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Biodiesel Production Techniques: A Review

C. Syed Aalam[1], C.G. Saravanan[2]
Department of Mechanical Engineering, Annamalai University, Tamilnadu, India

Abstract*— Increasing energy demand and environmental concerns have encouraged an evolution of alternative fuels. In this paper, a comparative review of the current technologies up to now used to produce biodiesel has been investigated. There are four most important ways to make biodiesel, transesterification, thermal cracking, direct use or blending and micro emulsions. The most common methods in the production of biodiesel, was emphasized in this review. The two important types of biodiesel production process; transesterification and thermal cracking are discussed at length in the paper. Both the advantages and disadvantages of the transesterification and thermal cracking methods are also discussed.
Keywords*— Biodiesel, Transesterification, Blending, Micro emulsion, Thermal cracking.

I. INTRODUCTION

Biodiesel, an alternative fuel, is made from biological sources such as vegetable oils and animal fats. It is eco-friendly and non-toxic has low emission profiles and so it is environmentally beneficial [1,2]. India is importing more than 75% of its fuel demand and expenses an enormous amount of money on fuel. Biodiesel is attaining more important as a smart fuel due to the fast depleting fossil fuel resources. The properties of biodiesel are almost similar to the diesel fuel; thus, it becomes a potential alternative to diesel fuel [3,4]. Fatty acids may be used to prepare biodiesel fuel. Thus, any agriculture lipid should be a substrate for the production of biodiesel. The use of vegetable oils for biodiesel production has recently been of big concern. The recent focus is the use of non-edible vegetable oil and waste products of edible oil as the feedstock for biodiesel production. The purpose of the transesterification or catalytic cracking process is to lower the viscosity of the raw oil [5-9]. The main problem of vegetable oil is their high viscosity and lower volatility, which causes poor atomization of fuel and incomplete combustion in diesel engines [10,11]. In this paper, the results of a few of the researchers have compared and summarized.

II. TRANSESTERIFICATION

Biodiesel production needs a bio feed and an alcohol. In several cases of biodiesel production, a catalyst also presents. Depends on the quality and quantity of the feed, either transesterification or esterification reactions are used for biodiesel production. Most of the biodiesel production operations use transesterification method. This method works fine if the free fatty acid (FFA) and moisture contents of oil are less than 0.1 percent [12-15]. Typical feedstocks for biodiesel production are soybean, Mahua, canola, cottonseed, sunflower, palm seed, corn and mustard seed oil. Poultry fat and waste oil also can be converted into biodiesel [15-18]. Animal fats may have a maximum amount of free fatty acid content, which causes the soap formation that has unfavorable effects on downstream processing and leads to yield drop [19]. There are two types of catalysis used for production of biodiesel. Scheme of the transesterification process is shown in figure 1.

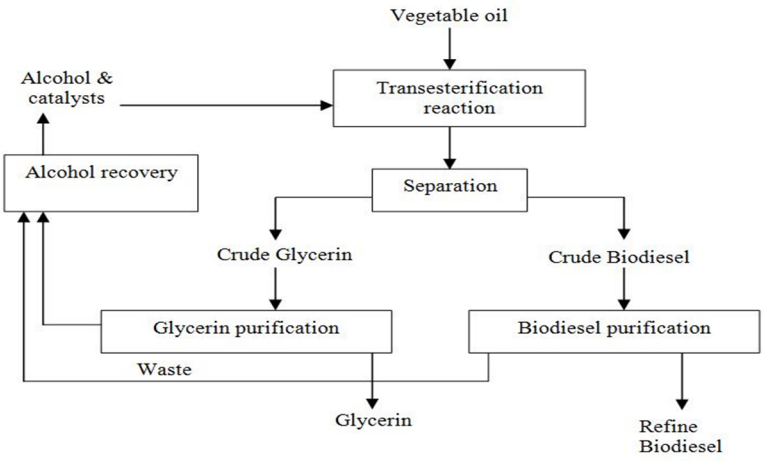

Figure 1. Scheme of transesterification process

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A. Base Catalysis

Potassium hydroxide (KOH) and sodium hydroxide (NaOH) are the common base catalysts for transesterification process. Sodium methylate is effective than KOH and NaOH as a catalyst, but it is expensive [20-22]. Base catalysts are extremely sensitive to the presence of FFA and water. The quantity of Sodium methylate required is 0.4 to 0.6 percent of the weight of the raw oil. A higher amount of catalyst (0.6 to 2 percent of the weight of the raw oil) is required when KOH or NaOH is used. KOH and NaOH lead to the formation of water, which reduces the reaction rate and causes the soap formation [23]. Methanol and ethanol are the most common alcohols used for conversion of oils to biodiesel. Both are inflammable, so proper handling is needed for safety [24]. Transesterification process is a reversible reaction. Thus, surplus methanol or ethanol is required to shift the equilibrium favorably. Dynamic mixing at the beginning of the chemical reaction improves reaction rates. Closer to the end of the reaction, reduced mixing helps the division of glycerin, and the reaction would continue faster in the top layer, which is methanol and oil. At ambient temperature (21ºC), normally the reaction takes five to eight hours to complete. The process is conducted at below the boiling point of methanol (60ºC). In this temperature, the process duration may vary between 15 minutes to one hour [25,26]. The mechanism of the transesterification process is shown in figure 2 and Schematic diagram of biodiesel plant is shown in figure3.

