is very difficult to collect the rice bran separately from the hull of the paddy, so most of the cases rice bran oil is extracted from a mixture of rice bran and hull. In the beginning of rice bran oil production it was mostly used as a cooking oil because it has a higher smoke point (about 232 °C or 450 °F) than the other vegetable oils, which prevent the oil from breaking down to form toxic substances [9]. Japan and are United States of America use rice bran oil to manufacture soap and skin crime. But the history of using rice bran as biodiesel is not too old with respect to use of other vegetable oils. The use of rice bran as biodiesel is mostly started after the middle half of the millennium in those countries which produce plenty of rice and has resources to convert rice bran oil in to biodiesel. Such countries are United States of America, China, India, Thailand, Brazil, Indonesia, Japan, Vietnam etc. In Asia India, China, Taiwan, Indonesia are giving priority of producing biodiesel from rice bran oil. But still today there is no prior investigation nor is research performed in Bangladesh to determine the prospect of producing biodiesel from rice bran oil. Rice bran oil (RBO) offers significant potential as an alternative low-cost feedback for biodiesel production for our country as the principal seasonal crop of Bangladesh is Paddy. The rice bran in Bangladesh is usually used for feeding the livestock or burring as a low cost fuel. The purpose of this study is to investigate the prospect of rice bran for the production of biodiesel including biodiesel production from rice bran and investigation of the fuel properties. Economic analysis will be carried out for the production cost clarification of biodiesel.

2. Methodology

2.1. Transesterification Process

Transesterification can be defined as a chemical reaction in which alcohol reacts with triglycerides of fatty acids (vegetable oil), in presence of catalyst. It is a reversible reaction. In this process an ester is transformed into another through interchange of the alkoxy moiety [10].Transesterification is used mainly in the synthesis of polyesters and in the production of biodiesel because it has more advantages than ester synthesis from carboxylic acids and alcohol

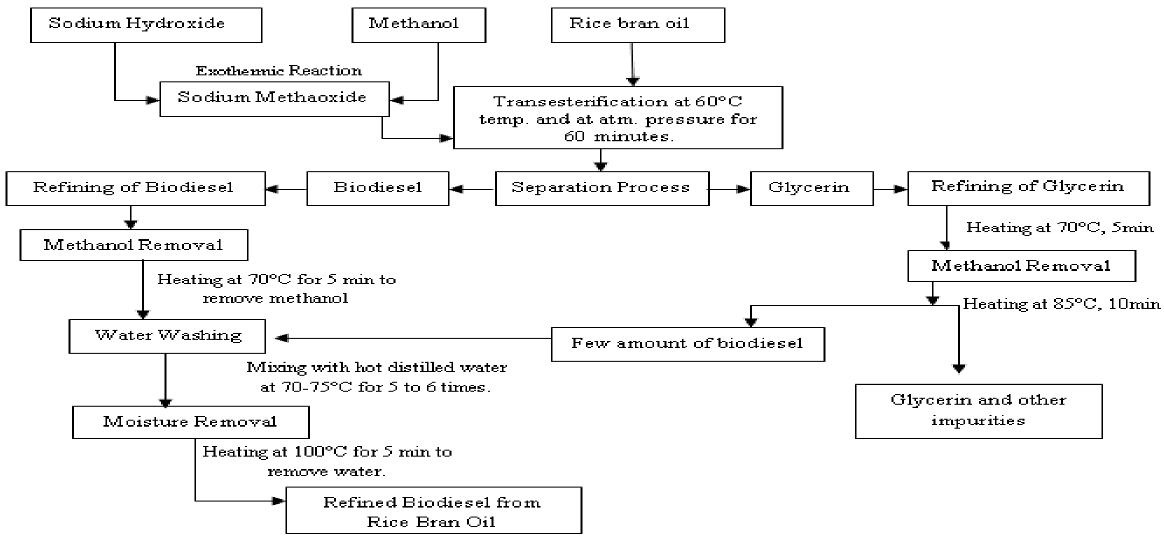
[11]. There are mainly three types of transesterification process based on the use of catalyst and those are Base-Catalyzed Transesterification, Acid-Catalyzed Transesterification and Lipase-Catalyzed Transesterification [12]. All the three have their own benefit for biodiesel production from various resources depending on FFA content, temperature and reaction time.[13,14,20,21,22,23] There are other few processes for example Heterogeneously Catalyzed Process, Non-Ionic Base-Catalyzed Processes etc.

