Selection of an Efficient Method of Biodiesel Production from Vegetable Oil Based on Fuel Properties

Abdullah Al Mamun[1], Shaila Siddiqua[2], Sheikh Md. Enayetul Babar[3]

[1,2] *Post Graduate Students, Biotechnology and Genetic Engineering Discipline, Khulna University, Khulna, Bangladesh.*
[3] *Professor, Biotechnology and Genetic Engineering Discipline, Khulna University, Khulna, Bangladesh.*

***Abstract*— Biodiesel has become more attractive recently because of its environmental benefits. Biodiesel is an alternative fuel for diesel engines consisting of the alkyl monoesters of fatty acids from vegetable oils or animal fats. Currently most of the biodiesel is made from vegetable oil, methanol, and an alkaline catalyst. In this study, three different methods were modified and used to extract biodiesel from four different sources e.g. soybean oil (*Glycine max*), sesame oil (*Sesamum orientale*), palm oil (*Elaeis guineensis*) and mustard oil (*Brassica nigra*). The objective of this study was to establish an efficient method from three modified methods by comparing the fuel properties (kinematic viscosity, flashpoint, calorific value and density) of extracted biodiesel from those methods. It was found that fuel properties of biodiesel produced by modified method 1 were better than biodiesel produced by modified method 2 and 3.**

***Keywords*— Biodiesel, Vegetable oil, Kinematic viscosity, Density, Calorific value, Flash point.**

I. INTRODUCTION

The concept of using vegetable oil as an engine fuel likely 100 years old, when Rudolf Diesel (1858- 1913) developed the first engine to run on peanut oil, as he demonstrated at the World Exhibition in Paris in 1900 [1]. In 1912 Rudolf Diesel said that “The use of vegetable oils for engine fuels may seem insignificant today. But such oils may in course of time be as important as petroleum and the coal tar products of the present time”. But, by the availability of low-priced petroleum products, use of biodiesel as a fuel never took off.

However in today’s world, the diminishing amount of petroleum reserves and increase need of fuel make us look through for an alternative fuel. The use of biodiesel comes as a promising solution to meet the current demand of fuel. Vegetable oils (VO) or animal fats are used in the production of Biodiesel, which just need to undergo a transesterification process to be able to use in the diesel engine [2], [3], [4]. In the transesterification process the vegetable oil chemically reacts with alcohol in the presence of a catalyst. Glycerol is produced as a by-product of transesterification reaction [5], [6].
The quality of biodiesel is most important for engine part of view and various standards have been specified to check the quality [7], [8]. The most standard process to determine the quality of biodiesel is to analyse the fuel properties of biodiesel such as kinematic viscosity, density, calorific value and flash point, etc.

Among the different fuel properties of biodiesel, kinematic viscosity is one of the major fuel properties, which is measured at 40 °C (ASTM D445) since it is the standard temperature for determining kinematic viscosity of biodiesel and petroleum [9]. Another important property of biodiesel is flash point, which is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a liquid's flash point requires an ignition source. Calorific value of biodiesel is the amount of heat released during the combustion of a specified amount of it. Density is the weight per unit volume. Oils that are denser contain more energy. For example, petrol and diesel fuels give comparable energy by weight, but biodiesel is denser and hence gives more energy per litre [10].

The objectives of this study were to analyse various biodiesel extraction methods and establish an efficient method based on the fuel properties. In this work three methods- method 1[11]; method 2 [12] and method 3 [12] are modified to lessen the working difficulties and production cost and to produce better quality biodiesel from soybean, palm, mustard and sesame oil. The extent of the quality of biodiesel is determined by analysing the four major fuel properties- kinematic viscosity, density, calorific value and flash point, and on the basis of this result the best method selected from these three methods which produce best quality biodiesel.

II. MATERIALS

The experiment was carried out with 4 types of VO (soybean, palm, mustard and sesame oil). Methanol and sodium hydroxide were used to produce sodium methoxide which react with VO to produce biodiesel through transesterification reaction. Methanol and sodium hydroxide were supplied by Merck, Germany. VO was collected from local marketplace (Khulna, Bangladesh).

