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Experimental Investigation of Mustard Biodiesel Blend Properties, Performance, Exhaust Emission and Noise in an Unmodified Diesel Engine

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Abstract

Mustard biodiesel was produced from waste mustard oil and physicochemical properties were investigated. MB showed superior calorific value (40.404 MJ/kg), oxidation stability (15.92 h), cloud point (5°C) and pour point (-18°C) than any other conventional biodiesels. During engine performance test MB10 and MB20 showed 8-13% higher BSFC and 5-6% lower BTE compared to B0. By contrast, MB blends produced 7-8% less BP and 6-8% less engine torque compared to B0. Engine emission and noise test showed 9-12% higher NO, 24-42% lower HC, 19-40% lower CO and 2-7% lower noise emission for MB blends compared to B0. Besides, comparable engine performance and emission characteristics were found for MB10 and MB20 compared to PB10 and PB20 respectively.

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Keywords: Mustard biodiesel; Characterization; Engine performance; Emission analysis; Noise

1. Introduction

Industrial economy of a country is very much dependent on non-renewable fossil resources like coal, petroleum and natural gas with applications in electric generators, power plants, heavy trucks, locomotives and mining equipment. This ever increasing drift of energy consumption is not sustainable due to unequal geographical distribution of fossil fuels as well as environmental, geopolitical and economic concern [1].

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Besides, use of fossil fuel triggers a huge amount of greenhouse gas and noise hence polluting the environment. This twin crisis of fossil fuel depletion and environmental degradation have motivated researchers to explore and evaluate the performance of alternative fuels such as biodiesel, bio hydrogen, bioethanol etc. in internal combustion engine [2].

Mustard plant belongs to the *Brassicaceae* plant family and this plant family is a very rich source of many important biodiesel feedstock such as Brassica alba L., Brassica napus L., Camelina sativa L., Brassica carinata L. etc. Among them rapeseed has gained widespread acceptance as a common biodiesel feedstock. Production cost of mustard oil is lower than rapeseed or canola though it is relatively a new feedstock for biodiesel production [3]. Mustard plant can be grown in drier areas and needs lesser pesticides and other agricultural inputs than rapeseed. Excessive amount of erucic acid (more than 50%) generally makes it non edible and mostly used as condiment and pickles. In some literatures, it was found that low quality mustard seed oil which is unsuitable for food use is adopted for biodiesel production [4]. After oil extraction mustard seed cannot be fed to livestock due to its hot mustard flavor. Hence, mustard oil is suitable for biodiesel production and unlike canola using mustard as biodiesel feedstock would not interfere with the food chain.

The aims of this experimental endeavor were to produce, characterize and analyze engine performance and emission of mustard biodiesel (MB) pressed from low quality inedible mustard seed. Engine performance, emission and noise test were carried out for 10% and 20% MB blends and compared with palm biodiesel (PB) blends and diesel fuel (D100).

2. Property test

The test fuels chosen to analyze engine performance were (i) 10% MB with 90% B0 (MB10), (ii) 20% MB with 80% B0 (MB20) (iii) 10% PB with 90% B0 (PB10), (iv) 20% PB with 80% B0 (PB20) and (v) 100% neat diesel fuel (D100). These blended percentages are volume based proportions. Blending was performed by a blending machine at 4000 rpm for 10-15 min.

Table 1 shows the summary of the equipment and methods used to determine fuel properties and Table 2 shows measured fuel properties of all tested fuels.

Table 1. List of equipment used for testing fuel properties

Property	Equipment	Model	Manufacturer	Standard method	Accuracy
Kinematic viscosity and density	Stabinger Viscometer	SVM 3000	Anton Paar	ASTM D7042	± 0.1 mm^2/s
Flash point	Pensky–martens flash point tester	NPM 440	Normalab, France	ASTM D93	± 0.1°C
Cloud and pour point	Cloud and pour point tester	NTE 450	Normalab, France	ASTM D2500	± 0.1°C
Oxidation stability	Rancimat testing machine	873Rancimat	Metrohm, Switzerland	EN 14112	± 0.01 h
Calorific value	Semi auto bomb calorimeter	6100EF	Perr, USA	ASTM D240	± 0.001 MJ/kg