2.2. Production of Biodiesel from Rice bran oil

Refined & neutralized rice bran oil collected from market containing following properties per litter [Moisture0.11 %, Free Fatty Acid (FFA) 0.25 %, Acid value (as KOH) 0.44 mg./ gm., Density at 30ºC is 0.913 gm. / ml, Unsaponifiable matters 0.75 %, Saponifiable matters (as mg KOH/g) 188.61, Peroxide Value (PV) 0.87 meg O/kg etc.]* All data are collected from Rashid Oil mill (for White Gold Rice Bran Oil [18]).

The selection of appropriate and economical transesterification process is the first priority for biodiesel production. As the FFA content of collected rice bran oil is less than 2% so the base catalyst transesterification process would be the right choice. In transesterification reaction three moles of alcohol reacts with one mole of triglyceride. So theoretically the molar ratio of RBO to alcohol should be 1:3. But transesterification is a reversible reaction; to take the reaction always forward excess amount of alcohol is used. Different studies show that best reaction occurs at the molar ratio of 1:5 to 1:7 of oil to methanol. Bradshaw and Meuly (1944) reported that a molar ratio greater than 1:5.25 is effective for better separation of ester and glycerol phases [23]. The average molecular weight of RBO is about 867.90 g/mol (source: Ying Xia Li, 2011 [24]; about 875g/mol by Lin L., 2008 [17]) and the molar mass of methanol is 32.04 g/mol. By the molar ratio to volume calculation we get for 1 litter of RBO about 255.2 ml of methanol is required (calculation for 1:6 molar ratio of oil to alcohol). For this catalyst NaOH is needed about 18.26 gram (for 2% catalyst) as the density of the RBO is 0.913 g/ml. For small scale production of biodiesel 250 ml oil, 63.8 ml methanol and 4.565 gm. sodium hydroxide is taken.

2.3. Flow diagram for Biodiesel production from rice bran oil



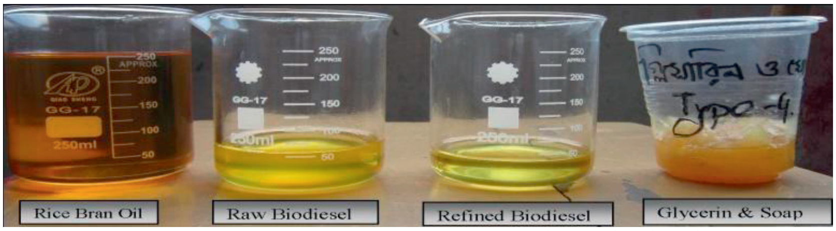


Fig. 2. Different stages of Rice Bran oil in Biodiesel Production.

3. Prospect of Rice Bran for Biodiesel in Bangladesh

According to the Energy and Mineral Resources Division (EMRD) of Bangladesh three major resources (natural gas, coal and petroleum) are used to fulfill the total energy crisis. Among them natural gas plays the most vital role by ensuring 75% of the commercial energy (source: EMRD). But most of this gas is used in electricity production, household purposes and industrial purposes. A new sector is booming which is CNG. Till June 2011 total number of CNG converted vehicles is 1, 96,783 (source: Petro Bangla). Although the total number of registered petroleum vehicles is about 18, 99,193 till May 2013(source: brta). Among them total number of diesel vehicles is about 2, 81,588 (source: brta). This huge amount of vehicles as well as Bangladesh railways consumed about 3.24 million metric ton of high speed diesel in year 2011-12 (source: BPC). The current consumption of Petroleum Products in Bangladesh is 3.7 MMT/annum and annual growth rate is 4% (source: BPC). The only natural resource to supply fuel (CNG) into this huge amount of vehicles in Bangladesh is natural gas.

