Proceedings of the
International Conference on Mechanical Engineeringand Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh

ICMERE2017-PI-210

PREPARATION AND PARAMETRIC ANALYSIS OF BIODIESEL USING MUSTARD OIL AND RICE BRAN OIL AS RAW MATERIALS BY TRANS-ESTERIFICATION METHOD

Shaon Talukdar[1] and Sharmi Mazumder[2]

[1]Assistant Professor, Department of Mechanical Engineering, DUET, Gazipur-1700, Bangladesh
[2]Lecturer, Department of Mechanical Engineering, DUET, Gazipur-1700, Bangladesh
shaonme@duet.ac.bd*, sharmi_me@duet.ac.bd

Abstract-*The amount of reserved fossil fuel for CI engine i.e. petro-diesel is decreasing day by day. Focusing on that topic, it is necessary to find out the alternatives. Biodiesel, as a highly renewable and biodegradable fuel, has been gaining the attention for the replacement of petro-diesel. Thus, the present work investigated the production of biodiesel from vegetable oils i.e. mustard oil and rice bran oil. Biodiesel was produced from the raw materials by a chemical reaction known as trans-esterification where sodium hydroxide (NaOH) and ethanol (C_2H_5OH) were present as catalyst and solvent of the reaction. Further, a parametric analysis of the produced biodiesel was analyzed and the determined values of different parameters were compared with the values of petro-diesel. Finally, a comparison between rice bran oil and mustard oil was made as a raw material for biodiesel production.*

Keywords: Renewable Energy, CI engine, Biodiesel, Vegetable oil, Trans-esterification

1. INTRODUCTION

Energy is a very important issue for social development of people as well as economic growth. Fossil fuels have been an important conventional energy source for years. Energy demand around the world is increasing day after day at a faster rate as a result of ongoing trends in industrialization and modernization. Alternative fuel means the term refers to substances (excluding conventional fuels) which can be used as fuels. The increasing need of energy has led to the increasing necessity for finding a feasible alternative fuel to conventional sources. Fossil sources are limited, and will eventually get used up. Only few countries have usable fossil reserves. Combustion of carbon-rich fuels leads to emissions like NO_x, SO_x, CO and CO_2, which are very harmful to the environment. Hydrogen is the most promising fossil fuel alternative for the future. It is the most common element in the universe, and yields the highest amounts of energy on combustion. Also, hydrogen combustion produces only energy and water, so it is completely ecofriendly. Experts predict that by 2020, problems in production, storage and distribution of hydrogen would been solved, making it the best solution to the current energy crisis [1,2,4]. Some of the typical optional fuels include bio diesel, ethanol, butanol, chemically stored electricity (batteries and fuel cells), hydrogen, methane, natural gas, wood, vegetable oil, biomass, and peanut oil. The term “alternative fuels” usually refers to a source of which energy is renewable. Renewable energy is the energy from renewable sources like wind power, solar power, tidal power, geothermal power, hydro power or thermal de-polymerization [3,8]. There is growing social interest, an economic and political need for the development of optional energy sources. This is due to general concerns of sustainability, environmental, economic, and geopolitical reasons. Two major concerns are that of rising cost of fossil derived fuels caused by an era of growing energy consumption and of global warming crisis [5, 6, 10].The major advantage of optional energy fuels is that it burns cleaner than the traditional petroleum fuels. It also helps to reduce such emissions as carbon monoxide, organic compounds, nitrogen oxide, sulfur and particulate matter [3]. Other advantages of optional fuels are that these fuels cost less, maintenance is cheaper and engines last longer. Most of the option energy fuels have greater conductivity and will increase the lubrication of engine parts depending on its performance [7, 11]. One of disadvantages of optional fuels is that it might be expensive to incorporate this technology into our already set up infrastructure. Compatibility is one of the major concerns of option fuels. The production of option fuels can have widespread effects. Whatever may be its advantages and disadvantages, due to the emerging needs of fuel, these renewable energy sources are better hope for us to solve the fuel crisis of the present and future [9]. The use of vegetable oils as an alternative fuel for diesel engines dates back to around a century. Due to rapid decline of crude oil reserve and increase in price, the use of vegetable oils is again prompted in many countries.