III. METHODS

A. Methods of Biodiesel Production

1) Modified Method-1: Method 1[11] was modified to produce biodiesel from soybean, palm, mustard and sesame oil. The catalyst sodium hydroxide, at an amount of 0.64 % (w/v) of vegetable oil was dissolved in the methanol at an amount of 20% (v/v) of vegetable oil by hand shaking and whirling to form sodium methoxide solution. The sodium methoxide solution was then poured into the beaker that contains vegetable oil (pre heated at 45°C) and the total mixture kept closed to the atmosphere to prevent the loss of alcohol. Then the beaker was gently shake for a few minutes and heated at 55°C on a water heater for 3 hours. After heating, the beaker was set aside undisturbed for 24 hours at normal temperature for completion of the reaction. From the reaction mixture 2 major products were found- raw biodiesel and glycerine. The biodiesel was then separated by gravity settling and pipetting and washed with water. Finally, extra water was removed by heating at100°C for 15 minutes to get pure, usable biodiesel.

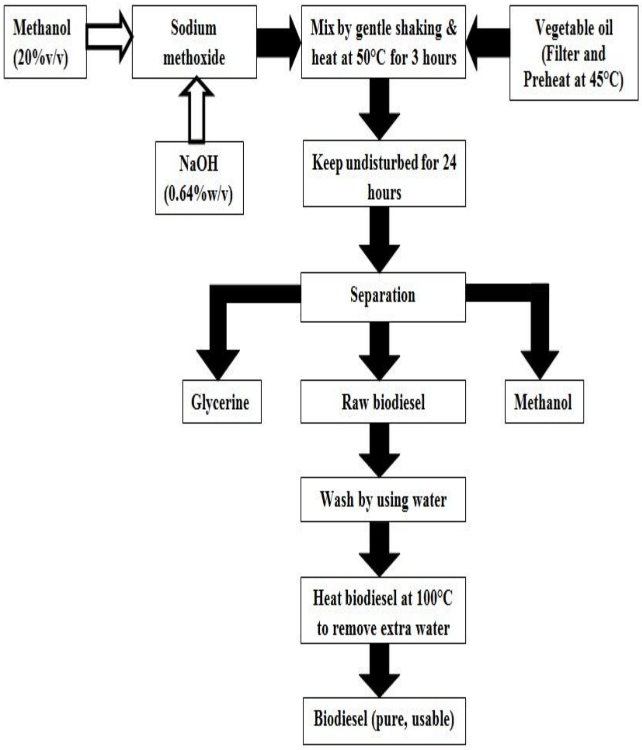

Figure 1 Scheme of biodiesel production (Modified Method 1)

2) Modified Method-2: Method 2 [12] was modified to produce biodiesel from soybean, palm, mustard and sesame oil. Sodium methoxide solution (same concentration as method-1) was poured into VO containing beaker and placed on a heating magnetic stirrer. Turned on the magnetic stirrer and stirred for 30 minutes at 45°C. The mixture was kept undisturbed for 24 hours at normal temperature at the end of stirring. Then the biodiesel was separated, washed and removed extra water to get pure biodiesel.

3) Modified Method-3: In method 3 [12] concentration of sodium hydroxide and methanol and stirring time were modified to produce biodiesel from soybean, palm, mustard and sesame oil. Sodium methoxide solution was (sodium hydroxide and methanol at an amount of 0.29 % (w/v) and 16.67 % (v/v) of vegetable oil respectively) mixed with VO and the beaker was placed on a magnetic stirrer, stirred for 20 minutes. The mixture kept undisturbed for 24 hours at normal temperature, the biodiesel was separated from glycerine. Then washed with water and excess water was removed to get pure biodiesel.

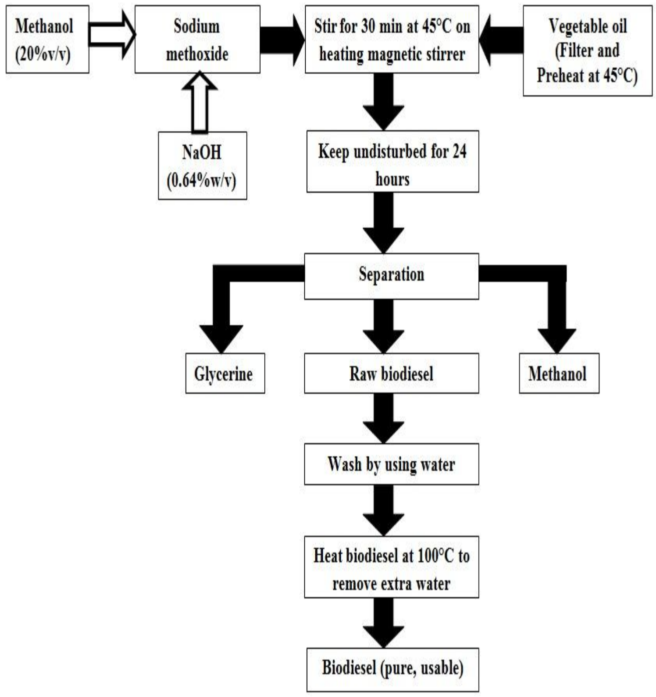

Figure 2 Scheme of biodiesel production (Modified Method 2)

