Production, Performance and Emission Study of Mahua (Madhuca Indica) Methyl Ester in Multicylinder 4-Stroke Petrol Engine

Sangram D. Jadhav [a], Madhukar S. Tandale [b]
[a, b] *Mechanical Engineering Department, Dr. Babasaheb Ambedkar Technological University , Lonere, Maharashtra, 402103, India*

Abstract

In this Investigation, Mahua oil Methyl Ester was prepared by transesterification using base (KOH) and acid (H_2SO_4) catalyst and tested in 4 stroke NA petrol engine. Tests were carried out at constant speed of 2500 RPM at different loads; 20, 40, 60, 80, 100% and blends: 2, 4, 6, 8, 10, 12% with petrol. Result showed that brake thermal efficiency of Mahua oil Methyl Ester (MOME) was comparable with petrol and it was observed that 34.92% for petrol whereas for MOME blends maximum up to 33.14% for M2 blend and minimum 24.72% for M12 blend. Emission of carbon monoxide, hydrocarbon and exhaust gas temperature were reduced around 52.73% by volume, minimum 17 ppm to maximum 48 ppm and 0-12% respectively, in case of blends of MOME to petrol. Based on this study, blends of MOME M2 to M10 can be found the suitability to be used as a substitute for petrol in petrol engine.

Keywords: *Transesterification; Biodiesel; Mahua oil Methyl Ester; Engine Performance and Emission*

1. Introduction

Today energy security has emerged as an important policy issue all over the world because of depletion of fossil fuel (like coal, crude oil and natural gas) of such a limited source. Global energy market almost 80 percent uses the fossil fuel as primary fuel. Being non-renewable, they have certain limits of availability due to which they depict global destabilizing price shocks, more so in recent years. The extensive worldwide use of fossil fuels has resultant is serious environmental concerns, particularly the climate change This is one of the key challenge facing the developing world is how to meet its growing energy needs and sustain economic growth without contributing to climate change. An emphasis on energy security has led to the quest for alternative sources of energy could reduce dependence on petroleum. Among the several alternative biodiesel have emerged as a most potential for enhancing the self- sufficiency in energy and minimize the dependency of fossil fuels [1-7]. Biodiesel is future fuel which is renewable source and eco-friendly in nature. The feedstock for biodiesel production are widely available globally in the world, among of them Edible and nonedible [1-2]. To avoiding the food and fuel conflicts nonedible seeds are widely used for biodiesel production [2-6]. The Mahua feedstock has the great potential because of its yield and availability [6]. The fruit of Mahua is ovoid, fleshy, greenish, 3 to 5 cm long, 1 to 4 seeded and ripens from Jun to august. The Mahua tree thrives under the normal annual rainfall in its natural distributional range which varies from 750 to 1875 millimeters. Mean relative humidity varying from 40 to 90%. The yield may vary from 5kg to about 200kg per tree depending upon the size and age of the tree [6]. The yield with age of tree and its chemical composition are given in **Table 1 and 2**.

Table no. 1 Yield of Mahua as per Age

Sr. No	**Age** (yrs.)	**Yield** yrs in kg per tree
1	10	10
2	20	30
3	30	60
4	40	60
5	50	135
6	60	140

Table no. 2 Chemical composition of Mahua

Sr. No.	**Constitutes**	**Percentage**
1	Moisture	18.0
2	Protein	6.4
3	Fat	0.4
4	Total Sugar	70.0
5	Fibre	1.7
6	Ash	2.7
7	Minrals, Vitamins	0.8

The Crude oil of Mahua seed is produced by using mechanical crusher and finds its suitability in engine without its modification. The specifications of straight crude Mahua oil are given in **Table 3 and 4.** The lot of researcher had reported the various problems viz; atomization, poor combustion, gumming, injector fouling piston and piston ring sticking and lubrication contamination [13]. The reported problems are due to crude oil properties such as: high viscosity, density, iodine value and poor non volatility. The main dominating factor is the viscosity and there is number of solution are, thermal cracking, transesterification, preheating the oil and blend it with fuel [5]. The wide literature shows that the transesterification is one of best and optimum way to use vegetable oil as a fuel in existing diesel engine. The alkalosis (the base catalyst and acid catalyst) established on the basis of acid number [14]. The literature shows the base catalyst (KOH) and acid catalyst (H_2SO_4) are the best choice for esterification and transesterification respectively [9, 16].