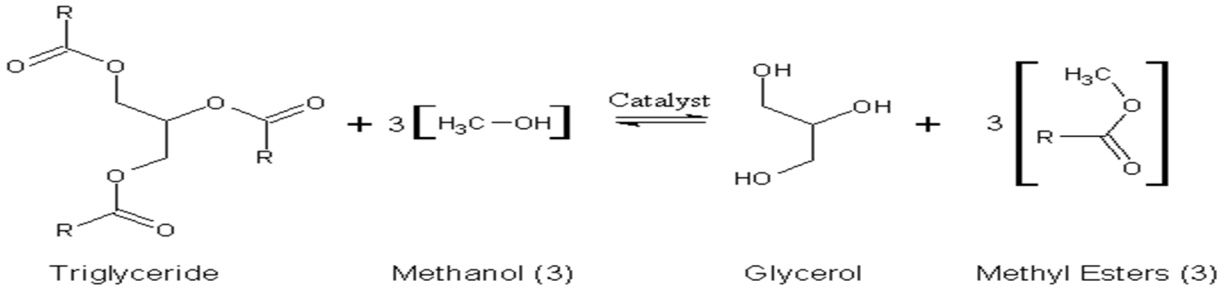

Figure 2. Mechanism of transesterification process

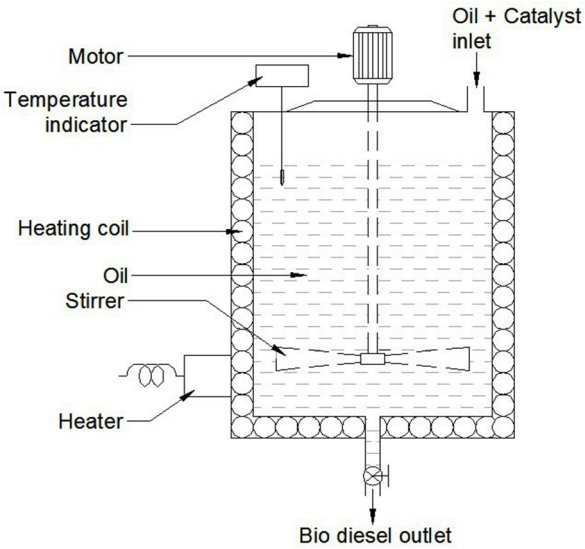

Figure 3 Schematic diagram of Biodiesel Plant

The reaction time is mainly depends on the temperature, but this requires the use of a pressure vessel. The reactor is sealed and equipped with a condenser to reduce alcohol evaporation during the conversion process. Higher oil conversion rates can be achieved if the production plant is set up as a continuous process with two reactors. In such cases, glycerin produced in the first reactor is removed, and the conversion is completed in the second reactor [27].

B. Acid Catalysis

If the FFA content of the raw oil is greater than 1 percent, base catalysis process is not suitable. There are two methods for treatment of high FFA content feedstock. One way would be to distill the feedstock before base catalysis. FFA can be removed by

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neutralization or deacidification [28]. Chemical neutralization involves treating the raw oil with caustic KOH or NaOH. Soap produced during this process is removed, and the residual oil is ready for the base catalysis. However, some oil is vanished during this process. Physical deacidification, also removes the FFA. This total process is performed under vacuum. Fats and oils with high FFA content can be converted to biodiesel fuel using acid catalysis process, which is the other approach to treating high FFA content feedstock [29,30]. Soap formation is not a major problem since there are no alkali metal particles present in the reaction medium. Acid catalysts can apply for transesterification of the triglycerides, but the reaction may take a number of days to complete. Acid catalysis method is also used for direct esterification of raw oils with high FFA content, or for the production of esters from soap, which is a by-product of the edible oil refining process. The esterification of FFA to alcohol esters is comparatively fast; it would take about 1-2 hours at 60ºC to complete the reaction. Water is produced during this esterification. To get better reaction rates, water present in the oil needs to be removed by phase separation [31]. Phosphoric acid and sulfuric acid are the most common acids used in acid catalysis. The raw oil is sometimes dried to 0.5 % water and filtered previous to the reaction. Then, acid and methanol mixture is added to the raw oil. The conversion of the fatty acids to methyl esters has attained equilibrium, the methanol and acid mixture was removed by settling [32]. Methanol and base catalyst (NaOH or KOH) are added into the residual oil for transesterification process. The rest of the conversion process is the same as the base catalysis. Transesterification process can be operated either as a batch or continuous process. A batch process is suitable for smaller plants. The continuous process allows the use of high-volume separation system, and therefore enhance the output volume [33,34].

