CHARACTERIZATION OF BIODIESEL FROM WASTE COOKING OIL-- FATTY ACID METHYL ESTER (FAME) PROFILE

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Abstract: Biodiesel from waste cooking oil (WCO) was prepared by the transesterification process. The fatty acid methyl ester profile using gas chromatography shows that the monounsaturated Oleic Acid Methyl Ester (C_{19}H_{36}O_{2}) was the dominant component. The physico-chemical properties of WCO-biodiesel were well within the range of ASTM D 6751 values. It makes this renewable energy resource one of the cheapest and ecologically green biofuels.

I. INTRODUCTION

Extensive use of fossil fuels in industry and transport have already started showing ecological and economic repercussions. These range from depleting finite resources to global warming. Efforts are on to find sustainable alternative sources which are less polluting as well as non-competitive with agricultural crops. Green diesel or biodiesel is one such viable alternative which is capable of fulfilling the requirements of our future energy needs. Extensive work initiated on this alternative fuel is a testimony of its potential in the modern scenario. Biodiesel possesses some advantages over conventional diesel. Since it does not have sulphur, it does not contribute to global warming. It is more eco-friendly on account of lower smoke and carbon emissions[1].

A variety of sources comprise the feedstock for biodiesel production. These include both edible and non-edible vegetable oils, waste cooking oil, animal fat, chicken waste along with algae and fruits. Amongst these, waste-cooking oil (WCO) or gutter oil holds great promise as one of the best sources of biodiesel production [2-3]. This is on account of its distinct economic and ecological advantages. Being the cheapest and easily procurable feedstock, it also helps in effective mitigation of soil and water pollution.

The present investigation was undertaken to analyze the fatty acid methyl ester (FAME) profile of WCO using a gas chromatograph, in order to study its influence on physico-chemical properties of biodiesel like density, specific gravity, viscosity, acid value, iodine value and calorific value. The values obtained have been compared with the ASTM D 6751 biodiesel standards.

II. METHODOLOGY

Raw materials: Waste cooking oil WCO (also known as waste frying oil WFC or Gutter oil) was collected from local restaurants and sweet shops in New Delhi. The oil was filtered and processed for measurement of properties.
Phosphoric acid, sulphuric acid, anhydrous methanol (99.8%), p-toluene sulphuric acid (PTSA), sodium methoxide and sodium hydroxide of analytical grade were used.

**Preparation of Biodiesel:** The WCO material was first dehydrated by heating at 100°C. Thereafter it was degummed (removal of solid gums and phospholipids) by using H₃PO₄ and water in a three necked round bottom flask at 60–70°C for one hour. Since the free fatty acid (FFA) content of WCO was found to be greater than 1% of oil, it was subjected to acid catalysis by using methanol at 60–70°C. H₂SO₄ and PTSA were used as catalysts.

The acid yield oil sample was poured into a reactor (a 1000 ml three necked round bottom flask; centre neck fitted with a stirrer, one neck equipped with a condenser and the other neck used as thermo well for sample collection fitted with a thermometer. The apparatus is connected to a speed- controlled magnetic stirrer). The catalyst sodium methoxide (0.6%), along with methanol were added to the reactor. The reaction (optimized in our earlier experiments [4]) was allowed to proceed for six hours at 60–70°C. After 24 hrs standing in a separating funnel the two layers were obtained. The upper layer containing biodiesel and residual methanol was separated and subjected to distillation. After several washings with water the organic layer was neutralized with 10% NaOH solution.

**Characterization of WCO and WCO Biodiesel:** Physical and chemical properties of WCO and WCO biodiesel were determined using standard test methods [5-10]. The values were calculated and compared with the standard ASTM (American Society for Testing and Materials) D6751 values.

**Gas Chromatography Analysis:** The GC-Analysis of WCO – biodiesel was conducted to identify and quantify the FAME composition. A 2 µl (micro liter) of biodiesel sample was injected into the gas chromatograph (equipped with a flame ionization detection; the split ratio 50:1, injection temperature 350°C and sample elution time of 45 minutes.) The GC apparatus used N₂ as the carrier gas with a flow rate of 8ml/minute.

