Alkali-catalyzed transesterification of rapeseed oil

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ABSTRACT

Most of the biodiesel produced today is made the base catalyzed reaction due to high conversion and no intermediate product during reaction. The experiments were carried out using methanol and two alkali catalysts i.e., Sodium hydroxide and Potassium hydroxide to transesterification of rapeseed oil were carried out for the production of biodiesel. The effect of catalyst concentration, methanol oil ratio, temperature, reaction time and stirring rate on the yield and quality of biodiesel was studied. The result of the study suggested that 0.6 % sodium hydroxide and 0.8 % potassium hydroxide catalyst concentration, 6:1 methanol oil ratio, 60 °C reaction temperature, 30 min reaction time and 300 rpm stirring rate were optimum for biodiesel production from rapeseed oil.

Keywords: Rapeseed, Transesterification, Biodiesel, Optimisation.

INTRODUCTION

The quick growing population, fast modernization and industrialisation have unrelentingly inflated the demand of energy in developing countries like republic of India. This demand of energy in India is generally met from non-renewable resources like petrochemicals, fossil fuel and coal (Adholeya and Dadhich, 2008). The dependency on these fossil fuels, which are for the most part been foreign, has serious implications on economy and environment (Varma and Basant, 2003; Sofer and Zaborsky, 1981). The vegetable oils (VOs) obtained from the renewable resources has caught the eye of researchers for the production of biodiesel (Ma and Hanna, 1999), that is biodegradable and contributes a minimum quantity of net greenhouse gases to the atmosphere. Though the calorific value of VOs is nearly as good as diesel oil, the low volatility and high consistency of VOs prohibits its direct application as fuel for diesel engines. However, this technical downside of higher viscosity of VOs has been overcome by transesterification (Ma and Hanna, 1999). Transesterification is the method of reacting triglyceride (vegetable oils) with alcohol in presence of catalyst. In the present study, we investigated the transesterification reaction of rapeseed oil with effect of catalyst concentration, methanol oil ratio, temperature, reaction time and stirring rate on the yield and quality of biodiesel (Vivek and Gupta, 2004; Karmee et al., 2004). The most recent study by Jeong et al. (2004) reported the optimum reaction conditions for alkali catalyzed transesterification of rapeseed oil as 1 % (w/w) KOH as catalyst; oil to methanol molar ratio 1:8 to 1:10 and 60 °C reaction temperature. In the above experiment a 98 % of methyl ester yield can be obtained in 30 min. In this paper, we have presented preliminary results on the effect catalyst concentration, methanol oil ratio, reaction temperature, reaction time and stirring rate on production of biodiesel from indigenously available rapeseed seed oil. The experiments were carried out with an aim to find out optimum reaction conditions.

MATERIALS AND METHODS

Chemicals: The reference standards of fatty acid methyl ester were procured from M/s Sigma-Aldrich. Methanol, sodium hydroxide and potassium hydroxide were obtained from M/s Himedia. All the chemicals used for experiments were analytical reagent grade and were used without further purification.

Extraction of oil: The seeds of rapeseed were obtained from Srinivasa seeds suppliers, Bangalore. Ultra sonication process was used for oil extraction. The extracted oil was filtered and left undisturbed for two-four days for settling of any suspended particles. The oil thus obtained was kept in an air tight container for further analysis.

Transesterification process: The reactor was charged with a given quantity of oil, that was stirred and preheated at totally different temperatures, meantime a solution of NaOH in methanol (CH₃OH) was added. The reaction condition was varied to get large range of methyl ester yields. Heating and stirring was then stopped, neutral with carboxylic acid and also the product was allowed to separate into two phases. The optimum of every parameter concerned within the method determined whereas the rest of them remained constant. Once every optimum was obtained, this value was thought of to be constant throughout the optimization of the next parameter. Ester yield results (given as percentages) were associated with the load of oil at the beginning. (Weight of ester/Weight of oil).

