Optimization of restaurant waste oil methyl ester yield

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Biodiesel may be cost effective if produced from low cost oils (animal fats, restaurant waste oil and frying oil), which, however, contain high amount of free fatty acids (FFA). In the present study, different amounts of methanol (20, 25, 30, 35, 40 and 45%), catalyst concentrations (0.3, 0.5, 0.7, 1.0 and 1.5 % NaOH), reaction temperature (30, 45 and 55°C) and different reaction times (60, 90 and 120 min) were selected for transesterification of restaurant waste oil in order to optimize experimental conditions for maximum biodiesel yield. Methyl ester yield (65.50-85.50 %) in the laboratory scale biodiesel reactor was obtained maximum (85.50 %) at the optimized process parameters such as methanol (35% by vol), NaOH (0.3 g), reaction temperature (55°C) and reaction time (90 min).

**Keywords.** Biodiesel, Esters, Free fatty acids (FFA), Restaurant waste oil methyl esters, Transesterification

**IPC Code:** C11B7/00

**Introduction**

Considerable research\(^1\)-\(^6\) has been conducted on biodiesel and its performance in engines. However, for biodiesel to be commercially viable, biodiesel is to use less expensive feedstocks. Waste oils and greases from restaurant and rendered animal fats are possible sources of low cost feedstocks for biodiesel. This paper presents use of two-stage transesterification method for conversion of restaurant waste oil into biodiesel and optimization of experimental conditions for biodiesel production.

**Materials and Methods**

A two-stage transesterification method was used (Fig. 1). A laboratory scale glass beaker (500 ml) was used for biodiesel production from restaurant waste oil by acidic-alkaline catalyzed transesterification process. Methanol was chosen as an alcohol for transesterification process because of its low cost. In the first stage sulphuric acid (H\(_2\)SO\(_4\)) is used as an acidic catalyst because it appears to be quite effective at converting high FFAs to esters and this reaction is fast enough to be practical. In the second stage, sodium hydroxide (NaOH) is used as an alkaline catalyst because it is cheaper and reacts faster than acidic catalyst\(^7\). Thus, acidic catalyzed pretreatment step is used to convert high FFAs to esters followed by an alkaline catalyzed step to convert triglycerides to biodiesel\(^8\)-\(^10\). Transesterification process is affected by amounts of methanol, NaOH, reaction time and reaction temperature\(^11\).

Molecular weight of restaurant waste oil with major chemical constituents was determined as 912. As per transesterification process, 3 moles of methanol were required to react with 1 mole of vegetable oil\(^12\). Molecular weight of methanol is 32 and hence 96 g of methanol was required for transesterification of 1 mole (912 g) of restaurant waste oil, which amounts to 10.52% methanol. To optimize the amount of methanol required for the process, experiments were conducted with six samples of methanol (20, 25, 30, 35, 40, 45 %) keeping reaction temperature, reaction time and catalyst concentration constant.

In several studies\(^13,\)\(^14\), NaOH (0.1-1.2 %, by wt) has been used for biodiesel production. In present study, to optimize NaOH concentration, 5 different catalyst concentrations (0.3, 0.5, 0.7, 1.0 and 1.5 % NaOH) were used, keeping methanol amount, reaction time and reaction temperature constant. For the preparation of

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NaOH solution, NaOH pellets were completely dissolved in methanol and added to esterified restaurant waste oil, since NaOH pellets would react with CO₂ and water present in the atmosphere and yield sodium carbonate, which would affect performance of the catalyst during transesterification process.

Reaction temperature influences reaction rate and yield of esters\(^1\). Reaction temperature should always
Table 1—Optimized process parameters for maximum yield of restaurant waste oil methyl esters