B. Methodology of Fuel Properties Determination

1) Kinematic Viscosity: 'SAYBOLT/REDWOOD viscometer bath' was used to determine kinematic viscosity. At first a cork stopper was inserted into the air chamber at the bottom of the viscometer and placed the thermometer. 80 ml sample was poured into the gallery of viscometer bath. When the temperature reached at 40°C, 60 ml sample was collected in the receiving flask. The time of collection was recorded by a stopwatch. Above stages were repeated three times. Then the average time was measured and the kinematic viscosity was determined by using the equation.

2) Flash Point: It was determined by 'flashpoint tester, type-00-ESR'. 80 ml sample was poured into the metal cup of the apparatus. Then the thermometer was placed and the flashpoint tester was switched on.

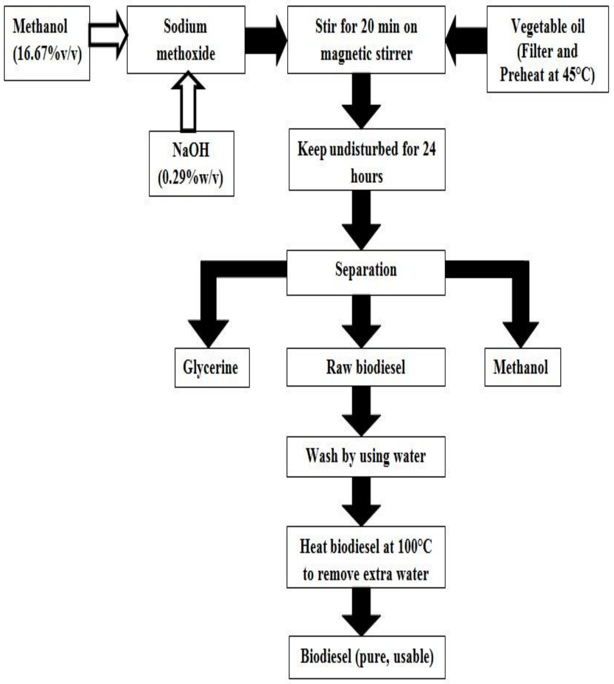

Figure 3 Scheme of biodiesel production (Modified Method 3)

The flash point of a volatile liquid is the lowest temperature at which it can vaporize to form an ignitable mixture in air. The flashpoint was checked after every 2°C and found the exact flashpoint.

3) Calorific Value: The heating value or calorific value was determined by 'oxygen bomb calorimeter'. At first less than 1.5g sample weight was determined. Then fuse was prepared and attached to the bomb of calorimeter. The bomb was closed tightly and oxygen punched into it. The bomb then placed into pot contained water and turned on the oxygen bomb calorimeter. Initial temperature was recorded and observed the temperature rise. When the temperature rise stopped the reading was taken. Calorific value was determined by using temperature difference and mass in the equation.

4) Density: Mass of 10 ml sample was measured by electric balance. This step repeated three times and average mass was determined. Density was determined by mass/volume equation.

IV. RESULT AND DISCUSSION

A. Analysis of Biodiesel Properties and Methods: Different properties of biodiesel were analysed to establish an efficient chemical method of biodiesel production from soybean, palm, mustard and sesame oil by using three different chemical method.

The comparison between different methods can be better understood by examining the following tables of kinematic viscosity, flashpoint, calorific value and density values.

Table I
Experimental Value for Kinematic Viscosity at 40°C (cst)

Modified Method No.	***Soybean biodiesel***	***Palm biodiesel***	***Mustard biodiesel***	***Sesame biodiesel***	***Accepted value****
1	*5.18*	*5.015*	*5.57*	*5.795*	*3.7-5.8*
2	*5.98*	*6.17*	*6.515*	*6.765*	
3	*8.74*	*8.445*	*8.765*	*8.88*	

* U.S. Department of Energy, (2009) [13].

Table 2
Experimental Value for Flashpoint [Degree Celsius (°C)]

Modified Method No.	***Soybean biodiesel***	***Palm biodiesel***	***Mustard biodiesel***	***Sesame biodiesel***	***Accepted value****
1	*131*	*142*	*154*	*164*	*>130*
2	*112*	*61*	*74*	*62*	
3	*65*	*74*	*132*	*53*	

* U.S. Department of Energy, (2009) [13].

