Biodiesel Synthesis and Analysis: A Technical Review

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Abstract— Due to the increased use of fossil fuels in recent years, its availability is decreasing day by day. Further, the environment is greatly affected by the emissions produced by these fuels. Thus many countries are in search of an alternative fuel which should be economical and less polluting. Biodiesel is one of the solutions that match this requirement. It is prepared from vegetable oil or animal fat by number of processes like esterification, Trans esterification processes. Biodiesel can also be extracted from different oils like Jatropha curcas, soybean oil, palm oil etc. This paper gives the review of how biodiesel is prepared from these oils by considering various process parameters like methanol to oil ratio, operating temperatures, concentration of NaOH or KOH and its results. It also gives the overview of how it is economical and less polluting than fossil fuels. Its use in automobiles, modifications required, its performance and its difficulties are also discussed.

Keywords: Biodiesel, Jatropha curcas, soybean oil, palm oil, waste cooking oil, transesterification and process parameters.

1 INTRODUCTION

The use of vegetable oil which produces biodiesel as engine fuel seems to be insignificant today. But, such oil will become as important as petroleum and tar products as it is today (Dr.Rudolf diesel, 1895). Biodiesel is defined as a mono alkyl methyl ester derived from vegetable oil or animal fat by Trans esterification process with NaOH or KOH as a catalyst. Due to the reason crisis in fossil fuels, there is a great demand for fuel all over the world. The fuel price also reaching its peak. Thus many developed countries are in search for an alternative fuel which is more economical and easily available. Fossil fuel is formed millions of years ago from dead organisms and plants which are dumped under the earth surface subjected to high temperature and pressure. Due to increase in population, the usage of fossil fuel is also increasing tremendously. As a result, there will not be any fuel left for future generation and it also affect the environment due to the pollution caused by the increased usage of fossil fuels. Bio diesel is found to be a great replacement for fossil fuel which is less polluting and easily available through its production cost is more. The production cost can be reduced by means of edible plant oil (like waste cooking oil, soybean oil, palm oil etc.) instead of raw vegetable oil. It can also be used in conventional diesel engine without any modifications as 100% or blending with diesel.

Researchers chose edible oil as an source for preparing biodiesel because it is easily available but ,some researchers chose non edible oil also for the same purpose [1] the difficulties in separation and purification of biodiesel can be greatly reduced by introducing membrane technology [2]. The viscosity of vegetable oil and animal fat is very high when compared to diesel which has to be reduced in order to use it in diesel engine. The emission of exhaust gases like CO and CO2 from the biodiesel produced from waste cooking oil is less when compared to ordinary diesel thus reducing the greenhouse gases causing global warming (Siti Fatimah Arifin, 2009). The waste cooking sunflower oil can used as a source of biodiesel which can be used in diesel engine[3]. The properties of biodiesel are good when compared with the conventional diesel fuel; it is free from sulphur content, nontoxic, renewable, biodegradable (Ayhan Demirbas, 2009). Biodiesel can also be produced by microwave heating method which is more energy efficient and better than conventional heating method [4]. When using B100 biodiesel its content of carbon deposition is much lower when compared with other fuels tested [5]. By using solid based heterogeneous catalyst CaO-ZnO for producing biodiesel by trans esterification process of palm oil [6]. One litter of biodiesel from soybean oil costs around 201.84 (296.82Tk) rupees in Bangladesh [7]. The production cost of bio diesel costs more because the cost of oil is more. This can be reduced by using used oil by removing its free fatty acid content (FFA) before processing [8]. By using biodiesel prepared from palm oil reduces the emission of particulate matter, SO2, CO [9]. Using biodiesel as an alternative fuel not only helps environment from pollution it also protects us from harmful emissions causing health risks [10].