**III. RESULTS AND DISCUSSION**

The methyl fatty acid ester composition in biodiesel produced from WCO reveals the presence of six esters present in variable ratios (Table 1). α-Linolenic Acid Methyl Ester (C₁₉H₃₂O₂) was present in least amounts (0.28% by weight). The most abundant component in the FAME profile was Oleic Acid Methyl Ester (C₁₉H₃₆O₂: 51.88%). Other esters found in the biodiesel were Linolelaidic Acid Methyl Ester (C₁₉H₃₄O₂: 31.81%), Palmetoleic Acid Methyl Ester; C₁₇H₃₄O₂: 13.76%, Cis-10-Heptadecenoic Acid Methyl Ester, C₁₈H₃₄O₂: 1.80% and γ-Linolenic Acid Methyl Ester, C₁₉H₃₄O₂: 0.36%).

The fatty acid methyl ester (FAME) profile of any feed stock is one of the most important indicators of its suitability for biodiesel production [11]. In the present study, the monounsaturated Oleic Acid Methyl Ester (Methyl [12E] octadecenoate) constitutes more than half by weight (51.88%). This is significant as the fatty acid composition of biodiesel determines many vital properties of this fuel viz., stability, and combustibility. Presence of high proportion of monounsaturated methyl esters indicates its suitability for use as a fuel. Biodiesel with predominance of monounsaturated components has low tendency of polymerization
and peroxidation [12]. The monounsaturated methyl esters do not have affinity for oxygen and the biodiesel is suitable for high temperatures. Similar monounsaturated FAMES have also been reported from biodiesel obtained from *Jatropha curcas*, palm and olive oil [13], rapeseed oil [14], pumpkin [15], and an alga *Dunaliella* [16].

Supplementary studies comprising the physico-chemical properties of WCO biodiesel such as viscosity acid value, specific gravity, iodine value calorific value and density show values quite near to the ASTM standard values (Tables 2-3). Thus the present experimental results strongly support WCO as one of the most promising and economically viable feed stocks for biodiesel production.

<table>
<thead>
<tr>
<th>Property</th>
<th>Experimental value</th>
<th>WCO Biodiesel</th>
<th>Biodiesel ASTM D6751</th>
<th>Diesel Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity at 25°C</td>
<td>0.8746</td>
<td>0.88(at 15.5°C)</td>
<td>0.85 (at 15.5°C)</td>
<td></td>
</tr>
<tr>
<td>Density g/cm³</td>
<td>0.8738</td>
<td>0.875–0.900</td>
<td>0.850</td>
<td></td>
</tr>
<tr>
<td>Viscosity (mm²/s) at 40°C</td>
<td>3.9970</td>
<td>1.9–6.0</td>
<td>2.60</td>
<td></td>
</tr>
<tr>
<td>Iodine Value (mg/g)</td>
<td>63.5</td>
<td>–</td>
<td>–</td>
<td>4200</td>
</tr>
<tr>
<td>Calorific Value (kJ/Kg)</td>
<td>9447.2664</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Acid Value (mgKOH/g oil)</td>
<td>0.92</td>
<td>&lt; 0.8</td>
<td>0.35</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Methyl Fatty Acid Esters Composition of WCO

<table>
<thead>
<tr>
<th>Methyl Esters</th>
<th>Mol. Formula</th>
<th>Db</th>
<th>Mol. Mass</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmitoleic Acid Methyl Ester</td>
<td>C17:1</td>
<td>1</td>
<td>268.431</td>
<td>13.76</td>
</tr>
<tr>
<td>Cis-10 Hepta decenoic Acid Methyl Ester</td>
<td>C18:1</td>
<td>1</td>
<td>282.461</td>
<td>1.80</td>
</tr>
<tr>
<td>Oleic Acid Methyl Ester</td>
<td>C19:1</td>
<td>1</td>
<td>296.461</td>
<td>51.88</td>
</tr>
<tr>
<td>Linolelaïd Acid Methyl Ester</td>
<td>C19:2</td>
<td>2</td>
<td>294.472</td>
<td>31.81</td>
</tr>
<tr>
<td>γ-Linolenic Acid Methyl Ester</td>
<td>C19:3</td>
<td>3</td>
<td>292.463</td>
<td>0.36</td>
</tr>
<tr>
<td>α-Linolenic Acid Methyl Ester</td>
<td>C19:3</td>
<td>3</td>
<td>292.463</td>
<td>0.28</td>
</tr>
</tbody>
</table>
IV. ACKNOWLEDGEMENT

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REFERENCES


