Performance evaluation of a single cylinder diesel engine fueled with biodiesel produced from pumpkin oil

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This study presents transesterification of pumpkin oil to produce biodiesel. A maximum biodiesel yield (96.32%) was observed under optimum conditions for pumpkin oil transesterification [temp., 50°C, molar ratio of methanol to oil, 6:1, KOH, 1.2% (by wt of oil) and time, 90 min]. Performance characteristics of B20 were found to be quite close to petroleum diesel. Thus, 20% blend of pumpkin oil biodiesel can be safely used with petroleum diesel.

Keywords: Biodiesel, Pumpkin oil, Transesterification

Introduction
Soaring price of petroleum products together with depletion of fossil fuels have prompted considerable research to identify alternative fuel sources. Search for alternatives to petrodiesel in India is of much importance since consumption of diesel is almost five times more than petrol. Biodiesel is the most widely accepted alternative to diesel fuel because of its similarity in properties with diesel fuel, renewability, biodegradability, reduced gas emissions and use of blends (2-30%) with fossil diesel without any modification of engine. Main constraint for the growth of biodiesel industry is the high cost of vegetable oils, which can be up to 75% of total manufacturing costs. Hence to improve the economy, pumpkin seed oil can be considered as one option. Pumpkin seeds contain fatty oil (36.6% dry basis), which contains primarily linoleic (40.4%) and oleic acid (35.9%). A number of studies on engine performance and exhaust emissions using jatropha oil, karanja oil, jojoba oil, nahar oil, sunflower oil, waste cooking oils, rice bran oil, castor oil, canola oil, thumba oil, palm oil, mahua oil and karabi seed oil biodiesel are available. First report on biodiesel production using pumpkin oil was without engine tests using pumpkin seed oil biodiesel. This study focuses on the production of biodiesel using pumpkin seed oil and its performance in a single cylinder engine.

Experimental Section
Pumpkin seeds were collected locally, dried in an oven and oil was extracted in a soxhlet apparatus using hexane as a solvent for 20 h. Acid value of the oil was sufficiently small (1.03 mg KOH/g of oil) to directly conduct base catalyzed transesterification.

Transesterification of Pumpkin Seed Oil
Transesterification was conducted in a round bottom reactor (3 l) equipped with two spiral condensers for efficient methanol recovery, an agitator with an rpm indicator cum controller and a platinum RTD temperature sensor (Pt-100) connected to digital temperature indicator. Proportional integral derivative (PID) controller was used to maintain temperature of reaction mixture. Pumpkin oil (150 g) was transferred to reactor and preheated to desired temperature. Specified amount of KOH was dissolved in calculated quantity of anhydrous methanol (99.5% purity). Resulting solution was transferred to reactor and stirred for desired time. Reaction mixture was cooled to room temperature (RT) and allowed to settle in a separating funnel for 24 h, resulting into top layer mainly of pumpkin oil methyl ester (POME) while lower layer comprised of glycerol as a major component. Excess methanol in both layers was recovered by distillation. Top layer was washed twice with warm distilled water (10%, v/v) and dried.

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Analytical Methods

Average molecular weight of pumpkin oil is related to saponification and acid values as

\[ M_{\text{Pumpkin oil}} = \frac{3 \times 56100}{(\text{Saponification value} - \text{Acid value})} \]

Glycerol formed in reaction was noted and conversion % of pumpkin oil was calculated as

Conversion (%) = \[ \frac{\text{Weight of glycerol produced actually}}{\text{Weight of glycerol produced stoichiometrically}} \times 100 \]

Yield of methyl esters (Y) was calculated based on amount of pumpkin oil taken as

Yield of POME = \[ \frac{\text{Weight of pumpkin oil methyl esters produced}}{\text{Weight of pumpkin oil taken for the reaction}} \times 100 \]

Engine Tests

Biodiesel was tested in a 4 stroke, vertical cylinder, water cooled, cold start, compression ignition diesel cycle GANGA diesel engine (5 BHP, compression ratio 16:1). Engine tests were performed with B0, B20 and B100 at 5 different loads (3-15 kgf). Performance characteristics [brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and volumetric efficiency (VE)], besides exhaust gas temperature (EGT) were determined for all runs.