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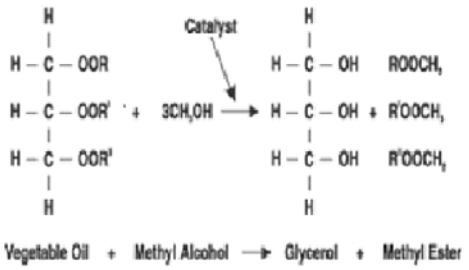
2 MATERIALS AND METHODS

2.1 Transesterification Process

Trans esterification process is defined as the process in which the methanol is reacted with triglycerides of vegetable oil to

form glycerol and methyl ester. The reaction is given below:



Vegetable oil or animal fat + methanol ⟶ methyl ester + glycerin

The catalyst such as NaOH and KOH can be used to speed up the reaction. In Trans esterification process the free fatty acid content of (FFA) is reduced to a desirable amount suitable for using it as fuel. Normally the oils used for producing biodiesel contains FFA content more than 3% which can be reduced by this process (A. Ribeiro, F. Castro and J. Carvalho, 2011). Methods like microwave irradiation methods and using supercritical methanol reduces the reaction time and increases the yield of methyl ester.

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2.2 Materials

In this study biodiesel is produced from Soybean oil, Jatropha oil, palm oil, waste cooking oil. Sodium hydroxide (NaOH), potassium hydroxide (KOH) can be used as a catalyst along with methyl alcohol by Trans esterification process. The methanol used should be 99.5% pure with density ranges from 0.791-0.792 kg/l [11].

2.3 Collection of Jatropha Seed

Jatropha curcas is a toxic plant which is commonly used for the production of biofuel. In India, it is mostly found in Assam and also in other parts of world such as Mexico and Central America. The seeds taken from the jatropha plant contains inedible oil can be converted to biodiesel, which can also be used in transportation and energy sectors. Biodiesel produced from jatropha emits 80% less CO2, 100% lower SO2, and has a higher flash point than fossil diesel fuel (Kamrun Nahar and Monica Ozores-Hampton). The oil extracted from the jatropha plant has similar energy value compared to diesel.

2.4 Preparation of Jatropha Biodiesel

Bielenberg ram press, Sayari oil expeller, the Komet Expeller, ultra sonication (S.Antony Raja, D.S.Robinson smart, and C.Lindon Robert Lee, 2011) are the various methods used for preparation of jatropha oil. The process used for making biodiesel from jatropha oil is base catalyzed transesterification process. It is conducted by taking 500 ml of Jatropha oil in conical flask and then it is heated at 70°C to remove the moisture (S.Antony Raja, D.S.Robinson smart, and C.Lindon Robert Lee, 2011). The optimum molar ratio of oil and methanol is taken as 6:1 with 1% NaOH as a catalyst [12] and these are added with the jatropha oil. Then the obtained mixture is stirred continuously for 1 hour at 420 rpm. After stirring process, the mixture is settled for 12hours to get the methyl ester fatty acid on the top and the glycerol layer at the bottom[13]. Finally, the biodiesel is obtained from the jatropha oil by carefully removing the glycerol from the mixture.

2.5 Collection of Soybean Oil

The experiments are conducted by procuring the soybean oil from the nearest supermarket. The desired impurities are removed by filtering the soybean oil under vacuum pump pressure (160psi/11bar) [14]. The methyl ester (methanol) and catalyst (NaOH) were purchased from the chemical and reagents dealer.

2.6 Preparation of Soybean Biodiesel

Trans esterification is the common process used for preparing biodiesel. It is an equilibrium reaction and by mixing the reactants, transformation occurs. First the soybean oil is heated at 100°C for 15 minutes and it is allowed to settle down for a day to remove the water content from it [15]. Sodium hydroxide is mixed with methanol and stirred continuously to produce sodium methoxide. The obtained catalyst – alcohol solution is poured into the conical flask. The heated oil (100ml) is taken and it is poured into the conical flask containing sodium methoxide mixture.[3]. The mixture is maintained at reaction temperature 55°C and it stirring takes place at 420 rpm for 1 hour. Then the mixture is allowed to settle for 1 day and finally, biodiesel from soybean oil is obtained by removing the glycerol content from the mixture which is at the bottom of the conical flask.