Table 3 Fatty acid composition of the MVO

Fatty acid	Formula	wt%
Palmitic	C16H32O2	17.8
Stearic	C18H36O2	14.0
Oleic	C18H34O2	46.3
Linoleic	C18H32O2	17.9
Arachidic	C20H40O2	1.5

Table 4 Characteristics of MVO

Property	Value
Refractive Index	1.45-1.462
Saponification Value	187-197
Iodine value	55-70
colour	Dark Yellow

2. Experimental

2.1 Mahua oil methyl ester preparations.

The mixture of Mahua oil (1000ml), Methanol (12:1 molar ratio with Mahua oil) and acid catalyst (H_2SO_4 1.0 % w/w) was heated in reactor (as shown in **Fig.1**) near the boiling point of methanol (65°C) for 3 hr and complete the esterification [14]. Then check the acid value and pH value to take it for transesterification. The mixture of esterified oil mix with Methanol (12:1 molar ratio with Mahua oil), base catalyst (KOH 0.5 % w/w) and maintain the temperature near the 65°c for 3 hr. Then the oil settling for 6hr to get the two layers, top one is crude biodiesel and other at bottom is glycerol.

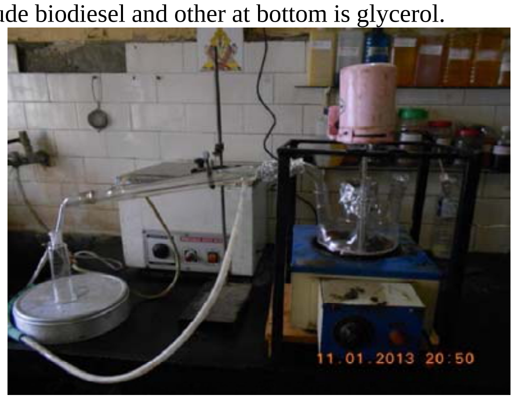

Fig.1. Esterification and Transesterification Setup

The biodiesel separated by gently washed with hot water and heated it at 100°c to get the demoisturization of pure biodiesel [3, 8, 17].

2.2 Engine test procedure

The engine used for this study consists of three cylinders, four strokes, Petrol (MPFI) Maruti-800 engine (Specification is as shown in **Table 5**) connected to eddy current type dynamometer for loading. Provision is made for interfacing air flow, fuel flow, temperatures and load measurement [13,16]. The set up has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rota meters are provided for cooling water and calorimeter water flow measurement (As shown in **Fig. 2** & **3**). It is provided with necessary instruments for combustion pressure and crank-angle measurements. The setup enables study of engine performance for brake power, specific fuel consumption, brake thermal efficiency, A/F ratio and heat balance.

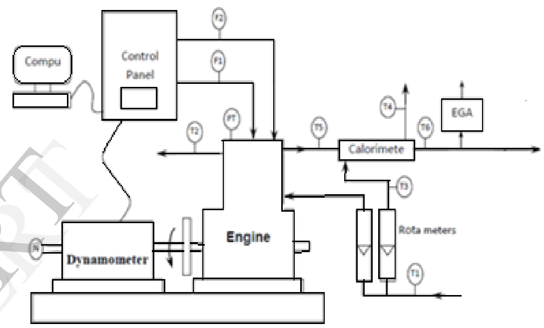

Fig. 2. - Block diagram of Experimental setup

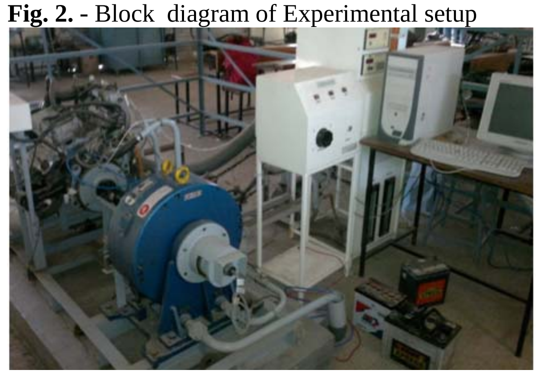

Fig. 3. - Experimental set up of SI engine

The emission such Carbon monoxide (CO) and hydrocarbons (HC) are measured by 4-Gas Emission Analyzer (Airrex HG-540), while exhaust gas temperature measured by iron constant thermocouple. The Engine test is to be done according to Bureau of Indian Standards (BIS) (Section-Methods of tests for Internal Combustion Engines IS: 10000 (Part VIII) Performance Tests). Parameters like speed of operation, fuel consumption and torque are to be measured from which brake power, brake specific fuel consumption, brake thermal efficiency etc are to be computed. The engine was start with petrol fuel and warmed up. The warm up period likely to be define on stability of cooling water temperature. Then to measure the fuel consumption, exhaust gas temperature and different emission. A similar procedure was repeated for MOME blends with petrol fuel [16-22].

3. Results and Discussions

The fuel properties of SVMO, MOME, Blends of MOME and standard petrol are given in **Table 6.** It was observed that properties of MOME and its blends were similar to standard petrol.