Results and Discussions

Transesterification

Under optimum conditions for transesterification [temp., 50°C, molar ratio of methanol to oil, 6:1; KOH, 1.2% (by wt of oil); and time, 90 min], a maximum yield of seed oil was 96.32%.

Properties of Biodiesel

All properties of pumpkin oil biodiesel (Table 1) were in agreement with ASTM D 6751 standards, except kinematic viscosity, which was slightly higher than the upper limit of 6 mm²/s. This may result in slight increase of BSFC because of poor atomization of fuel spray and less accurate operation of fuel injectors. A high value of flash point indicates that the fuel is safe. Pour and cloud points were also sufficiently low, indicating that the performance of pumpkin oil biodiesel will be satisfactory in cold climates too.

Brake Thermal Efficiency (BTE)

BTE (Fig. 1) was maximum (28.1%) for B20 at load of 12 kgf, followed by B0 (26.8%) and B100 (26.1%). B100 has higher oxygen content than B0, but lower calorific value (43.3 MJ/kg v/s 45 MJ/kg in present study). B20 had a slightly lower calorific value than B0, but better oxygen content than B0, thus giving a better performance.

Brake Specific Fuel Consumption (BSFC)

BSFC was found to be decreasing with respect to brake power (Fig. 2). However, increasing the load beyond 9 kgf did not affect the parameter much. B100 exhibited a maximum BSFC of 0.5378 (kg/kWh) at a load of 3 kgf. Further, BSFC of B20 was 0.38, 6.51, 0.57, 1.75 and 2.86% higher than B0 at loads of 3, 6, 9, 12 and 15 kgf respectively. Since calorific value of B100 is slightly less than B0 (3.92% lower), these deviations are relatively less. Low calorific value, high density and viscosity of biodiesel are responsible for higher

<p>| Table 1—Comparison of fuel properties of pumpkin oil biodiesel with ASTM biodiesel standard |</p>
<table>
<thead>
<tr>
<th>Fuel property</th>
<th>Pumpkin oil biodiesel</th>
<th>ASTM D6751</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid value, mg KOH/g oil</td>
<td>0.38</td>
<td>0.5 max.</td>
</tr>
<tr>
<td>Density at 5°C, g/ml</td>
<td>0.883</td>
<td>0.86-0.9</td>
</tr>
<tr>
<td>Kinematic viscosity at 40°C, mm²/s</td>
<td>6.3</td>
<td>3.5-6</td>
</tr>
<tr>
<td>Flash point, °C</td>
<td>179</td>
<td>Min.100</td>
</tr>
<tr>
<td>Higher heating value, MJ/kg</td>
<td>43.3</td>
<td>-</td>
</tr>
<tr>
<td>Pour point, °C</td>
<td>-8</td>
<td>-</td>
</tr>
<tr>
<td>Cloud point, °C</td>
<td>-2</td>
<td>-</td>
</tr>
</tbody>
</table>

![Fig. 1—Brake thermal efficiency vs brake power](image)
biodiesel are responsible for higher consumption of biodiesel and its blends for the same power developed.

**Exhaust Gas Temperature (EGT)**

EGT (Fig. 3) increases with increasing load and is maximum for B0 for all loads. Low EGT of B20 and B100 are because of early combustion, which allows more time and crank angle for the expansion process to remove energy from hot combustion gases, thus reducing exhaust temperature. Also, EGTs of B0 and B20 were closer to each other at all loads.

**Volumetric Efficiency (VE)**

VE is the ratio of actual consumption of air to theoretical consumption. Actual consumption of air directly varies as air head causing flow. Air head is inversely proportional to density of air, which will be low at high temperatures. Because of high calorific value of B0, it can be expected that combustion temperatures for B0 are higher as compared to other two samples, thus resulting in low density of air. The low density of air thus increases air head causing the flow and hence VE. In general, VE was found to be decreasing with increase in brake power (Fig. 4). This is because air-fuel ratio decreases with increasing brake power (Fig. 5).

**Conclusions**

Pumpkin oil based biodiesel can be a suitable feedstock for biodiesel industry. Performance characteristics of B20 (BSFC, BTE, EGT and VE) were quite close to petroleum diesel. Thus, a 20% blend of pumpkin oil biodiesel can be safely used with petroleum diesel without significantly affecting its fuel properties and performance.
References