Table 2. Measured fuel properties of all tested fuels

Properties	D100	MB100	PB100	MB20	PB20	MB10	PB10	ASTM D 6751-02
Density (kg/m^3)	821	864.8	859.2	830.7	828.6	826.3	824.5	-

Viscosity at 40°C (mm^2/s)	3.69	5.76	4.62	4.13	3.98	3.92	3.71	1.9-6.0
Flash point (°C)	72.5	149.5	172.5	80.5	90.5	77.5	82.5	>130
Cloud point (°C)	-8	16	16	8	7	5	5	-3~12
Pour point (°C)	-6	-18	15	-3	-1	-3	-3	-15~10
Oxidation stability (h)	-	15.92	2.72	50.21	12.41	70.28	14.33	3
Calorific value (MJ/kg)	45.27	40.40	39.91	44.38	40.12	44.88	40.36	-

Table 3. Test engine specification

Engine type	4 cylinder inline
Manufacturer	Mitsubishi Pajero engine
Displacement	2.5 L (2,476 cc)
Bore	91.1 mm
Stroke	95.0 mm
Torque	132 N.m , at 2000 rpm
Maximum engine speed	4500 rpm
Compression ratio	21:1
Cooling system	Water cooled

3. Experimental Set up

An inline 4-cylinder, Mitsubishi, Pajero engine was used to evaluate performance and emission of all tested fuels. Engine specification is presented in Table 3. Data were collected through DYNOMAX 2000 data control system. To determine the exhaust emission BOSCH (model ETT 0.08.36) exhaust gas analyser was used. NO and HC were measured in ppm and CO was measured in % vol. by using BOSCH exhaust gas analyser. Exhaust gas analyser specification is presented in Table 4. NI sound level measurement system was adopted to measure the sound level. A series of PCB 130 array microphones (model 130D20) were used in this regard. Microphones were positioned 1m away from the engine faces according to SAE recommendations for microphone position. Similar experiments were also performed by Zhang and Bing [5] by following similar standard.

Table 4. Details of BOSCH exhaust gas analyser

Equipment name	**Model**	**Measuring element**	**Measuring method**	**Upper limit**	**Accuracy**
BOSCH gas analyser	BEA-350	CO	Non-dispersive infrared	10.00 vol.%	±0.02 vol. %
		CO_2	Non-dispersive infrared	18.00 vol.%	±0.03 vol. %
		HC	Flame ionization detector	9999 ppm	±1 ppm
		NO	Heated vacuum typechemiluminescence detector	5000 ppm	±1 ppm

4. Results and discussion

Fig. 1 and Fig. 2 show the variation of BSFC and power for all tested fuels with respect to engine speed. Average BSFC for MB10 and MB20 were found 8.5% and 13.4% higher than D100. Due to higher density and lower calorific value of biodiesel, increase in BSFC than D100 is obvious. On average, the BSFC of MB10 and MB20 were found 1% and 3.5% higher than PB10 and PB20 respectively. On contrast, maximum engine power output of MB10 and MB20 were 10.8% and 6.7% less than D100 respectively. Maximum and average power output of MB blends was found almost same as PB blends.

