EFFECT OF FATTY ACID PROFILE OF BIODIESEL ON ADIABATIC COMPRESSIONIBILITY AND VISCOSITY OF BIODIESEL AND BLENDS

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ABSTRACT
Biodiesel is an alternative environmental friendly fuel to Petroleum Diesel (PD). In this work, adiabatic compressibility and viscosity of Cotton Seed Oil Methyl Esters (CSOME) and Palm Stearin Methyl Esters (PSME) biodiesels and their blends with PD were investigated as a function of fatty acid profile of biodiesels. Adiabatic compressibility was measured using ultrasonic interferometer of frequency 2 MHz. Viscosity was measured using capillary flow technique. The fatty acid profile was measured using Gas Chromatography (GC) method with Flame Ionization Detector (FID). CSOME biodiesel was rich in unsaturated Fatty Acid Methyl Esters (FAME) and PSME biodiesel in saturated FAME. Adiabatic compressibility decreased linearly in similar fashion at different rates with increase in blend percent of both biodiesels with PD. Viscosity was increased non linearly in similar fashion for both the biodiesel blends with increase in blend percent of biodiesel in PD. Adiabatic compressibility and viscosity were constant in the lower blends irrespective of FAME composition of biodiesels. Significant difference in adiabatic compressibility and viscosity was observed for pure biodiesels. The physical properties, adiabatic compressibility and viscosity were changed in the similar fashion with small difference in values even though having significant structural difference between saturated and unsaturated FAME.

Key Words: Biodiesel, Biodiesel Blends, Saturated Fame, Unsaturated Fame, Adiabatic Compressibility, Viscosity

INTRODUCTION
Biodiesel is an alternative diesel fuel derived from vegetable oils or animal fats. The transesterification of an oil or fat with a monohydric alcohol, generally methanol, yields the corresponding mono alkyl esters, called as Fatty Acid Methyl Esters (FAME), and is defined as biodiesel (Knothe, 2005; Moser, 2009). Advantages of biodiesel include domestic origin, renewability, biodegradability, higher flash point, inherent lubricity, reduction of most of the exhaust emissions, as well as miscibility with PD at all levels. One of the attractive characteristics of biodiesel is that its use does not require any significant modifications to the diesel engine (Knothe, 2008; Knothe, 2005; Tat and Van Gerpen, 2003). One of the problems with biodiesel is its poor cold flow properties. Biodiesel is miscible with PD at all levels. So, often it is used as blend component in petroleum diesel (Joshi and Pegg, 2007, Tat and Van Gerpen, 2003). The fuel properties of biodiesel and PD blends change with the amount of biodiesel in the fuel mixture because biodiesel has different fuel properties compared to conventional PD (Alptekin and Canakci, 2009). Several properties of biodiesel directly depend upon fatty acid profile of biodiesel. Most of the biodiesel feedstocks such as soybean, sunflower, palm and peanut oils contain saturated fatty esters of such as hexadecanoic acid (C16:0), octadecanoic acid (C18:0) and unsaturated fatty esters of such as octadecenoic acid (C18:1), octadecadienoic acid (C18:2) and octadecatrienoic acid (C18:3). A variety of other fatty acids are present in minor components in all oils and fats used as biodiesel feedstocks (Knothe, 2008).
Biodiesel has physical and chemical properties different from Petroleum Diesel (PD). It has higher density, higher viscosity, and higher speed of sound and lower compressibility. The compressibility of fuel in the diesel engine cylinder affects fuel injection timing. If the fuel is less compressible and speed of sound is greater, the fuel injection pressure will develop faster and the fuel will be injected sooner (Tat and Van Gerpen, 2003; Tat et al., 2000).
Viscosity is one of the most important fuel properties. The effects of viscosity can be seen in the quality of atomization and combustion as well as engine wears. The higher viscosity of biodiesel compared to PD makes it an excellent lubricity additive (Tate et al., 2006). Reducing viscosity is the main reason why vegetable oils or fats are transesterified to biodiesel because the high viscosity of pure vegetable oils or fats ultimately leads to operational problems such as engine deposits (Knothe and Steidley, 2005).

The fuel properties of biodiesel and PD blends change with the amount of biodiesel in the fuel mixture because biodiesel has different fuel properties compared to conventional PD (Alptekin and Canakci, 2009). The objective of the present study is to study the variation of viscosity and adiabatic compressibility of two different biodiesels and their blends with PD as a function of their fatty acid profile.

MATERIALS AND METHODS

Materials
Two commercially available biodiesels and one PD were collected. One biodiesel is Cotton Seed Oil Methyl Esters (CSOME), collected from Southern online biotechnologies Pvt Limited, Hyderabad, Andhra Pradesh (AP), India and another biodiesel is Palm Stearin Methyl Esters (PSME), collected from Universal bio fuels Pvt Limited, Hyderabad, AP, and India. The PD was collected from an Indian oil outlet, Hyderabad, AP, India.

Blend Preparation
Five different blends of both biodiesels CSOME and PSME with PD in the volume % of 10, 20, 30, 40 and 50 were prepared on simple mixing of the two.

GC of Biodiesels
The fatty acid profile of both CSOME and PSME biodiesels with GC-FID was studied and reported elsewhere (Rajagopal et al., 2012). It is one of the recommended methods for FAME analysis of biodiesels (Knothe, 2001).