III. THERMAL CRACKING PROCESS

This method is able to crack the complex hydrocarbons to yield the less complex structures. The reaction is conducted at lower pressures and temperatures with or without the help of a catalyst, moreover the quantity and quality of the product is very nearer to that of diesel fuel, which is far superior to the oil produced by the transesterification process [35]. The most common catalysts used in thermal cracking are aluminium, redmud and Zeolite. In the catalytic cracking process, a batch reactor is packed with raw oil, which has a highly bonded structure along with known amount of alumina, redmud and zeolite catalyst per litre of oil in first, second and third reactor respectively [36]. When heat is applied a speedy chemical reaction takes place, in the process complex structure is split into a simple structure, producing low viscosity and low density biodiesel [37]. Scheme of thermal cracking process and treated procedure is shown in figure 4. The yielding of biodiesel starts at a temperature of 250°C and continues up to 300°C with some percent of residue remaining in the reactor. Catalytic cracking plant consists of a reactor with oil inlet to pour raw oil mixed with the catalyst, safety valve to safeguard the reactor, a pressure gauge to indicate the pressure inside the reactor and drain hole to eradicate the residue and waste.

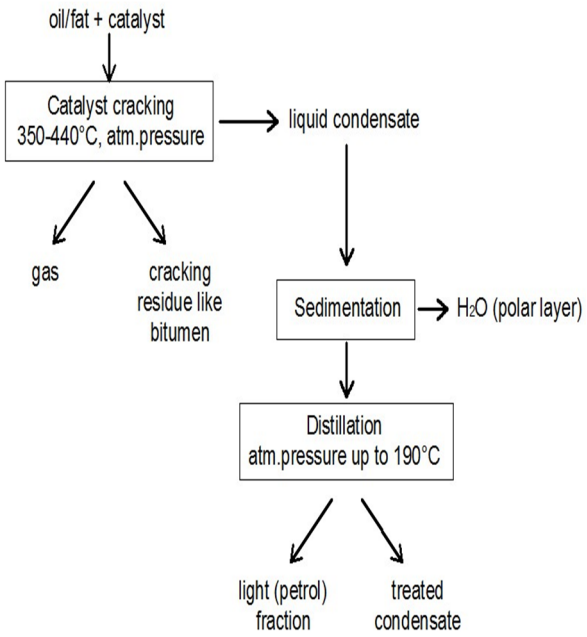

Figure 4. Scheme of thermal cracking process and treated procedure

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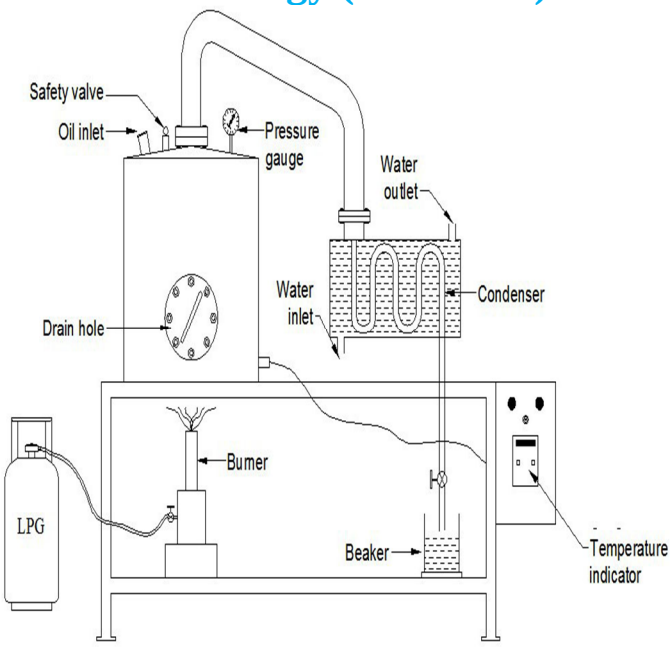

Figure 5. Schematic diagram of catalytic cracking biodiesel plant

Heat is supplied at the base of the reactor by using a burner. Temperature indicator is to show the temperature inside the reactor. Smoke formed in the reactor passes through the condenser and condensed into liquid fuel called biodiesel that is collected in the mug. Schematic diagram of catalytic cracking biodiesel plant is shown in figure 5.