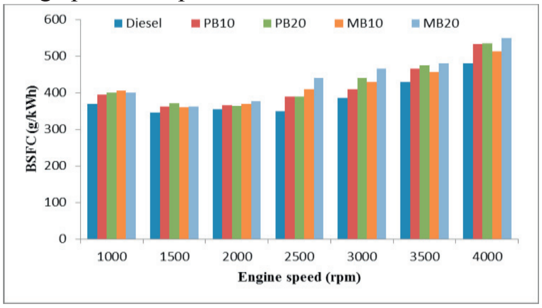

Fig. 1. Variation of BSFC with engine speed

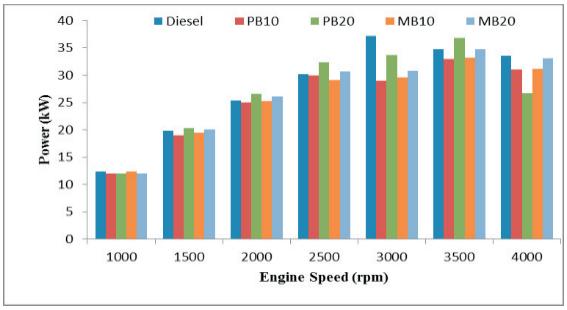

Fig. 2. Variation of engine power with engine speed

Fig. 3 and Fig. 4 show the variation of HC and CO for all tested fuels with respect to engine speed. Average HC emission of MB10 and MB20 were 24% and 42% lower than B0 respectively. Higher oxygen content of biodiesel ensures more complete combustion which helps to reduce HC emission. However, HC emission for MB10 and MB20 were found 9% and 1.5% higher than PB10 and PB20 respectively.

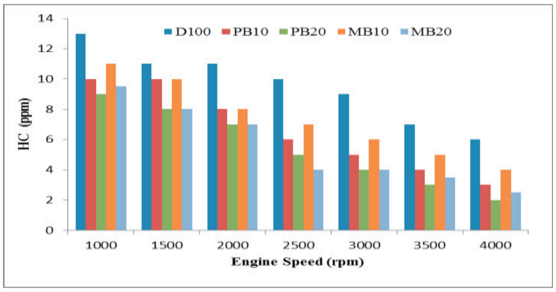

Fig. 3. Variation of HC with engine speed

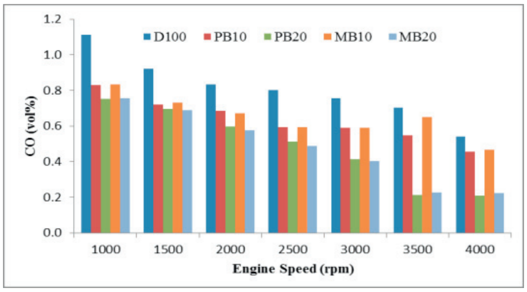

Fig. 4. Variation of CO with engine speed

Fig. 5 and Fig. 6 show the variation of NO and sound level for all tested fuels with respect to engine speed. On an average, it was observed that MB10 and MB20 produced 9% and 12% higher NO than diesel fuel respectively. Higher cetane number and shorter ignition delay of MB increased NO emission. However, average NO emission of MB10 and MB20 were varied slightly (within 3%) compared to PB10 and PB20.

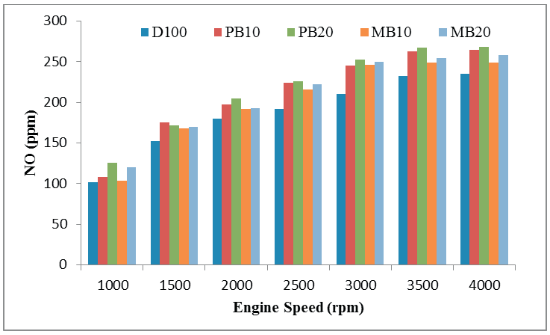

Fig. 5. Variation of NO with engine speed

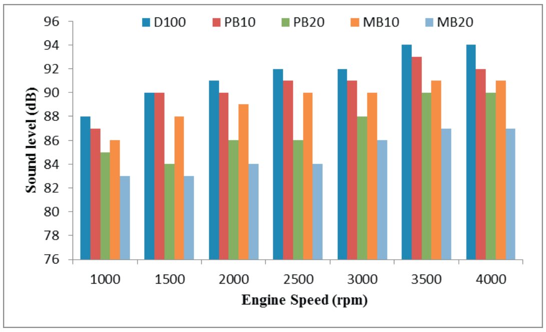

Fig. 6. Variation of sound level with engine speed

5. Conclusion

Mustard oil is a promising and relatively new feedstock for biodiesel production.Mustard biodiesel showed promising fuel properties compared to other conventional biodiesels. Engine performance , emission and noise characteristics were also found promising. As a conclusion, MB10 and MB 20 can be used in diesel engines without modifications. Further research can be carried out to analyze particulate matter, smoke and other emission of MB blends.

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