Biodiesel Production from Waste Cooking Oil Using Mechanical stirring and Ultrasonic Cavitation method

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Abstract. Energy security and air pollution is the challenging issues these days. Biodiesel is an effective alternative fuel. In present study, biodiesel is prepared using waste cooking oil. Mechanical stirring and ultrasonic cavitation method is used to draw biodiesel. Present study showed that mechanical stirring method provides higher yield % as compared to ultrasonic cavitation method. The reaction time in case of ultrasonic cavitation is significantly lesser as compared to mechanical stirring method.

1. Introduction

In the era of technological advancement, energy requirement is increasing drastically. Energy security is the great concern of the country. Petroleum products are used to fulfil the energy requirement of the nation [1]. Due to the exponential increase in energy demand, the dependency on petroleum products is increased. The rise or fall in the price of petroleum products play significant role in GDP growth of every nation [2].

Now days air pollution is increased up to the alarming situation. In metro cities it becomes very serious issue. The increased number of vehicles make it difficult to the human life. Although there are so many causes of increase in air pollution but among all of them exhaust gases of vehicles is the major issue [3]. Alternative fuels and electric vehicles are the potential solution of this problem. Among all alternative fuels, biodiesel is very effective and potential fuel [4]. It is renewable and can be drawn through various edible and non-edibles oils. Biodiesel is used in IC engines as substitute of conventional fuel [5]. Biodiesel can be synthesized by transesterification reaction. In transesterification reaction vegetable oils, or waste cooking oil (WCO) is reacted with ethyl/methyl alcohols. Biodiesel can be prepared using edible or non-edible oil [6].

WCO is injurious to human health. Hotels and restaurant normally discard it. Therefore, it can be obtained from big hotels and food chains in India. Many agencies charge for collecting WCO to dispose it at suitable place [7]. It means the cost WCO is negligible. Cost of feedstock decides the cost of biodiesel [8]. Therefore, the cost of biodiesel derived from WCO is lower as compared others.

As per Planning commission report of 2006, Table 1 shows the energy requirement in India

| Source      | Units          | 2006-07 | 2011-12 | 2016-17 | 2021-22 | 2026-27 |
|-------------|----------------|---------|---------|---------|---------|---------|
| Electricity | Billion units  | 711     | 1026    | 1425    | 1981    | 2680    |
| Coal        | Million tonnes | 337     | 463     | 603     | 832     | 1109    |
| Natural gas | Billion cubic meters | 12 | 19 | 33 | 52 | 77 |
| Oil products| Million tonnes | 6       | 8       | 9       | 12      | 14      |
1.1. Transesterification reaction

Biodiesel is derived through transesterification reaction. In the transesterification reaction Glycerides reacts with alcohol and produce esters and glycerine [9]. Normally KOH is used as catalyst.

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\begin{align*}
\text{CH}_2\text{-OOC-}R_1 & \quad \text{R}_1\text{-COO-R'} & \quad \text{CH}_2\text{-OH} \\
| & \quad \text{Catalyst} & \\
\text{CH-OOC-}R_2 & + 3\text{R'}\text{OH} & \xrightarrow{\text{R}_2\text{-COO-R'} + \text{CH-}OH} \\
| & & \\
\text{CH}_2\text{-OOC-}R_3 & \quad \text{R}_3\text{-COO-R'} & \quad \text{CH}_2\text{-OH}
\end{align*}
\]

Glycerides \quad \text{Alcohol} \quad \text{Esters} \quad \text{Glycerin}

Where, R shows the various alkyl group.

The objective of the present project work is to extract biodiesel from waste cooking oil through mechanical stirring and ultrasonic cavitation methods. The biodiesel yield obtained in both the process are compared to identify the most suitable process and parameters.

2. Method and Materials

2.1 Mechanical/Magnetic Stirring

WCO and alcohol are put together in a container. Magnetic stirrer is used to mix both of them properly. A magnetic capsule is dipped in the immiscible liquid. As magnetic stirrer starts, capsule starts rotating. Rotating capsule creates turbulence in the mixture and leading to the emulsification state of the liquids.

