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Research Article

EFFECT OF FATTY ACID PROFILE OF BIODIESEL ON ADIABATIC COMPRESSIBILITY 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

$$\beta = 1/v^2\rho$$

Where v = velocity of ultrasound

ρ = 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

$$\eta = (R^2\rho g)/8v_o$$

Where R = radius of bore of capillary tube

g = acceleration due to gravity

v_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).

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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

S.No.	Vol % of Biodiesel in PD, C	Density, ρ* (g/cc)		Ultrasonic Velocity, v (cm/s) × 10^2		Adiabatic Compressibility, β (cm^2/dyne) ×10^{-11}		Viscosity, η (poise)	
		CSOME Blends	PSME Blends	CSOME Blends	PSME Blends	CSOME Blends	PSME Blends	CSOME Blends	PSME Blends
1	PD	0.8138	0.8138	1328.8	1328.8	6.96	6.96	0.029	0.029
2	10	0.8194	0.8173	1333.6	1331.2	6.86	6.9	0.029	0.033
3	20	0.8227	0.8218	1338.4	1333.6	6.79	6.84	0.031	0.030
4	30	0.8279	0.8256	1340	1337.6	6.73	6.77	0.034	0.033
5	40	0.8306	0.8287	1344.8	1343.2	6.66	6.69	0.034	0.038
6	50	0.8381	0.8316	1349.6	1348	6.55	6.62	0.035	0.039
7	100	0.861	0.8525	1380.8	1369.6	6.09	6.25	0.051	0.055

**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

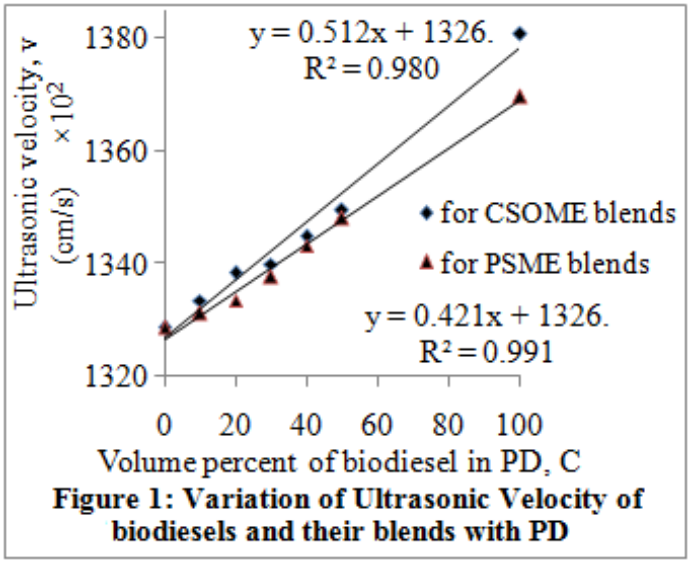

Figure 1: Variation of Ultrasonic Velocity of biodiesels and their blends with PD

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).

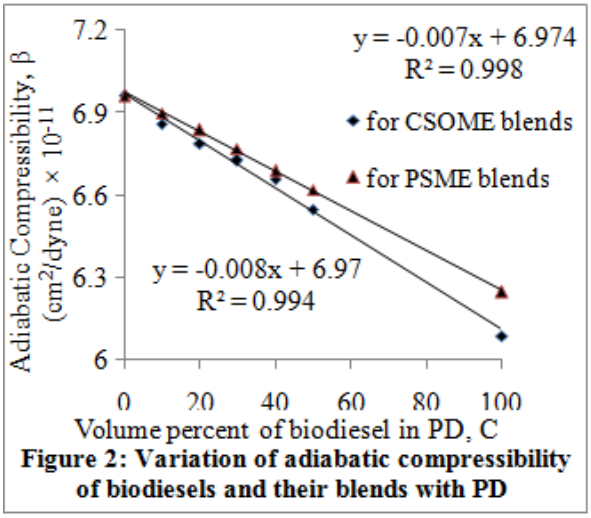

Figure 2: Variation of adiabatic compressibility of biodiesels and their blends with PD

