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Methyl Esters of Mahua Oil as an Ecofriendly Fuel in Heavy Duty Vehicles

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In this investigation, Mahua oil methyl ester (MOME) was prepared by transesterfication using potassium hydroxide. According to the ASTM procedure, several tests were conducted to characterize mahua oil in relation to diesel oil. Various physical, chemical and thermal properties such as viscosity, flash point, fire point and calorific value were evaluated. From the analysis, it was observed that the properties of mahua oil methyl ester are close to diesel oil. To evaluate the mahua oil methyl ester as a fuel for diesel engine and dual engine, it was used as a fuel in a single cylinder, four stroke, direct injection, constant speed, compression ignition diesel engine and dual fuel engine. From the experimental results, it was observed that the mahua oil methyl ester result in performance and emissions close to diesel operation.

Key Words: Methyl esters, Mahua oil, Fuel.

INTRODUCTION

In the transportation sector, a large number of investigations have been carried out internationally in the area of vegetable oils as fuel. Jamieson[1] listed over 350 oil-bearing crops while Duke *et al.*[2] identified 70 species of oil seeds with considerable potential. Sunflower, safflower, soybean, cottonseed, winter rape and peanut oil have been reported as substitutes for petroleum based fuels. The interest in using vegetable oils as alternative fuels originated within the agricultural community as a fuel for agricultural tractors and equipment[3].

Mahua name for a medium to larger tree, *Madhuca longifolia* of family Sapotaceae with wider and round canopy. The tree may attain a height of up to 20 m. Mahua is a slow growing species, attains a mean height of 0.9 to 1.2 m at the end of the fourth year. The variety latifolia is common throughout the Indian sub-continent, including Bangladesh. It is a tree of deciduous nature, of the dry tropical and sub-tropical climate. As a planta-

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tion tree, Mahua is an important plant having vital socio-economic value. This species can be planted on roadside, canal banks, *etc.* on commercial scale and in social forestry programmes, particularly in tribal areas. The drying and decortification yield 70 % kernel on the weight of seed. The kernel of seed contains about 50 % oil. The oil yields in an expeller is nearly 34-37 %. The fresh oil from properly stored seed is yellow in colour[4].

Coupland *et al.*[5] determined the physical properties of liquid edible oils. Shashikant *et al.*[6] developed a technique to produce biodiesel from mahua oil having high free fatty acids. The high FFA level of mahua oil was reduced to less than 1 % by a two-step pretreatment process. Each step was carried out with 0.30-0.35 v/v methanol-to-oil ratio in the presence of 1 % v/v H_2SO_4 as an acid catalyst in 1 h reaction at 60 °C. After the reaction, the mixture was allowed to settle for 1 h and methanol-water mixture that separated at the top was removed. The second step product at the bottom was transesterified using 0.25 v/v methanol and 0.7 % w/v KOH as alkaline catalyst to produce biodiesel. Shashikant *et al.*[7] studied the effect of methanol quantity, acid concentration and reaction time on the reduction of free fatty acids content of mahua oil during its pretreatment for making biodiesel. Chandraju *et al.*[8] used ethyl ester of honge oil and palm oil blends with diesel as an ecofriendly fuel in heavy duty vehicles. They reported that the engine works smoothly with the blend. Bhat *et al.*[9,10] tested four blends of mahua oil with diesel and pure oil in the diesel engine at compression ratio of 20:1, 18:1 and 16:1. The fuel blends were prepared in the proportion of 20, 40, 60 and 80 % volume by volume with diesel, respectively. They did not make any modification in the fuel supply system. They reported that the blends of mahua oil and diesel results in lower thermal efficiency as compared to diesel oil operation.

In the present work, Mahua oil methyl ester (MOME) was prepared by transesterfication method. The properties of MOME and its blends with diesel were compared with those of diesel oil. To study the suitability of blends of MOME and diesel as fuel for diesel engine, the blends of MOME and diesel were used as fuel in four stroke direct injection diesel engine.

EXPERIMENTAL

Unrefined crude mahua oil was obtained from the kernel of mahua tree and it was refined and filtered for the present work. Generally, vegetable oil contains fatty acids like *viz.*, palmitic, stearic, oleic, linoleic, lignoceric, eicosenoic, arachidic and behenic. Of these, the mahua oil contains the saturated acids, palmitic (hexadecanoic acid) and stearic (octadecanoic acid) and the unsaturated acids, oleic (octadec-9-enoic acid) and linoleic (9,12-octadecadienoic acid). The fatty acid composition of the mahua oil is given in Table-1.