Depending upon soil condition and climate, different nations are looking for different vegetable oils. Bio-diesel refers to non-petroleum based substances which powers a diesel engine. Vegetable oils and used fry-oil have been used as biodiesels, after being subject to some processing. They are effective alternatives to petro diesel, producing similar amounts of energy with lesser emissions.

2. BIODIESEL AS AN ALTERNATIVE FUEL FOR CI ENGINE

Biodiesel is a liquid bio fuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines, alone or blended with diesel oil. Blends with diesel fuel are indicated as ‘‘BX’’, where ‘‘X’’ is the percentage of bio-diesel in the blend. For instance, ‘‘B5’’ indicates a blend with 5% bio-diesel and95% diesel fuel; in consequence, B100 indicates pure bio-diesel.

3. BIODIESEL PREPARATION

Biodiesel is produced from vegetable oils or animal fats and an alcohol, through a trans-esterification reaction. This chemical reaction converts an ester (vegetable oil or animal fat) into a mixture of esters of the fatty acids that makes up the oil (or fat). Bio-diesel is obtained from the purification of the mixture of fatty acid methyl esters (FAME). A catalyst is used to accelerate the reaction. According to the catalyst used, trans-esterification can be basic, acidic or enzymatic, the former being the most frequently used.

3.1Trans-esterification

Trans-esterification is the chemical reaction between triglycerides and short-chain alcohol in the presence of catalyst to produce mono-ester which produces FAME with glycerol.

$$Tri - acylglycerides + Methanol \xrightarrow{Catalyst} FAME + Glycerol$$

3.2 Stages of Biodiesel Preparation

There are five stages involved in the production of bio-diesel. The stages are shown in the following:

Treatment of raw materials

↓

Alcohol-catalyst mixing

↓

Chemical reaction

↓

Separation of the reaction products

↓

Purification of the reaction products

3.2.1 Treatment of Raw Materials

The content of free fatty acids, water and non-saponificable substances are key parameters to achieve high conversion efficiency in the trans-esterification reaction. The use of basic catalysts in triglycerides with high content of free fatty acids is not advisable since part of the latter reacts with the catalyst to form soaps. In consequence, part of the catalyst is spent, and it is no longer available for trans-esterification. In summary the efficiency of the reaction diminishes with the increase of the acidity of the oil; basic trans-esterification is viable if the content of free fatty acids (FFAs) is less than 3%.

3.2.2 Alcohol Catalyst Mixing

The alcohol used for bio-diesel production must be mixed with the catalyst before adding the oil. The mixture is stirred until the catalyst is completely dissolved in the alcohol. It must be noted that the alcohol must be water-free. Sodium and potassium hydroxides are among the most widely used basic catalysts. In present work NaOH is used as the catalyst. The stoichiometric ratio requires 1 mole of oil to react with 3 mole of alcohol, to obtain 3 mole of fatty acids methyl esters (FAME) and 1 mole of glycerin. However, since the reaction is reversible, excess alcohol as a reactant will shift the equilibrium to the right side of the equation, increasing the amount of products.

3.2.3 Chemical Reaction

The trans-esterification process may be carried out at different temperatures. For the same reaction time, the conversion is greater at higher temperatures. Since the boiling point of methanol is approximately 68ºC (341 K), the temperature for trans-esterification at atmospheric pressure is usually in the range between 50 and 60ºC. It is very useful to know the chemical composition of the mixture during the reaction; then, if the reaction mechanism and kinetics are known, the process can be optimized.