<table>
<thead>
<tr>
<th>Samples</th>
<th>Oil ml</th>
<th>Methanol ml</th>
<th>Acidic catalyst (H₂SO₄) ml</th>
<th>Basic catalyst (NaOH) g</th>
<th>Reaction Temperature °C</th>
<th>Reaction Time min</th>
<th>Biodiesel ml</th>
<th>Glycerol %</th>
<th>% Esters</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>100</td>
<td>20</td>
<td>1.0</td>
<td>0.3</td>
<td>55</td>
<td>90</td>
<td>65.50</td>
<td>34.50</td>
<td>65.50</td>
</tr>
<tr>
<td>S2</td>
<td>25</td>
<td>23</td>
<td>1.0</td>
<td>0.3</td>
<td>55</td>
<td>90</td>
<td>70.50</td>
<td>29.50</td>
<td>70.50</td>
</tr>
<tr>
<td>S3</td>
<td>30</td>
<td>30</td>
<td>1.0</td>
<td>0.3</td>
<td>55</td>
<td>90</td>
<td>78.50</td>
<td>21.50</td>
<td>78.50</td>
</tr>
<tr>
<td>S4</td>
<td>35</td>
<td>35</td>
<td>1.0</td>
<td>0.3</td>
<td>55</td>
<td>90</td>
<td>85.50</td>
<td>14.50</td>
<td>85.50</td>
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<tr>
<td>S5</td>
<td>40</td>
<td>40</td>
<td>1.0</td>
<td>0.3</td>
<td>55</td>
<td>90</td>
<td>82.50</td>
<td>17.50</td>
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</tr>
<tr>
<td>S6</td>
<td>45</td>
<td>45</td>
<td>1.0</td>
<td>0.3</td>
<td>55</td>
<td>90</td>
<td>80.50</td>
<td>19.50</td>
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</tr>
<tr>
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<td>100</td>
<td>35</td>
<td>1.0</td>
<td>0.5</td>
<td>55</td>
<td>90</td>
<td>81.50</td>
<td>18.76</td>
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<tr>
<td>S8</td>
<td>100</td>
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<td>1.0</td>
<td>0.7</td>
<td>55</td>
<td>90</td>
<td>83.50</td>
<td>16.66</td>
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<tr>
<td>S9</td>
<td>100</td>
<td>35</td>
<td>1.0</td>
<td>1.0</td>
<td>55</td>
<td>90</td>
<td>80.50</td>
<td>19.77</td>
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</tr>
<tr>
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<td>100</td>
<td>35</td>
<td>1.0</td>
<td>1.5</td>
<td>55</td>
<td>90</td>
<td>78.50</td>
<td>21.75</td>
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<td>90</td>
<td>78.50</td>
<td>21.87</td>
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<td>0.7</td>
<td>45</td>
<td>90</td>
<td>80.50</td>
<td>19.77</td>
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<tr>
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<td>0.7</td>
<td>55</td>
<td>60</td>
<td>79.50</td>
<td>20.77</td>
<td>79.50</td>
</tr>
<tr>
<td>S14</td>
<td>100</td>
<td>35</td>
<td>1.0</td>
<td>0.7</td>
<td>55</td>
<td>120</td>
<td>80.50</td>
<td>19.88</td>
<td>80.50</td>
</tr>
</tbody>
</table>

be maintained below boiling point (65°C) of methanol. Hence to optimize reaction temperature, three different temperatures (30, 45 and 55°C) were used, keeping alcohol, catalyst concentration and reaction time constant.

Methyl ester conversion rate increases with reaction time. The process required 3 h for making ester and the reaction mixture was stirred for 90 min before transferring it to separation funnel. Hence, to optimize reaction time, three different reaction times (60, 90 and 120 min) were selected, keeping alcohol, catalyst concentrations, and reaction temperature constant.

**Experimental Method**

Clean restaurant waste oil of sunflower (100 ml), which was reused 2-3 times and collected from roast of Sambhram resort, Bangalore (India), was taken in each of six round bottom flasks and heated to 35°C. Required quantity of methanol (99% purity) was added to heated oil of each flask. After mixing for 5 min, samples became murky. To these mixtures, 1 ml of 95% H₂SO₄ is added. Stirring continued for 1 h by maintaining temperature at 35°C. In the mean time, sodium methoxide solution was prepared by dissolving required amount of NaOH pellets in 0.12 l of methanol per liter of oil. After 8 h, half of the prepared sodium methoxide solution is added to the mixture, which is then heated at 55°C and then remaining half of sodium methoxide solution is added. Stirring was continued for another hour at 55°C. Mixture was allowed to separate and settle overnight by gravity settling into a clear, golden color liquid biodiesel on the top and light brown glycerol at the bottom. Next day, glycerol was drained off, leaving biodiesel (yield, 85.50%), which was collected and water washed to bring down pH (7).

**Results and Discussion**

Optimum values (Table 1) of methanol (35%), catalyst NaOH (0.3%), reaction time (90 min) and reaction temperature (55°C) required for the transesterification of restaurant waste oil were obtained by varying the concentration of methanol (20-45%, by vol), NaOH concentration (0.3-1.5%, by wt), reaction temperature (30-55°C) and reaction time (60-120 min). Maximum
yield (85.50%) of biodiesel (methyl ester of restaurant waste oil) was obtained at optimum amount of methanol (Fig. 2a), catalyst NaOH concentration (Fig. 2b), temperature (Fig. 2c) and reaction time (Fig. 2d).

Conclusions

Restaurant waste oil was transesterified using a two-stage transesterification method to obtain methyl ester of oil (biodiesel). Maximum yield (85.50%) of biodiesel was obtained at optimum values of methanol (35%), NaOH concentration (0.3%), temperature (55°C) and reaction time (90 min).

References


![Fig. 2—Biodiesel yield with variation in: a) Methanol; b) NaOH concentration; c) Reaction temperature; d) Reaction time](image)

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