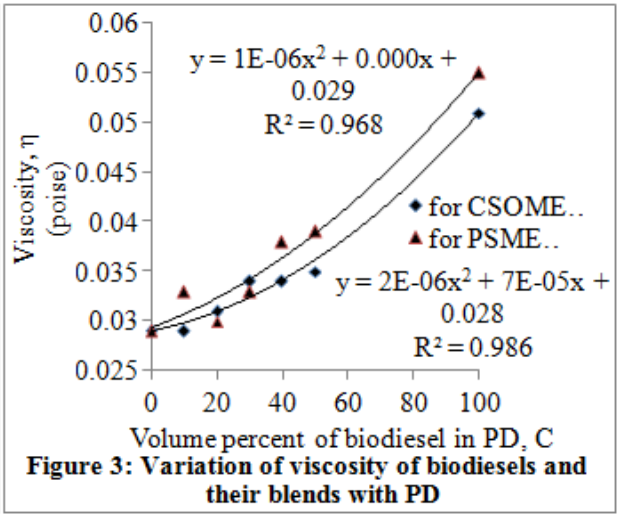

Figure 3: Variation of viscosity of biodiesels and their blends with PD

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.

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REFERENCES

Ahmad MG, Almazyad A, Kaleem Ahmed Jaleeli and Adeel Ahmad (2009). Viscosity of blood of patients suffering from diabetes. *Journal of Pure and Applied Physics* **21**(2) 139-140.

Alptekin E and Canakci M (2009). Characterization of key fuel properties of methyl ester-diesel fuel blends. *Fuel* **88**(1) 75-80.

Joshi RM, and Pegg MJ (2007). Flow properties of biodiesel fuel blends at low temperatures. *Fuel* **86**(1-2) 143-151.

Knothe G (2008). "Designer" biodiesel: Optimizing fatty ester composition to improve fuel properties. *Energy and Fuels* **22**(2) 1358-1364.

Knothe G (2005). Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters. *Fuel Processing Technology* **86**(10) 1059-1070.

Knothe G (2001). Analytical methods used in the production and fuel quality assessment of biodiesel. *Transactions of American Society for Agricultural Engineers (ASAE)* **44**(2) 193-200.

Knothe G and Steidley KR (2005). Kinematic viscosity of biodiesel fuel components and related compounds: Influence of compound structure and comparison to petrodiesel fuel components. *Fuel* **84**(9) 1059-1065.

Moser BR (2009). Biodiesel production, properties and feedstocks. *In Vitro Cellular & Developmental Biology - Plant,* **45**(3), 229-266.

Rajagopal K, Bindu Ch, Prasad RBN and Adeel Ahmad (2012). Cloud point of biodiesel and blends. *Journal of Chemical, Biological and Physical Sciences Section C* **2**(4) 1998-2003.

Rajagopal K, Kaleem Ahmed Jaleeli and Adeel Ahmad, (2011). Refractive index of biodiesels and their blends. *Journal of Pure and Applied Physics* **23**(4) 631-635.

Rodrigues JrJdeA, Cardoso FdeP, Lachter ER, Estevao LRM, Lima E and Nascimento RSV (2006). Correlating chemical structure and physical properties of vegetable oil esters. *Journal of American Oil Chemists Society* **83**(4) 353-357.

Tat ME and Van Gerpen JH (2003). Effect of temperature and pressure on the speed of sound and isentropic bulk modulus of mixtures of biodiesel and diesel fuel. *Journal of American Oil Chemists Society* **80**(11) 1127-1130.

Tat ME, Van Gerpen JH, Soylu S, Canakci M, Monyem A and Wormley S (2000). The speed of sound and isentropic bulk modulus of biodiesel at 21^{o}C from atmospheric pressure to 35 MPa. *Journal of American Oil Chemists Society* **77**(3) 286-289.

Tate RE, Watts KC, Allen CAW and Wilkie KI (2006). The viscosities of three biodiesel fuels at temperatures up to 300^{o}C. *Fuel* **85**(7-8) 1010-1015.