3.2.3 Separation of Reaction Products

The separation of reaction products takes place by decantation, the mixture of FAME separates from glycerin forming two phases, since they have different densities; the two phases begin to form immediately after the stirring of the mixture is stopped. Due to their different chemical affinities, most of the catalyst and excess alcohol will concentrate in the lower phase (glycerin), while most of the mono-, di-, and triglycerides will concentrate in the upper phase . Once the inter phase is clearly and completely defined, the two phases may be physically separated. It must be noted that if decantation takes place due to the action of gravity alone, it will take several hours to complete.

3.2.4 Purification of Reaction Products

The mixture of FAME obtained from the trans-esterification reaction must be purified in order to comply with established quality standards for bio-diesel. Therefore, FAME must be washed, neutralized and dried. Successive washing steps with water remove the remains of methanol, catalyst and glycerin, since these contaminants are water-soluble. Care must be taken to avoid the formation of emulsions during the washing steps, since they would reduce the efficiency of the process. The first washing step is carried out with acidified water, to neutralize the mixture of esters. Then, two additional washing steps are made with water only. Finally the traces of water must be eliminated by a drying step. After drying, the purified product is ready for characterization as bio-diesel according to international standards.

4. RESULT AND DISCUSSION

Molar ratio is a key parameter to find the best conversion of FAME from reactants of trans-esterification reaction. Studies were conducted to establish the effect of molar ratio of alcohol (ethanol) to oil (rice bran and mustard). In this study, experiments were conducted for different molar ratios. These were 3:1, 4:1, and 6:1. At each molar ratio, seven reaction times (15, 30, 45, 60, 120, 240, and 360 minutes) were studied. Figure 1 illustrates the results of several experiments. This figure also shows that conversion is higher at higher molar ratio for reaction time 15 to 120 minutes. Curves show almost same pattern when reaction time belongs 120 to 240 minutes and the further increase of reaction time show that the rate is almost constant for lower molar ratio.

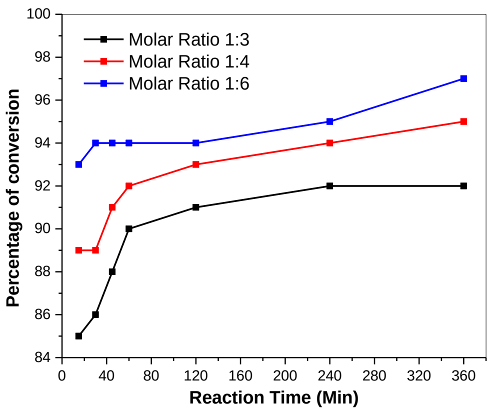

Fig.1: Effect of molar ratio to the percent of conversion with reaction time

Table 1 shows the various chemical and physical properties of bio diesel produced from mustard oil and rice bran oil as raw materials. Properties are measured by using the appropriate experimental set up where the different measuring instruments are in standard operating conditions. Hygrometer, Saybolt viscosimeter, Penky-Merten flash and fire point meter, bomb calorimeter and ignition quality tester are used to determine the values of density, kinematic viscosity, flash and fire point, higher calorific value and cetane number of produced bio diesels. All parameters except cetane number are measured at different laboratories in DUET. Cetane number is measured in BCSIR. The properties measured for both the bio diesels are compared with the ASTM standard for bio diesel. The comparison shows that, properties are in between the standard limit. The flash point of bio diesel produced from the rice bran oil has a higher value than that of the bio diesel produced from mustard oil. The calorific value also shows the same criteria but in case of kinematic viscosity, that bio diesel has a lower value that of the bio diesel produced using mustard oil.