RESULTS AND DISCUSSION

Catalyst optimization: The amount of alkali catalyst NaOH used affects the conversion efficiency of the method. The catalyst quantity is varied within the range of 0.4-1.4 wt% for six totally different values. The result of the catalyst quantity on the yield is shown in Fig. 1. It is noted that in the current experiments, the excess addition of NaOH increases its yield. The optimum was achieved using 0.6 wt% of NaOH, which produced an 91 % yield of transparent ester. NaOH amounts greater than 0.6 wt% produced a smaller ester yield, because of the presence of soaps, which prevents ester layer separation (Coteron et al. 1997; Phan and Phan, 2008). Optimum concentration of NaOH was 0.6 wt% for 91% yield which is lower than the findings of Phan (0.75 wt% NaOH for 90 % yield). It can be concluded that the concentration of NaOH strongly dependent on the type of oils use.

Reaction temperature optimization: The effect of the temperature on the yield is shown in Fig. 2. The optimum temperature for the reaction is found to be in the range of 60 °C. Maximum yield of 96.1 % esters occurred at this temperature 60 °C. This result clearly shows that the rate of the reaction was strongly influenced by temperature (Ma and Hanna, 1999; Antonlin et al. 2002). However there
was a slight decrease in yield after 60 °C due to the enhancement of transesterification and saponification reaction (Phan and Phan, 2008). The requirement of higher temperature in yield was due to difference in raw feed stock oil (Ma and Hanna, 1999).

**Reaction time optimization:** The dependency of reaction time was studied at totally different time intervals starting from 20-70 min. Results obtained from this experiment with oil disclosed that concerning 30 min of reaction are sufficient for the completion of the esterification. The maximum yield of 97 occurs at 30 min. The increase in reaction temperature speeds up the reaction rate and shortens the interval (Antonlin et al., 2002). The result of the time on the yield is shown in Fig.3.

**Methanol oil molar ratio optimization:** The molar ratio of alcohol to rapeseed oil is one in all the vital factors that have an effect on the conversion efficiency also as cost of bio-diesel. The impact of molar ratio on yield is shown in Fig. 4. The methanol of concerning 25-150 % excess was studied. The most conversion efficiency is achieved at the molar ratio of 6:1. The methyl ester group yield achieved in 30 min is 97 % when the methanol was 100 percent excess (6:1, Methanol:Oil). Also Ramadhas et al. ascertained the optimum yield at constant 100 percent excess in vegetable oil and rubber seed oil.

**Stirring optimization:** The result of stirring on yield is shown in Fig. 5. Methanolysis is conducted with completely different rate of stirring like 150, 200, 250, 300, 350 and 400 rpm. The reaction is incomplete at the speed of 150-250 rpm and rate of blending was insignificant for methanolysis. The yield of biodiesel at 300 and 350 rpm was same when 30 min i.e. 97.4 %. The optimum of 300 rpm is usually recommended.

**Optimization using KOH catalyst:** Similar optimization procedure was followed to determine the optimized parameters when KOH is used as catalyst. Maximum yield 96.7 % was obtained at 0.8 % potassium hydroxide catalyst concentration, 70 °C reaction temperature, 30 min reaction time, 6:1 methanol oil ratio and 350 rpm stirring rate.

![Table 1: Fuel properties of Rapeseed biodiesel](attachment:image)

<table>
<thead>
<tr>
<th>Properties</th>
<th>NaOH</th>
<th>KOH</th>
<th>ASTM D6571</th>
<th>IS1 5607:2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15 C, kg/m³</td>
<td>0.9</td>
<td>0.9</td>
<td>-</td>
<td>860–900</td>
</tr>
<tr>
<td>Viscosity, 40 C (mm²/s)</td>
<td>6.11</td>
<td>5.51</td>
<td>1.9–6.0</td>
<td>2.5–6.0</td>
</tr>
<tr>
<td>Flash point, C</td>
<td>190</td>
<td>184</td>
<td>&gt;130</td>
<td>&gt;130</td>
</tr>
<tr>
<td>Acid value, mg KOH/gm</td>
<td>0.365</td>
<td>0.266</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Calorific value (MJ/kg)</td>
<td>39.28</td>
<td>39.16</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**CONCLUSION**

The biodiesel from rapeseed oil was successfully produced by alkali catalyzed transesterification reaction that 0.6 % sodium hydroxide and 0.8 % potassium hydroxide catalyst concentration, 6:1 methanol oil ratio, 60 °C reaction temperature, 30 min reaction time and 300 rpm stirring rate were optimum for biodiesel production from rapeseed oil (table.1).

**REFERENCES**

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