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Effect of blends of Palm-Jatropha-Pongamia biodiesels on cloud point and pour point

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ABSTRACT

To minimize use of biodiesels synthesized from edible oils like Palm due to raising food versus fuel issue, Palm biodiesel (PBD) was blended with biodiesels derived from tree borne non-edible oil seeds Jatropha, and Pongamia to examine the effect on cloud point (CP) and pour point (PP) of PBD. Dependence of CP and PP on esters of fatty acid composition was also examined. Good correlations between CP and palmitic acid methyl ester (PAME) and between PP and PAME were obtained. A correlation between CP and total unsaturated fatty acid methyl ester (X) was also obtained and correlation between PP and X was also determined. Using these four correlations, cloud and pour points of different biodiesel blends can be determined.

1. Introduction

Alternate fuels are being explored world over due to increasing environmental concern and diminishing petroleum reserves. Number of researchers have investigated on alternate renewable fuel sources and concluded that vegetable oil based fuels can be used as alternative fuels [1–8]. Soybean oil and rapeseed are common feedstocks used for biodiesel production in USA and Europe. The majority of Asian countries are net importers of edible oils; therefore these oils cannot be used for the production of biodiesel. South-East Asian countries like Malaysia and Thailand have surplus Palm crops. The production of biofuel from edible oils has raised serious concerns on preserving food security of the planet [9,10]. It is estimated that even if all the edible oils are used for biodiesel production, even then they will not be sufficient for meeting fuel demand [11]. In addition, it will lead to inflationary pressures in vegetable oil market, which was recently being witnessed.

Energy demand of Indian industry is also increasing due to growing economy and India is not self sufficient in edible oils. Researchers also analyzed the technical and economic prospects of sustainable bioenergy for India [12,13]. Therefore, there is need to find alternate feedstocks. In South Asian countries like India, biodiesel can be harvested and sourced from non-edible seed oils like Jatropha and Pongamia. *Jatropha curcas* and *Pongamia pinnata* are two such trees which can grow on any type of soil, needs minimum input and management, have low moisture demand, start giving seeds after third and fifth years of plantation respectively, have 25–30% oil content and productive life is more than 40 years [14]. In fact, implementation of biodiesel in India will lead to many advantages like providing green cover to wasteland, support to agricultural and rural economy, and reduction in dependency on imported crude oil and reduction in air pollution [15,16].

Although biodiesel is environmentally compatible but it has certain limitations at low temperatures. The low temperature flow properties of biodiesel are characterized by cloud point (CP) and pour point (PP) and these must be considered when operating compression-ignition engines in moderate temperature climate during winter months. “CP” is the temperature at which a sample of the fuel starts to appear cloudy, indicating that wax crystals have begun to form which can clog fuel lines and filters in a vehicle’s fuel system and “PP” is the temperature below which the fuel will not flow [17–19].

As CP is the trigger for negative effect on fuel injection, its prediction is extremely meaningful. Several researchers have studied the cloud and pour point of neat biodiesel and biodiesel–

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Table 1
Physico-chemical properties of PBD, JBD and PoBD.

Property (units)	ASTM D 6751–08 test method	ASTM D 6751–08 limits	IS 15607 test method	IS 15607 limits	PBD	JBD	PoBD
Flash point (°C)	D-93	Min.130	IS 1448 P:21	Min. 120	138	163	142
Viscosity at 40 °C (cSt)	D-445	1.9–6.0	IS 1448 P:25	2.5–6.0	4.50	4.30	4.23
Sulphated ash (% mass)	D-874	Max. 0.02	IS 1448 P:4	Max. 0.02	0.002	0.002	0.002
Sulphur(% mass)	D-5453	Max. 0.05	ASTM D 5453	Max. 0.005	0.003	0.004	0.0043
Copper corrosion	D-130	Max. 3	IS 1448 P:15	Max. 1	1	1	1
Cetane number	D-613	Min. 47	IS 1448 P:9	Min. 51	55.3	57.4	55.27
Water and sediment(vol. %)	D-2709	Max. 0.05	D-2709	Max. 0.05	0.01	0.05	0.03
Conradson carbon residue (CCR) 100%(%mass)	D-4530	Max. 0.05	D-4530	Max. 0.05	0.032	0.037	0.036
Neutralization value (mg, KOH/gm)	D-664	Max. 0.80	IS 1448 P:1/Sec.1	Max. 0.50	0.26	0.48	0.42
Free glycerin (%mass)	D-6584	Max. 0.02	D-6584	Max. 0.02	0.01	0.01	0.01
Total glycerin (%mass)	D-6584	Max. 0.24	D-6584	Max. 0.25	0.015	0.02	0.015
Phosphorus (%mass)	D-4951	Max. 0.001	D-4951	Max. 0.001	<0.001	<0.001	<0.001
Distillation temperature	D-1160	90% at 360 °C	Not under spec.	Min 90%	>90%	>90%	>90%
Oxidation stability at 110 °C (h)	EN 14112	Min. 3 h	EN 14112	Min. 6 h	9.24	3.95	2.54
Cloud point (°C)	D 2500	–	IS 1448 P:10	–	16	4	−1
Pour point (°C)	D 97	–	IS 1448 P:10	–	12	−3	−6