TABLE-1
FATTY ACID PROFILE OF MAHUA OIL

Fatty acid	Formula	Structure	Weight (%)
Oleic	$C_{18}H_{34}O_2$	18:1	37.0
Stearic	$C_{18}H_{36}O_2$	18:0	22.7
Palmitic	$C_{16}H_{32}O_2$	16:0	24.5
Linoleic	$C_{18}H_{32}O_2$	18:2	14.3
Arachidic	$C_{20}H_{40}O_2$	20:0	1.5

The mahua oil is in dark yellow colour and has a repulsive odour. It is used for medicinal applications. It is popular due to its low cost and ready availability. Table-2 shows the characteristics of crude mahua oil.

TABLE-2
CHARACTERISTIC OF MAHUA OIL

Property	Value
Refractive index	1.456
Saponification value	190
Iodine value	59
Unsaponifiable matter (%)	1.3
Colour	Dark yellow
Water content (%)	2

This oil was converted into biodiesel by the following procedure. 4 g of anhydrous sodium hydroxide pallets were dissolved in 170 mL of methanol and 420 mL of mahua oil was added. The mixture was refluxed in a water bath at 65 °C for 1 h using a water-cooled condenser and for another 0.5 h without condensing, to remove excess methanol. The mixture was kept in a 250 mL separator funnel for *ca.* 2 h to allow phase separation. The top layer containing esters were washed 3-4 times with warm water to wash out impurities like soap and other residues. Finally the methyl esters were dried using 10 g of anhydrous sodium sulphates.

Evaluation of properties of mahua oil and blends: Flash point, fire point, density, calorific value, viscosity and specific gravity of the MOME, blends of MOME and diesel and diesel were evaluated. Flash and fire points of the oils were determined using Cleveland's cup and cone tester. Viscosities of the oils were determined using Saybolt viscometer. Calorific value was determined using a Bomb calorimeter.

RESULTS AND DISCUSSION

The important fuel properties of MOME and its blends with diesel are shown in Table-3. From the table, it is observed that the flash point, fire point, density and kinematic viscosity of MOME lower than mahua oil. As the percentage of MOME in the blend of MOME and diesel oil increases, all fuel property values increases except that of the calorific value.

TABLE-3
PROPERTIES OF MOME AND ITS BLENDS WITH DIESEL

Property	Mahua Oil	MOME	Diesel	B10	B20	B30	B40	B50
Flash point (ºC)	212	129	56	100	103	105	108	111
Fire point (ºC)	223	141	63	109	111	114	120	123
Calorific value (kJ/kg)	35614	36914	42960	42349	41750	41156	40668	39963
Kinematic viscosity at 40 ºC (cst)	37.63	5.10	2.68	3.11	3.24	3.40	3.52	3.65
Density at 40 ºC (kg/m^3)	891	863	828	830	833	837	839	842

Engine testing for performance and emission

Sole fuel mode: Engine tests were carried out on a diesel engine using MOME and its blends with diesel as fuel. Brake thermal efficiency is defined as the ratio of brake power to the heat supplied. Fig. 1 shows the variation of brake thermal efficiency with load. From this figure, it is observed that B20 blend (20 % MOME and 80 % diesel) gives higher efficiency than other blends and diesel oil. B50 blend results in lower thermal efficiency. This may be due to higher viscosity of the blend, which results in poor atomization and incomplete combustion of the fuel.

The variation of smoke opacity with load is shown in Fig. 2. The smoke is formed due to incomplete combustion of the fuel. From the figure, it is observed that the B20 blend results in lower smoke opacity compared to other blends and diesel oil. This may be due to better combustion of the fuel.

Dual fuel mode: The diesel engine was modified to work in dual fuel mode and LPG was used as primary fuel and liquid fuel was used as pilot fuel. From the Fig. 3, it is observed that the thermal efficiency of the dual fuel engine was higher with MOME as compared to diesel at higher load. Similarly, the smoke emission was found lower with MOME. This may be due to oxygen content of MOME which results in larger heat source for the combustion of the fuel.