Table 6 Properties of straight vegetable Mahua oil and its blend with petrol

Fuel Sample	Density (gm/cc)	Visc. Cst	Cal. value (kcal/kg)	Fire point (°C)
Petrol	0.753	0.4	10500	118
SVMO	0.945	28	8600	250
MOME 0%	0.878	5.24	8900	155
MOME 2%	0.756	0.44	10470	118
MOME 4%	0.757	0.453	10430	119
MOME 6%	0.765	0.468	10400	120
MOME 8%	0.770	0.470	10370	121
MOME 10%	0.785	0.475	10340	123
MOME 12%	0.790	0.485	10300	125

The specification of MOME matches that of biodiesel standard. The kinematic viscosity of straight vegetable Mahua oil (SVMO) is higher compared with standard petrol fuel. The calorific value is 20% lower than that of standard petrol, while almost equal in blends. Flash and fire points are higher in case of MOME than those of petrol so, beneficial in case of transportation [11-12].

3.1 Engine Performance

3.1.1 Brake specific fuel consumption

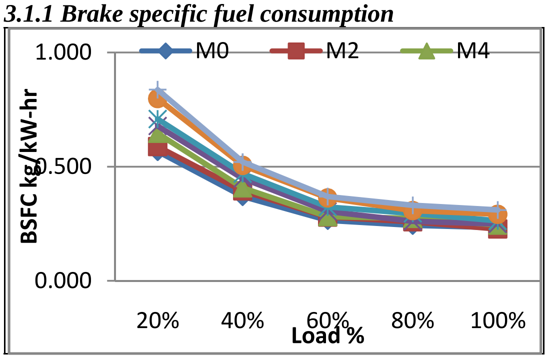

Fig. 4. BSFC vs Load

Fig. 4 shows the variation of Brake Specific Fuel Consumption (BSFC) with respect Load. It was observe that a large amount of MOME blends (0.014 to 0.138 kg/kW-hr) is supplied to the engine compared to that of standard petrol. Fuel pump (Inside the fuel tank) of the engine is design for petrol as a fuel and on volumetric basis. As the density of MOME is higher than petrol, the fuel discharges more blend of MOME compared to that of petrol. Therefore BSFC for MOME and its blends is higher than petrol.

3.1.2 Brake thermal efficiency

The variation of Brake thermal efficiency (bthe) with respect to Load is as shown in **Fig. 5**.

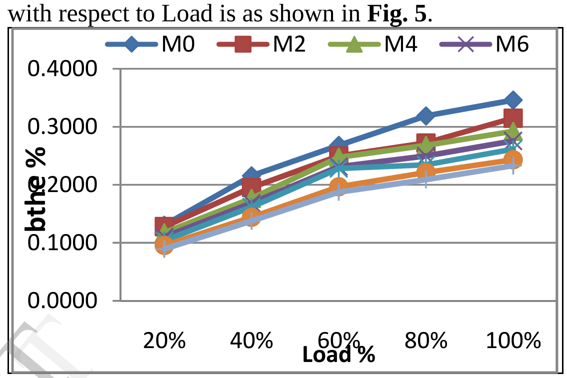

Fig. 5. Bthe (%) vs Load (%)

From the test it was observed that the brake thermal of 34.92% was achieved with petrol, whereas for MOME blends maximum up to 33.14% for M2 and minimum 24.72% for M12. This small variation of thermal efficiency with blends may be due to chemical composition with absence of physical contact and some extent of blend viscosity, which promotes the combustion processes.

3.2 Emissions

3.2.1 Carbon Monoxide (CO)

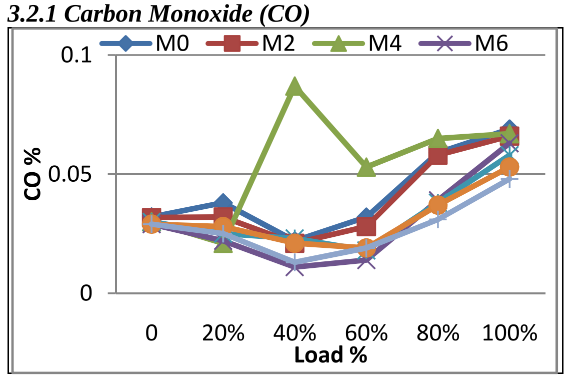

Fig. 6. Carbon monoxide (CO) vs Load (%)

Fig. 6 shows the Carbon monoxide (CO) emission with respect Load (%) for blends of MOME and standard petrol. Emission of Carbon monoxide is mainly depends on the chemical properties of fuel. The main difference in methyl based fuel and petrol is the oxygen content and the octane number. Since the methyl based fuel contains small amount of oxygen and that acts as a combustion promoter inside the cylinder. This result is better combustion for blends of MOME, than the standard petrol fuel. Hence Carbon monoxide, which is present in the exhaust gas due to incomplete combustion, is lower in comparison to standard petrol fuel. The reduction of Carbon monoxide (CO) in case of blends of MOME is around average of 52.73% compared to petrol.