Adiabatic Compressibility of Biodiesels and their Blends
Adiabatic compressibility was measured on finding the velocity of ultrasound. Velocity of ultrasound was measured using Mittal F80 ultrasonic interferometer of frequency 2 MHz. Distance moved by the micrometer for 50 maxima were measured. Least count of micrometer screw was 0.01 mm and velocity was measured with accuracy of 0.8 ms⁻¹. Adiabatic compressibility was calculated using the following relation

\[ \beta = \frac{1}{\nu^2 \rho} \]

Where \( \nu \) = velocity of ultrasound
\( \rho \) = density of sample

For every sample 3 trials were made and average adiabatic compressibility was recorded.

Viscosity of Biodiesels and their Blends
Viscosity was measured using capillary flow method on finding time of flow through a fixed distance (Ahmad et al., 2009). Three trials were made and average was recorded. Viscosity was calculated using the following relation

\[ \eta = \frac{R^2 \rho g}{8 \nu_o} \]

Where \( R \) = radius of bore of capillary tube
\( g \) = acceleration due to gravity
\( \nu_o \) = velocity of flow

The radius of capillary bore was measured using a travelling microscope of accuracy 0.001 cm.

Density of Biodiesels and their Blends
Density was measured using specific gravity bottle of volume 10 ml and reported elsewhere (Rajagopal et al., 2011).

RESULTS AND DISCUSSION
The CSOME biodiesel is rich in unsaturated FAME with 57.2 wt %, particularly in C18:2 FAME and PSME biodiesel is rich in saturated FAME with 62.1 wt %, particularly in C16:0 (Rajagopal et al., 2012).
Research Article

The data on ultrasound velocity, adiabatic compressibility and viscosity of both CSOME and PSME biodiesels and their blends with PD are shown in Table I. Corresponding graphical variations are shown in Figs. I, II and III respectively. The ultrasound velocity is more in both biodiesels than in PD. Velocity of ultrasound is slightly more in CSOME blends than in PSME blends. Velocity of ultrasound is significantly more in pure CSOME biodiesel than in PSME biodiesel. Correspondingly adiabatic compressibility is significantly less for pure CSOME biodiesel than PSME biodiesel. So, it can be concluded that unsaturated FAME, particularly C18:2 is less compressible than saturated FAME, particularly C16:0. Adiabatic compressibility is approximately same for both the biodiesel blends irrespective of nature of FAME content of biodiesels. There is good linear variation of both velocity of ultrasound and adiabatic compressibility. Even though there is difference in FAME content of biodiesels, there is similar linear variation for both CSOME and PSME blends at different rates.

Table I: Ultrasonic velocity, adiabatic compressibility and viscosity of CSOME and PSME biodiesels and their blends with PD

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Vol % of Biodiesel in PD, C</th>
<th>Density, $\rho$ (g/cc)</th>
<th>Ultrasonic Velocity, $v$ (cm/s) $\times 10^2$</th>
<th>Adiabatic Compressibility, $\beta$ (cm$^2$/dyne) $\times 10^{-11}$</th>
<th>Viscosity, $\eta$ (poise)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CSOME Blends</td>
<td>PSME Blends</td>
<td>CSOME Blends</td>
<td>PSME Blends</td>
<td>CSOME Blends</td>
</tr>
<tr>
<td>1</td>
<td>PD</td>
<td>0.8138</td>
<td>0.8138</td>
<td>1328.8</td>
<td>1328.8</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>0.8194</td>
<td>0.8173</td>
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<td>1331.2</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
<td>40</td>
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<tr>
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<td>100</td>
<td>0.861</td>
<td>0.8525</td>
<td>1380.8</td>
<td>1369.6</td>
</tr>
</tbody>
</table>

*reported in Rajagopal et al., (2011)

Viscosity of both CSOME and PSME biodiesels and their blends with PD are shown in Table II and the corresponding graphical variations are shown in Fig. III. The viscosity of both biodiesels is much more than PD. The viscosity of PSME biodiesel is slightly more than CSOME biodiesel. Both biodiesel blends have shown non linear increase in viscosity with increase in volume percent of biodiesel in PD. The viscosity of both biodiesel blends is almost constant with little fluctuation up to 30 % volume blend irrespective of whether biodiesel is rich in saturated or unsaturated FAME. Later, the increase in viscosity is more rapid than lower blends for both biodiesels. Even, the nature of variation of viscosity of both biodiesel blends is same at different rates irrespective of the FAME composition of biodiesels. It is in contrast with variation of chemical
property such as cloud point of biodiesel and their blends with PD, which varied non-linearly in different fashions for both CSOME and PSME biodiesel blends (Rajagopal et al., 2012).

The saturated FAME has straight linear structure and unsaturated FAME has non linear structure with kinks near the positions of double bonds (Rodrihues et al., 2006). It appears that structural difference has less influence on adiabatic compressibility and viscosity of both biodiesel blends. There is significant difference in viscosity for pure biodiesels. That is why often any biodiesel is used as blend component with PD up to 20% volume so that viscosity of fuel is not effected (Moser, 2009).

CONCLUSIONS
Adiabatic compressibility and viscosity of both CSOME and PSME biodiesel blends are approximately same irrespective of richness of saturated or unsaturated FAME. There is significant difference for pure biodiesels, that too by small value. The variation of adiabatic compressibility and viscosity of both biodiesel blends, with respect to volume percent of biodiesel in PD is in the similar way, linearly for adiabatic compressibility and slightly non-linearly for viscosity in contrast to chemical property such as cloud point of biodiesel and their blends with PD.

ACKNOWLEDGEMENTS
Authors are acknowledging Sri Brahmananda Reddy of Southern Online Biotechnologies Pvt Ltd and Sri T.V. Rambabu, Vice-President, Universal Biofuels Pvt Ltd, Hyderabad, and Andhra Pradesh, India for providing CSOME and PSME biodiesel samples.

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