Table 3
Experimental Value for Calorific Value (Kcal/kg)

Modified Method No.	***Soybean biodiesel***	***Palm biodiesel***	***Mustard biodiesel***	***Sesame biodiesel***	***Accepted value****

1	9308	9289.21	9573.525	9237.11	8850-10000
2	8879.525	8669.155	8785.885	8601.405	
3	8735.19	8803.135	9325.985	8458.74	

* U.S. Department of Energy, (2009) [13].

Table 4
Experimental value for density (gm/ml)

Modified Method No.	Soybean biodiesel	Palm biodiesel	Mustard biodiesel	Sesame biodiesel	Accepted value*
1	0.8733	0.8787	0.87515	0.8856	0.87-0.89
2	0.8595	0.856	0.8605	0.8565	
3	0.947	0.918	0.859	0.9785	

* U.S. Department of Energy, (2009) [13].

From the values shown in the table 1, table 2 and table 3 for kinematic viscosity, flashpoint and calorific value consequently, it is clear that the values of modified method 1 for soybean, palm, mustard and sesame biodiesel belong in the accepted range of biodiesel for all of three properties. While the values of modified method 2 and 3, have mostly been deviated from the accepted range of biodiesel.

In case of density, it is observed that the values for density for modified method 1 for soybean, palm, mustard and sesame biodiesel belong in the accepted range of biodiesel. On the other hand, the values of density of modified method 2 were less than that of minimum accepted value (0.87 g/ml) and the values of modified method 3 were more than maximum accepted value (0.89 g/ml).

B. Discussion

From the above result, it is observed that the values of different physical properties found in modified method 2 and 3 differ greatly from the standard values of biodiesel. The deviation of the values may caused by different reasons. Presence of much soap in the solution may increase the viscosity and density of the biodiesel. As the viscosity increases it loses its fuel properties and became lubricating oil.

If the reaction was not completed properly, the vegetable oil would not convert fully into biodiesel. As a result the density would become lower. In case of modified method 2 and 3, the quality of biodiesel may be affected by the change in concentration of methanol and NaOH, reaction and heating time and temperature. The variation in this condition may also affect the flashpoint and calorific value of biodiesel. The reaction and heating time and temperature of modified method 2 and 3 are lower than modified method 1, and this might be a cause of lower quality biodiesel production.

Table 5
Comparison of Experimental Value of Method 1 and Standard Value of Biodiesel and Diesel

Properties	Experimental value (for modified method 1)				Standard value	
	Soybean biodiesel	Palm biodiesel	Mustard biodiesel	Sesame biodiesel	Biodiesel*	Diesel*
Kinematic viscosity at 40°C(cst)	5.18	5.015	5.57	5.795	3.7-5.8	1.3–4.1
Flashpoint (°C)	131	142	154	164	>130	60–80
Calorific value (Kcal/kg)	9308	9289.21	9573.525	9237.11	8800-1000	10500
Density (gm/ml)	0.8733	0.8787	0.8752	0.8856	0.87-0.89	7.1

* U.S. Department of Energy, (2009) [13].

Flash point is the lowest temperature at which certain liquid can vaporize to form an ignitable mixture in air. Since biodiesel burns at much higher temperature compared to standard diesel the chances of biodiesel to accidentally combust are much lower compared to standard diesel. Biodiesel is much safer to use compared to standard diesel because it has significantly higher flash point than standard diesel (130 °C compared to 75 °C), and table 5 shows that experimental values of four types of biodiesel for flash point have significantly higher than standard diesel. Biodiesel also has less energy content compared to standard diesel. The amount of energy per gallon of biodiesel is approximately 11 percent lower than that of petroleum diesel. The densities of soybean, palm, mustard and sesame biodiesel are close to the density of diesel (0.82-0.86). So it is obvious that the biodiesel extracted from soybean, palm, mustard and sesame oil by using modified method 1 is more suitable as an alternative of diesel.

V. CONCLUSSION

Four types of biodiesel were produced from soybean, sesame, palm and mustard oil by three modified methods, and the quality of those biodiesel were analysed by comparing the experimental value of fuel properties (kinematic viscosity, flashpoint, calorific value and density) with the standard value of biodiesel. According to the experimental result, values of the fuel properties of biodiesels of modified method 1 belong in the range of standard value, while the values of biodiesels of modified method 2 and 3 have mostly been deviated from the standard values. Thus from the result it may be concluded that modified method 1 produces better quality biodiesel than modified method 2 and 3.

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