3.2.2 Exhaust Gas Temperature

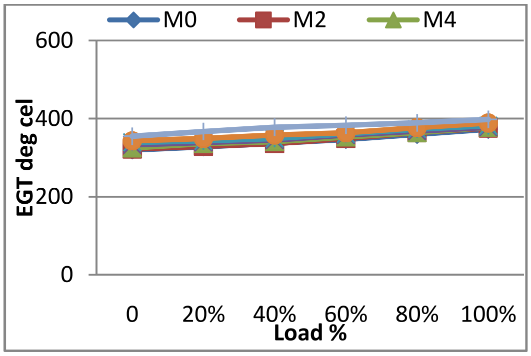

Fig. 7. Exhaust gas temperature (°C) vs Load (%)

Fig. 7 shows the variation of exhaust gas temperature with load in the range of part load (20%) to full load (100%) for petrol and blends of MOME. The result shows that the exhaust gas temperature increased with load in both cases. The highest value of exhaust gas temperature was observed 362.5°C (M2) to 393.4°C (M12) for blends of MOME, whereas for petrol it was found to be 363.8 °C only. The variation of exhaust gas temperature is due to present of oxygen content and better combustion in MOME blends.

3.2.3 Hydrocarbons (HC)

The hydrocarbon (HC) emission for blends of MOME and petrol are as shown in **Fig. 8**. The combustion is efficient when fuel is mix, atomize and ignite properly. The atomization and mixing of fuel depends on the physical and chemical properties of the fuel.

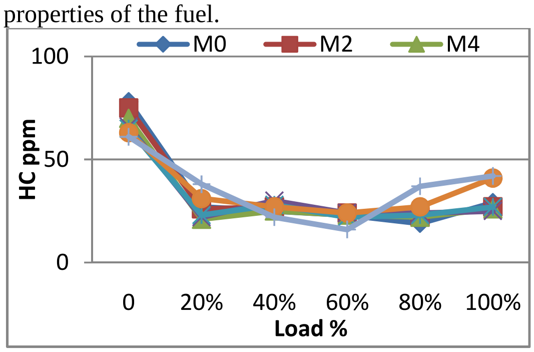

Fig. 8. Hydrocarbons (HC*)* vs Load (%)

The fuel viscosity and cohesiveness property affect the mixing and atomization of petrol and air. The octane number of the fuel plays a vital role in ignition processes. The octane number of methyl ester fuel is more than the petrol, it exhibits a shorter semipropagating nucleus of flame and result is better combustion. Therefore oxygen content and octane number leads to low carbon monoxide and hydrocarbon emission. The result is clear that blends of MOME emit lower hydrocarbons. The reduction of hydrocarbons in case of MOME blends to petrol is an average around 17 to 48 ppm.

4. Conclusion

To considering the need for alternate fuels, the experimental investigations are carried out in the present work in order to run the gasoline engine with Mahua oil methyl ester's blend with petrol. Mahua vegetable oil was converted into their respective methyl esters (bio-diesel) using transesterification. The Mahua oil methyl ester was obtained with methanol in presence of H_2SO_4 (Acid Catalyst) and KOH (Base Catalyst) nearer at boiling temperature of methanol (65°C) for esterification and transesterification respectively. Physical and chemical properties of Mahua oil methyl ester and its blend with petrol were determined. The produced fuel was tested in 4 stroke multi cylinder naturally aspirated MPFI petrol engine. The comparison of MOME blends with petrol in terms of engine performance and emission shows the better result and their suitability as an alternative fuel is examined. The important conclusions are investigated as and technically suggested MOME blend can be used as substitute petrol in petrol engine as follows:

1. Results of the measured fuel properties showed that the octane number and flash point of MOME prohibit its direct use as an alternative fuel in unmodified petrol engines, but it could be used in the blends (M2 to M10) with petrol fuel, while more with diesel.
2. The brake specific fuel consumption for MOME blends with petrol was slightly higher (Average 0.014 kg/kW-hr (M2) to 0.138) kg/kW-hr (M12) than pure petrol.
3. Brake thermal efficiency for MOME blends with petrol was slightly lower than pure petrol. A maximum brake thermal efficiency of 34.92 % was achieved for petrol, while for MOME blend; maximum brake thermal efficiency was 33.14 % for M2 blend and minimum 24.72% for M12. This is because of lower calorific value and higher viscosity coupled with density of the fuel.
4. CO emission for MOME blend with petrol fuel was reduced on an average of 52.73% by volume as compared to pure petrol. This is due to oxygen content and complete combustion of the fuel blends.

5. Un-burnt hydrocarbons (HC) for MOME blend with petrol fuel were reduced up to 48 ppm compared to pure petrol. This is because of the excess oxygen present in the blends and octane rating exhibits shorter semipropagating nucleus of flame.

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