The scarcity of energy is not for a split of a moment, it has an increasing rate with development and modernization of the human race. So the selected biodiesel must have the raw material which is available all year round, purchasing cost is low, should not effect on the cultivation of human food products and has an increasing rate of production to meet the energy hunger. In Bangladesh it can be said undoubtedly that production of rice is peerless comparing to the production of other biodiesel raw material such as Jatropha, Neem, Sunflower, Coconut, Algae, Cottonseed, Soybean, Mosna etc as shown in table 1.

Table 1. Data for different vegetable oil seed or source produced for the year 2008-09 and estimation of vegetable oil production.

SL. NO.	Component	Cultivation area(acres)	Total production of oil seed or source (metric tons)	Projected estimation of Oil (metric tons)
1.	Jatropha	1711.48	4.970 (Projected by using: area 710 ha × 7 ton per hectare [19])	1.57 (Based on 32%** oil content)
2.	Sun Flower	2344*	747*	209.16 (Based on 28%*** oil content)
3.	Coconut	6862*	316408*	215157.44 (Based on 68%*** oil content)
4.	Soybean	99282*	59395*	11879 (Based on 20%*** oil content)
5.	Rice	27872000*	6263400 (Projected production of rice Bran and Hull mixture; production in that year 31317000× 20%*** oil content)	1252680 (Projected by using: 6263400× 20%*** oil content)

* Source: Global Market Study on Jatropha by WWF.** Source: Bangladesh Bureau of Statistics (bbs).*** Standard value of that operation.

From the table it can be said unambiguously that without hampering the valuable land to produce necessary human foods, selection of raw materials for biodiesel production in Bangladesh must be rice bran. From a graph of raw material availability and projected estimation for biodiesel production for year 2008-09, 2009-10 and 2010-11 (for rice production of 31.317, 31.975 and 33.54 million metric ton respectively) the prospect of rice bran for biodiesel production can be shown physically in figure 3.

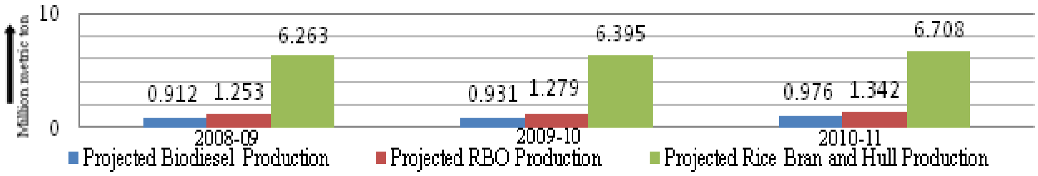


Fig 3. Raw Material Availability and Projected Estimation of Biodiesel Production in Bangladesh.

Although the supply is not equal to the desire level of demand, But using rice bran for the production of biodiesel can be a solution to this hunger for diesel product. If the estimated amount of rice bran oil (RBO) per year is converted into biodiesel, this can satisfy a huge amount of our diesel need.

4. Results and discussions

Table 2. Data for comparison of different properties of rice bran oil, diesel and biodiesel (for 0.9 % catalyst) from rice bran oil.

SL. NO.	Properties	Rice Bran Oil	Biodiesel from RBO	Diesel*
1.	Density (g/cc) at 30˚C	0.913**	0.748	0.82
2.	Flash Point (°C)	327**	Higher than 170°C	55
3.	Boiling Point (°C)	319**	332	248
4.	Calorific Value(MJ/Kg)	36.99**	37.5	44.5
5.	Kinematic Viscosity at 30˚C (mm^2/s)	67.7	6.09	1.6-2.9
6.	Kinematic Viscosity at 40˚C(mm^2/s)	42.87	4.6	2.5-3.5

*Properties of diesel are taken as standard value (source: http://www.dieselnet.com/standards/fuels.php); ** Source: www.rashidgroupbd.com

Cost of production: Biodiesel produced from 1 litre of rice bran oil (RBO) =0.728 Litre.

Total amount for the production of 0.728 litre biodiesel is = 345.29 TK. **Cost of biodiesel per litre = 474 TK.**

Total by-product produced during biodiesel production are De-oiled rice cake, soap and glycerine, Wax and gum which amount as = 79.55 Tk.[Price of wax and gum is assumed as 20 Tk (apx.)]. So the neat production cost without methanol recovery of biodiesel becomes **= 393.45 Tk.**

Table 3. Data for the production cost of biodiesel from various resources.