Figure 1: Photograph of Mechanical stirrer
Figure 1 shows the mechanical stirrer, used in present investigation. During the process temperature is monitored regularly. The temperature of mixture is maintained between 45-60 °C. Samples are prepared taking 100-gram WCO, methyl alcohol and KOH as catalyst. In experiment study, first of all impurities are removed by filtration process of WCO. After filtration process oil is heated to remove the moisture contents. After removal of moisture contents oil is cooled up to the room temperature. Now required quantity of methyl alcohol and KOH are stirred together. In next step this mixture is stirred with WCO with the help of mechanical stirrer. During mixing temperature is kept around 45-60 °C. If mechanical stirration continues, after some time period, transesterification reaction takes place. After completion of transesterification reaction, biodiesel is transparent and lighter as compared to glycerol [10]. Therefore, biodiesel is appeared in upper layer while glycerol settled down in the container. Biodiesel is separated and washed three to four times, to remove the contents of KOH. Water is heavier as compared to biodiesel, so it settled down in the container[11]. This settling is shown in Figure 2. After washing, biodiesel is again heated to 60-70 °C, to remove the methyl alcohol completely. In the present investigation, 4.5:1 and 6:1 molar ratio is considered. Figure 3 shows that yield % is maximum when 0.75% catalyst KOH and 6:1 molar ratio is used.

![Figure 2: Washing process of biodiesel](image)

![Figure 3: Biodiesel yield % through mechanical stirring method using molar ratio 6:1](image)
Figure 4: Biodiesel yield % through mechanical stirring method using molar ratio 4.5:1

Figure 4 shows that yield % is maximum when 0.75 % KOH and 4.5:1 molar ratio is used. It is noticed that after 60-75 minutes the yield % is constant. Yield % is slightly higher in case of 0.75% KOH as compared to 0.50% KOH.

2.2 Ultrasonic cavitation

In this process ultrasonic waves are used to sonicate the liquids. Ultrasonic waves create fine micro bubbles in both the fluids. Bubbles collapse near the boundary of the liquids and finally both the liquids get mixed properly [12]. Figure 5 show the mixing process through horn type ultrasonic reactor. There are two types of ultrasonic reactor, one is bath type and other is horn type. In present study horn type ultrasonic reactor is used. The frequency output of this processor is 20-35 kHZ. Mixture of Waste cooking oil(100gm), alcohol and KOH is taken into a beaker and then it is placed under the ultrasonic reactor. The reaction is carried out by ultrasonic irradiation produced by rod horn. Temperature of mixture is monitored regularly and kept at 40-45°C.

Figure 5: Mixing through ultrasonic processor
Figure 6: Biodiesel yield % through ultrasonic cavitation method using molar ratio 6:1

Figure 6 shows that yield % is maximum when 1.0 % KOH and 6:1 molar ratio is used. It is noticed that after 20 minutes the yield % is same for using 0.5% and 1.0% KOH. KOH is very harmful so it is to be used in small quantity.

Figure 7: Biodiesel yield % through ultrasonic cavitation method using molar ratio 4.5:1

Figure 7 shows that yield % is maximum when 1.0 % KOH and 4.5:1 molar ratio is used. It is noticed that after 20 minutes the yield % is slightly higher for 1.0% as compared to 0.5% and 0.75% KOH.

3. Comparison of mechanical stirring and ultrasonic cavitation techniques

Yield % of biodiesel prepared by ultrasonic cavitation and magnetic stirring method is shown in Figure 8-9. Figure 8 shows that yield % is higher through magnetic stirring method as compared to ultrasonic cavitation method. Maximum yield (98.32 %) is obtained with 0.75% KOH catalyst.
Figure 8: Comparison biodiesel yield % for molar ratio 6:1

Figure 9 shows biodiesel yield % for 4.5:1 molar ratio through ultrasonic cavitation and magnetic stirring method. Biodiesel yield % is higher through ultrasonic cavitation as compared to magnetic stirring method for 0.5% and 1.0% catalyst. Yield % is higher through magnetic stirring method as compared to ultrasonic cavitation method for 0.75% catalyst. Maximum biodiesel yield (97.1%) is obtained through ultrasonic cavitation method using 1.0% KOH and 4.5:1 molar ratio.

4. Conclusions

Magnetic stirring and Ultrasonic cavitation are very effective methods for the biodiesel production. Waste cooking oil can be a good source of biodiesel production. Following are the outcomes of the present investigation:
• Ultrasonic cavitation method takes lesser time for biodiesel production as compared to magnetic stirring method.
• Magnetic stirring method provides more biodiesel yield as compared to ultrasonic cavitation method.
• It is observed that there is very less increase in yield (%) and decrease in reaction time by taking catalyst 1% of oil with the ultrasonic cavitation method and therefore 0.75% catalyst is optimum catalyst to be used because catalyst is an impurity and its use should be low as much as possible.

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