Table 1: Physical and chemical properties of biodiesels prepared from rice bran oil and mustard oil compared with ASTM specifications

Properties	Biodiesel from rice bran oil	Biodiesel from mustard oil	ASTM D 6751 standard for biodiesel fuel	ASTM D 975 standard for biodiesel fuel
Cetane index	56.2	42.6	48 to 65	40 to 55
Flash point, ºC	160	142	100 to 170	60 to 80
Specific gravity at 15 ºC	0.88	0.883	0.88	0.85
Kinematic viscosity at 40 ºC, mm^2/sec	3.3	5.6	1.9 to 6	1.3 to 4.1
Calorific value, MJ/Kg	40.07	36.16	-	-

5. CONCLUSION

The all-round study of production of bio-diesel from rice bran oil and mustard oil was carried out. Overall results confirm that rice bran oil and mustard oil may be used as a resource to obtain bio-diesel by a series of experiments. The main conclusions derived from this study are:

(1) The best combination of based-catalyzed esterification condition is: 6:1 ethanol to oil molar ratio; 60ºC reaction temperature and 360 min reaction time. The maximum conversion efficiency was 98.7% under these reaction conditions.

(2) The product of esterification was refined to become bio-diesel. The main fuel properties of rice bran oil and mustard oil bio-diesel agreed well within the parameters imposed according to the specifications of the ASTM D 6751 and D 975 standards for bio-diesel.

As a raw material for bio-diesel, crude rice bran oil contains a high free fatty acid level rather than mustard oil. As a result of high free fatty acid level, it is required to reduce the level of free fatty acid of crude rice bran oil to a suitable range by esterification process. After esterification, bio diesel is produced by trans-esterification reaction. That is, the process of preparing bio-diesel involves two steps in case of crude rice bran oil. This will be more time than the one step method and this process will be more expensive. Therefore, it can be said that the production of bio-diesel from mustard oil is easier than the crude rice bran oil. On the other hand, bio-diesel produced from rice bran oil has the properties which are more preferable for using in a diesel engine as an alternative of petro diesel rather than the bio-diesel produced from mustard.

6. REFERENCES

[1] Radwan MS, Ismail MA, Elfeky SMS, Abu-Elyazeed OSM, "Jojoba methyl ester as a diesel fuel substitute: Preparation and characterization", *Applied Thermal Engineering*, 2007, 27: 314–322.

[2] Berchmans HJ, Hirata S, "Biodiesel production from crude Jatrophacurcas L. seed oil with a high content of free fatty acids", *Bio resource Technology*, 2008, 99: 1716–1721.

[3] Naik M, Meher LC, Naik SN, Das LM, "Production of biodiesel from high free fatty acid Karanja (Pongamiapinnata) oil," *Biomass and Bio-energy*, 2008, 32: 354-357.

[4] Forhad A, Rowshan AR, Habib MA, Islam MA, "Production and Performance of Biodiesel as an Alternative to Diesel",*International Conference on Mechanical Engineering*, 2009.

[5] Khan MY, Khan SY, Ahmad N, "Performance characteristics of compression ignition engine when operated on preheated Neem oil," *Proceeding of International Conference on Advances in Mechanical Engineering*, 2006, Punjab, Dec 1-3.

[6] Altan R, Cetinkay S, Yucesu HS, "The potential of using vegetable oil fuels as fuel for diesel engines",*Energy Conversion and Management*, 2001, 42(5): 529-538.

[7] Huzayyin AS, Bawady AH, Rady MA, Dawood A, "Experimental evaluation of Diesel engine performance and emission using blends of jojoba oil and Diesel fuel",*Energy Conversion and Management*, 2004 45: 2093–2112.

[8] Lin CY, Chen LW, Wang LW,"Correlation of black smoke and nitrogen oxides emissions through field testing of in-use diesel vehicles",*Environmental Monitoring and Assessment*, 2006, 116(1-3): 291-305.

[9] Narayan CM, "Vegetable oil as engine fuels—prospect and retrospect",*Proceedings on Recent Trends in Automotive Fuels*, 2002, Nagpur, India.

[10] Ghormade TK, Deshpande NV, "Soybean oil as an alternative fuels for I. C. engines,"*Proceedings of Recent Trends in Automotive Fuels*, 2002, Nagpur, India.

[11] Kumar, Reddy VK, "Experimental investigations on the use of vegetable oil fuels in a 4-stroke single cylinder diesel engine", Ph.D Thesis, 2000, submitted at JNTU, Anantapur.