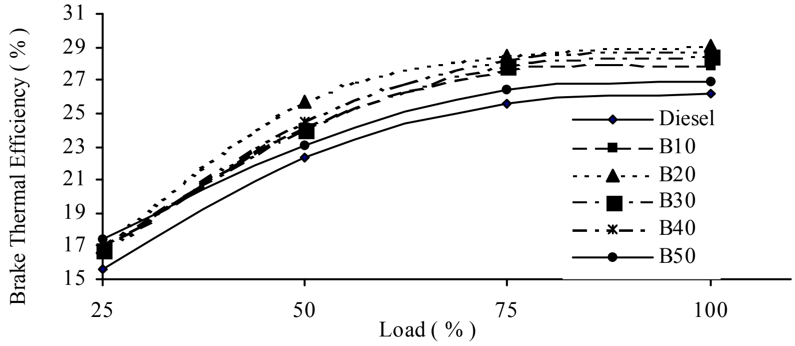

Fig. 1. Variation of brake thermal efficiency with load

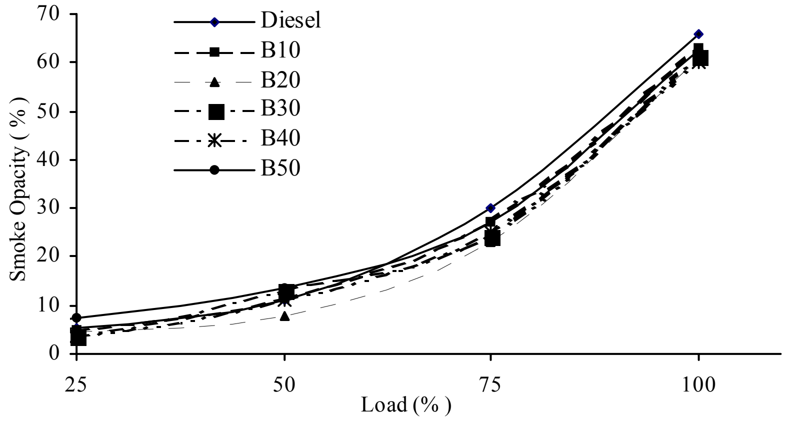

Fig. 2. Variation of smoke opacity with load

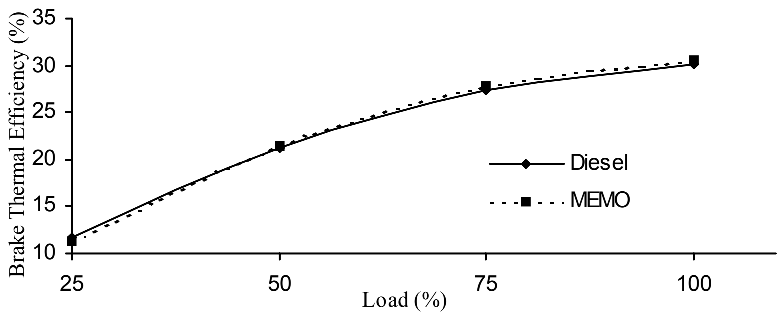

Fig. 3. Variation of brake thermal efficiency with laod

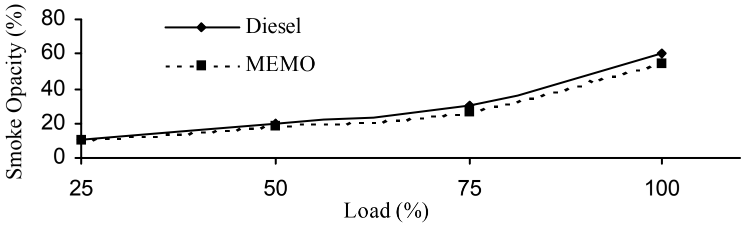

Fig. 4. Variation of smoke opacity with load

From the experiments, it was observed that the diesel engine and dual fuel engine works smoothly with the MEMO.

Conclusions

The following conclusions are made based on the results and discussions. • Fuel properties of MOME are better than raw mahua oil and close to diesel. • In sole fuel mode, B20 blend (20 % MOME and 80 % diesel) gives higher brake thermal efficiency than other blends. • In dual fuel mode, MEMO results in higher thermal efficiency and lower smoke emission than diesel.

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