2.7 Collection of Palm Oil

Palm oil produced from the fresh fruit bunches by oil palm plantation [16]. The oil was extracted by oil mill and for every 22 kilogram of palm oil extraction, 100 kilogram of fruit bunches are needed[17]. The reason for choosing sludge palm oil as a feedstock is a significant raw material used for biodiesel production. (A. Hayyan, M.Z. Alam, M.E.S. Mirghani, N.A. Kabbashi, N.I.N. M. Hakimi, Y.M. Siran and S. Tahiruddin, 2010).

2.8 Preparation of palm oil Biodiesel

The free fatty acid present in the palm oil is 0.3-0.6% and it has less than 1% moisture content [18]. The required reactants needed for preparation of biodiesel are palm oil and methanol with potassium hydroxide as a catalyst. A stirrer, thermometer, heating mantle, three catalyst loadings (0.15%, 0.5%, 1.5% NaOH wt. /wt.) are required for trans esterification process which is maintaining at reaction temperature range 58°C – 62°C.[11] Palm oil is added with the mixture of methanol and KOH in the 1 liter flask and the stirring process continues till 1 hr at 420 rpm. The obtained mixture is then allowed to settle

for 1 day. Thus the biodiesel from a palm oil is obtained by carefully removing glycerol from the solution[20].

2.9 Collection of vegetable oil

The waste cooking oil was collected from various cafeterias and hostel kitchens [21]. The oil samples are heated to 120°C and filtered to remove the unwanted impurities from it (Richard C. Ehiri, 2003). An alkaline catalyst such as potassium hydroxide is used in the Trans esterification process to reduce the free fatty acid [22]. Low cost and preventing the environmental pollution are the main advantage by using waste vegetable cooking oil (Siti Fatimah Arifin, 2009).

2.10 Preparation of vegetable oil biodiesel

Transesterication process is used to produce the biodiesel from waste cooking oil. Here the catalyst used (NaOH or KOH) is to improve the action rate and yield [10] and solvent used is methanol. 100 ml of waste cooking oil is taken in a 2litre flask [24]. The catalyst and the solvent are mixed in optimum proportions and then poured into a flask containing cooking oil. The mixture in the flask is heated to 55°C and stirrer continuously rotates at 320 rpm.The obtained mixture is allowed to settle for 12 hours and finally, the biodiesel from a waste cooking oil is obtained by carefully removing the glycerol from the mixture solutions.

3 RESULTS AND DISCUSSION

3.1 Waster Cooking Oil

The acid catalyzed process of producing biodiesel from waste cooking oil is found to be more feasible and less complex than the alkali catalyzed process thus making it more competitive method of producing commercial biodiesel than alkali catalyzed process [25]. The emission of biodiesel from waste cooking oil is less than the conventional diesel fuel[21]. Solid acid catalyst can be used because it is very intensive towards FFA content, it can easily separate from the final product, it can perform both esterification and trans esterification processes efficiently [26]. The viscosity of vegetable oil and animal fat is very high when compared to diesel which has to be reduced in order to use it in diesel engine. The emission of exhaust gases like CO and CO2 from the biodiesel produced from waste cooking oil is less when compared to ordinary diesel thus reducing the greenhouse gases causing global warming [27]. The waste cooking sunflower oil can be used as a source of biodiesel which can be used in diesel engine [3]. The maximum yield of biodiesel obtained from waste cooking oil is 90.5% by maintaining methanol to oil ratio at 6.6:1 for 1 hour reaction time and 60oC reaction temperature using composite loaded catalyst system of 0.03% concentration [29]. The reaction time can be greatly reduced to 5 to 9 min when compared to conventional methods of 60 to180 min by microwave irradiation method [22]. Biodiesel with high yield and purity is obtained from waste cooking oil at 60 reaction time and 1.5% concentration of KOH (potassium hydroxide) as catalyst [28].