diesel blends [20–22]. High CP and PP values of biodiesel can be explained by high contents of the saturated fatty acid alkyl esters because the unsaturated fatty acid alkyl esters have lower melting points than the saturated fatty acid alkyl esters [23]. Imahara et al. found that the CP of biodiesel could be determined only by amount of saturated fatty acid methyl esters regardless of composition of unsaturated esters [24]. Soriano et al. have reported the effect of ozonized vegetable oil as PP depressant for sunflower oil, soybean oil and rapeseed oil [25]. Saiban et al. developed a semi-empirical model for predicting the cloud points [26]. Chiu et al. have studied the impact of cold flow improvers on soybean biodiesel blend [27]. Mathematical relationships between higher heating value and viscosity, density, or flash point of various biodiesel fuels have been developed [28].

From the above mentioned literature reports, it can be concluded that there is raising concern regarding use of biodiesel derived from edible oils like Palm and it will not be possible to use biodiesel as fuel having high CP and PP and none of the reports determined blending effects of biodiesels synthesized from non-edible oils on CP and PP of biodiesel synthesized from edible oil.

Properties of various individual fatty esters that comprise biodiesel determine the overall fuel properties of biodiesel fuel and in turn, the properties of various fatty esters are determined by the structural features of the fatty acid that comprise a fatty ester [23]. Blending of biodiesel with different fatty acid methyl esters compositions is therefore expected to improve the low temperature flow properties. When Palm and Jatropha biodiesels or Palm and Pongamia biodiesels are blended, the blended biodiesel will have lower cloud point and pour point than PBD.

Therefore, the first objective of this study is to examine and improve the low temperature flow properties like CP and PP of PBD by blending it with Jatropha and Pongamia biodiesels so that to minimize the use of edible oil Palm. The second objective is to study the effect of the fatty acid methyl esters compositions in the blended biodiesels on CP and PP and to determine correlation between them.

2. Experimental

2.1. Biodiesel samples

PBD, Jatropha biodiesel (JBD) and Pongamia biodiesel (PoBD) samples were kindly supplied by Indian Oil Corporation Ltd., R&D centre, Faridabad in India. Biodiesel samples were tested for physico-chemical properties as per American standard test method ASTM D-6751 and Indian standard IS-15607 specification (Table 1). PBD, JBD and PoBD were blended with different weight ratios (%) as follows:

100:00:00, 80:20:00, 80:00:20, 60:40:00, 60:20:20, 60:00:40, 40:60:00, 40:40:20, 40:20:40, 40:00:60, 20:80:00, 20:60:20, 20:40:40, 20:20:60, 20:00:80, 00:100:00, 00:80:20, 00:60:40, 00:40:60, 00:20:80, 00:00:100 respectively. The above mentioned twenty one biodiesel samples were used for experiment.

2.2. Biodiesel testing

Fatty acid methyl ester (FAME) compositions of PBD, JBD and PoBD samples and their twenty one blends were determined by gas chromatography on a gas chromatograph (GC), using nitrogen as a carrier gas and di(ethylene glycol) succinate column (DEGS). Detailed fatty acid methyl esters composition is given in Table 2.

CP and PP were measured according to ASTM D-6751 test methods ASTM D2500, D97 respectively and IS: 1448 P: 10 using the cloud and pour point apparatus (Widsons, Delhi, India). The sample was cooled in a glass tube under prescribed conditions and inspected at intervals of 1 °C until a cloud or haze appeared. This temperature was recorded as CP. In determination of PP, sample was cooled in a glass tube under prescribed conditions and inspected at intervals of 3 °C until it no longer moved when the place of surface was held vertical for 65 seconds; the PP was then taken as 3 °C above the temperature of cessation of flow. Data for all analytical measurements are means of triplicate. Subsequent analysis showed no stastically significant difference among the measurements.

Table 2
Fatty acid methyl ester composition of biodiesel samples.

Fatty acid methyl ester	Palm BD (wt%)	Jatropha BD (wt%)	Pongamia BD (wt%)
Caprylic (C8/0)	–	–	–
Capric (C10/0)	–	–	–
Lauric (C12/0)	–	–	–
Myristic (C14/0)	–	–	–
Palmitic (C16/0)	40.3	14.2	9.8
Palmitoleic (C16/1)	–	1.4	–
Stearic (C18/0)	4.1	6.9	6.2
Oleic (C18/1)	43.4	43.1	72.2
Linoleic (C18/2)	12.2	34.4	11.8
Linolenic (C18/3)	–	–	–
Arachidic (C20/0)	–	–	–
Behenic (C22/0)	–	–	–
Saturated	44.4	21.1	16.0
Unsaturated	55.6	78.9	84.0