SL. NO.	Name of the vegetable oil	Cost of Biodiesel without recovery (Glycerin and soap) (Tk.)	Amount of Biodiesel (L)	Total Cost of Biodiesel per litre (Tk.)
1.	Jatropha[1]	2385.5	0.9	2650.5
2.	Neem[2]	2253.5	0.95	2372.1
3.	Castor[3]	2264	0.9	2515.55
4.	Sunflower[4]	305.56	0.7	436.51
5.	Coconut[4]	333.6	0.75	444.8
6.	Rice Bran	344.5	0.728	473.21

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[2]Biodiesel from Neem Oil as an Alternative Fuel for Diesel Engine, Department of Mechanical Engineering, **KUET,** June 2012.
[3]Biodiesel from Castor Oil as an Alternative Fuel for Diesel Engine, Department of Mechanical Engineering, **KUET,** June 2012.
[4]Production of Biodiesel from Vegetable Oil as Alternative Fuel for Diesel Engine, Department of Mechanical Engineering, **KUET,** August 2013.

Due to the O_2 content in Vegetable oils, heating value is about 10% less than the diesel oil. Also large molecular mass and chemical structure increases the viscosity. The high viscosity of vegetable oils leads to unfavourable pumping and spray characteristics [16]. So the basic aim at the start of this study was to reduce the viscosity of the rice bran oil and bring down the kinematic viscosity at the range of 1.9 to 6.0 mm^2/s(ASTM standard). It is found that with the use of 1:6 volumetric ratio of RBO to methanol with .5%, 1%, 1.5% and 2% catalyst (weight of the oil) to reduce the viscosity, the mixture was not appropriate. By using the 1:6 molar ratio of oil to methanol the production rate was high instead of any other molar ratio which is tested carefully. For 0.5% catalyst (weight of the oil) the production of biodiesel was high comparing to the glycerine and soap production but the biodiesel had to water wash 6-7 times. The Kinematic viscosity of this biodiesel is about 6.21 mm^2/s at 40˚C, which is higher than the ASTM Standard. In the same process for 1%, 1.5% and 2% catalyst (weight of the oil) we obtain the biodiesel from RBO of Kinematic viscosity 4.57, 4.45 and 4.11 mm^2/s respectively at 40˚C. With the increase in amount of catalyst the amount of soap was increased and decrease in water washing times. It is observed that with the increase of catalyst percentage the biodiesel production rate was decreased. Data for 0.9% catalyst shows a promising improvement both in higher biodiesel production rate with less soap and glycerine. It also reduces the water washing time than 0.5% catalyst use. It also passed the ASTM standard for kinematic viscosity 4.60 mm^2/s at 40˚C. During the further test of fuel properties it was obtained that the biodiesel boiling point is 338 ˚C for 2% catalyst use and 332 ˚C for 0.9% catalyst use. The calorific value was determined was about 37.5 MJ / Kg. The calorific value was increased than the rice bran oil. Not only the fuel properties of a biodiesel is important but also the feasibility of the production is also important

5. Conclusion

The primary objective of this study was to determine the prospect of rice bran for biodiesel production in Bangladesh. To achieve it, at first, the extraction process of rice bran oil from the rice bran is analyzed. In the second stage the appropriate and economical transesterification process was determined to obtain biodiesel and analyzed the prospect of rice bran for biodiesel production with cost analysis. The highest production rate was obtained with 0.9 % (wt. % of oil) catalyst use. It is estimated that if total produced rice bran is utilized the projected estimation of biodiesel production in Bangladesh would be nearly 1 million metric ton for year 2010-11 which is about half of the demand of diesel on that year. If rice bran is selected for biodiesel production in Bangladesh to reduce load on diesel, it will not only strength the economic backbone of Bangladesh but also help to ensure a green environment. Bangladesh is not an oil producer country; a large amount of the budget has to invest to import diesel fuel effecting the economic growth of the country. Rice bran can defend for the improvement in the total economic condition.

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