3.2 Palm Oil

Bio diesel can also be obtained from palm oil. The biofuel obtained from palm oil will reduce the total pollution by 3.4%, particulate matter and CO emission by 3.7%, SO2 emission by 7.6%[9]. The 78.88% and 79.62% yield of biodiesel is obtained from palm oil by maintain the solid based catalyst (CaO-ZnO) at 1:3 atomic ratio at reaction time and temperature of 8 hours and 60oC and oil methanol ratio at 1:15[6]. The cost of the biodiesel produced from palm oil can be reduced by maintaining the methanol to oil ratio 6:1 at reaction temperature 70°C for 20 min[8]. The properties of palm oil methyl ester is found to be flash point: 140°C, pour point: 9°C, kinematic viscosity at 40°C: 4.1 cst [19]. By using 3%wt of $NaOH/Al_2O_3$ catalyst at 60°C and 3 hours operating temperature and time by maintaining the methanol to oil ratio at 15:1 we can 99% yield of biodiesel from palm oil [31].

3.3 Soybean Oil

The conversation rate of triglyceride of waste soybean oil is 72.7% when the methanol to oil ratio is 1:1 maintaining at 50oC for 2 hours reaction time with 1.0 wt. % of sodium hydroxide catalyst [32]. Soybean oil can be converted in to biodiesel by trans esterification process with porcine pancreas lipase as a catalyst. By maintaining the operating conditions like methanol to oil ratio, operating temperature and time, catalyst concentration and stirring speed at 3:1, 45oC, 72 hours, 5% and 180 rpm respectively an yield of more than 34.1% biodiesel can be obtained[33]. The yield of soybean oil can reach a maximum of about 99% by using microwave system and sodium methoxide catalyst[34]. This method also reduces the reaction time to about 3 min by providing a microwave power of 750W. In America the yield per acre of soybean oil is about 48 gal/acre and it is used to make biodiesel in US even though its productivity is less. The high Acid oil of soybean can be used to produce biodiesel by using supercritical methanol as a catalyst [35]

3.4 Jatropha Curcus Oil

The Free Fatty Acid content of crude jatropha curcas oil is about 15%. The FFA content less than 1% and methyl ester yield of 90% can be achieved by two stage trans esterification process [13]. The high FFA content of Jatropha curcas can be reduced to a great extent by trans esterification using an alkaline catalyst [33]. The yield of biodiesel can be varied by using different catalyst (NaOH, KOH) with different reaction time. It can also be varied by using ethanol instead of methanol in pilot plant [12]. The blends of raw Jatropha oil can used in diesel engine without any modification and it is found that 10% blend at 200 bar injection pressure gives better result [34]. It is found that solvent extraction showed better biodiesel yield than mechanical extraction. Also using KOH instead of NaOH as catalyst give better quality of biodiesel [35]. In India there is about 33 million hectares of waste land is available and it can be used for cultivating Jatropha Curcus. India can save 7.3x10^6 tons of diesel per year by blending 20% biodiesel with conventional diesel (Deepak Sain, Bulk Agro (India) Pvt. Ltd).

4 CONCLUSION

Thus from the above study we can say that biodiesel is a better alternative for conventional diesel in near future. Different yield of biodiesel can be obtained by varying the values of process matters like methanol to oil ratio, catalyst concentration, reaction temperature and time. By using different methods like microwave irradiation and supercritical methanol the reaction time is reduced to 5-9 min and yield of methyl ester to a larger value. Low cost biodiesel can be produced by using used or waste veg oil, palm oil, and soybean oil instead of using virgin oil. It can be used in diesel engine without any modifications and it causes less pollution when compared with diesel.

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