IV. CONCLUSIONS

There are two aspects of the cost of biodiesel fuel, the cost of processing and the costs of raw material. The cost of raw materials (vegetable oil or animal fat) accounts for 65 to 80% of the total cost of biodiesel. The use of vegetable oil can lower the cost significantly. In terms of production cost of biodiesel, there also are two aspects, the by-product recovery and transesterification process. A continuous transesterification process is a better choice to lower the production cost of biodiesel. The continuous transesterification process is a shorter reaction time and maximum production capacity. The recovery of glycerol is another way to lower the production cost. Because, water is present in the system, the biodiesel glycerol is more concentrated. In terms of biodiesel production cost, transesterification is better than the thermal cracking process.

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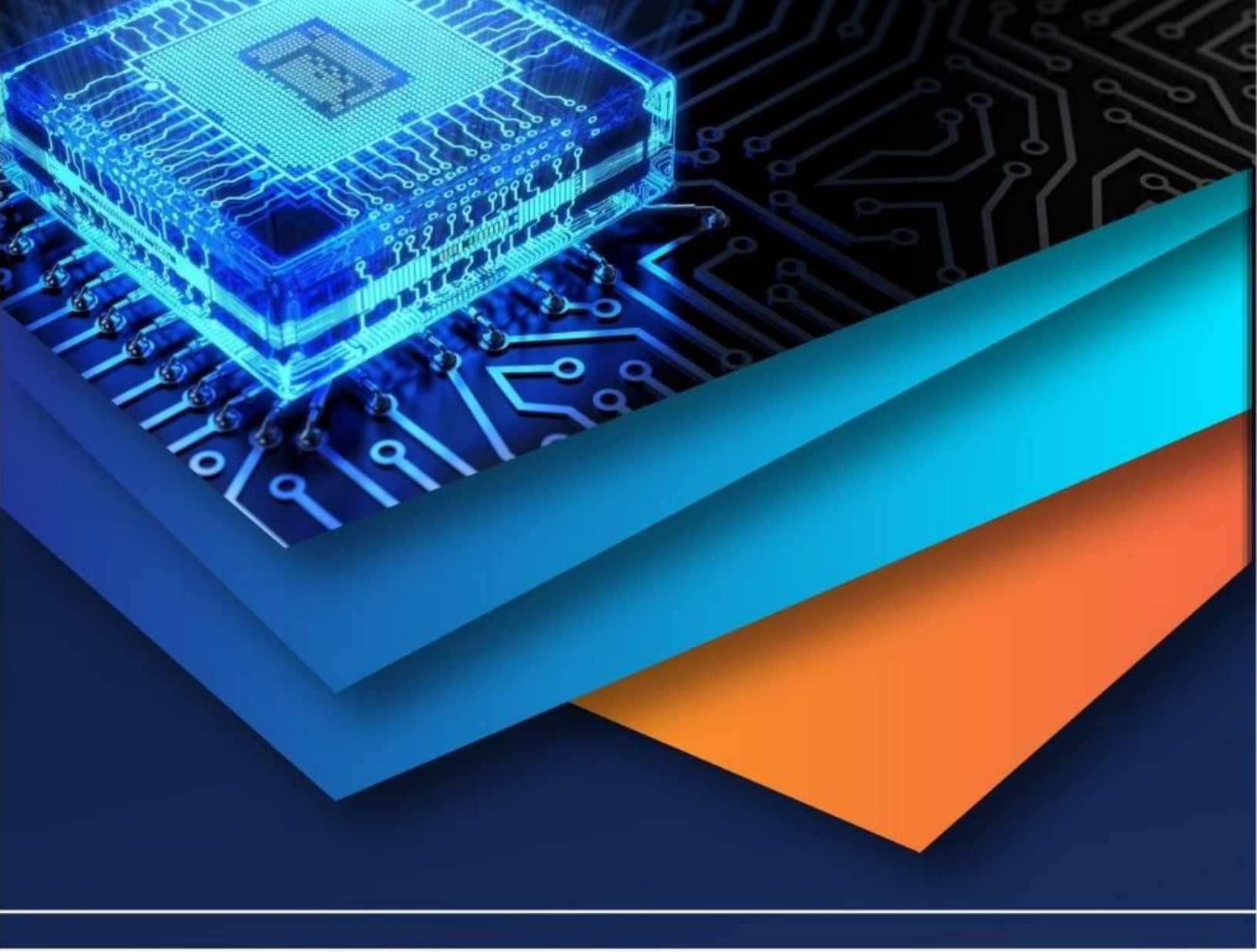

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