

Performance Study of Diesel Engine by using Mahua Methyl Ester (biodiesel) and its Blends with Diesel Fuel

M.K.Ghosal, D.K.Das, S.C.Pradhan and N.Sahoo

College of Agricultural Engineering and Technology
Orissa University of Agriculture and Technology,
Bhubaneswar-751003, India

mkgghosal1@rediffmail.com / mkgghosal@yahoo.com

ABSTRACT

The results of the performance of a compression ignition engine (direct injected, 4-stroke 2-cylinder engine) by using mahua methyl ester from non-edible vegetable oil (*Madhuca indica*) and its blends with diesel fuel have been presented in this paper. Short-term engine performance tests were conducted using four different blends of mahua methyl ester oil with diesel fuel from 20% to 100% by volume at three fuel temperatures (30, 50 and 70⁰-C) and at two injection pressures (17640 kPa and 24010 kPa). The engine performance parameters studied were power output, brake specific fuel consumption (BSFC), brake thermal efficiency (BThE) and exhaust gas temperature (ExGT) by using diesel fuel alone and the above mentioned blend fuels. The performance of engine with blend fuel (20% mahua methyl ester and 80% diesel) was found to be better than the other blend fuels. But the values of power output, BSFC, BThE and ExGT in case of blend fuel B20 (20% mahua methyl ester and 80% diesel) were observed to be respectively 3% more, 9% more, 12% more and 0.5% less than the diesel fuel at 70⁰-C temperature and 24010 kPa pressure. The mahua methyl ester (blends of B20) can be used as an alternative diesel fuel replacement with little sacrifice in brake specific fuel consumption.

Keywords: Vegetable oil fuel, alternative fuel, *madhuca indica*, mahua methyl ester (biodiesel), diesel blend, India

1. INTRODUCTION

Among the alternate fuels for the petroleum fuel, vegetable oil esters (biodiesel) have gained good promise and suitability for their use in compression ignition engine (Srivastava and Prasad, 2000, Verma and Gupta, 2000, Mcdonell et al., 2000, Lang E et al. 2001., Bhatt and Mathur, 2002, Pathak, 2004). Biodiesel is a non-toxic and renewable in nature. Further advantages over petro-diesel include higher cetane number, no sulphur emission, low aromatics, low volatility and the presence of oxygen atoms in the fuel molecule. According to the report entitled "comprehensive analysis of biodiesel impacts on exhaust emissions" published by Environmental Protection Agency, US (2002), biodiesel fuel burns up to 70% cleaner with 93% lower total HC, 50% lower CO and 45% lower particulate matter in comparison with conventional diesel fuel (Chhina et al., 2005).

The vegetable oil esters from edible oils may not be the right option for their substitution in diesel engine due to the lack of self-sufficiency of edible oil production in India. Hence attention

has been diverted to test the suitability of non-edible vegetable oils for diesel engine (Bhatt, 1987). With the abundance of forest and tree-borne non-edible oils available in India, not much attempt has been made to use the esters of these non-edible oils as the alternative fuels for diesel engine. Mahua (*Madhuca indica*) is one of the forest based tree-borne non-edible oils with large production potential of about 60 million tones per annum in India (Das S.S., 2005). The mahua tree belongs to the genus *Mahuca*. The tree, its seed and flowers have been very useful in Indian economy for a long time. The flowering season extends from February to April. It is rich in sugar (73 %) and next to cane molasses; it constitutes the most important raw material for alcohol fermentation. The yield of alcohol is 405 litres from one tonne of dried flower. The kernel of the mahua fruit contains about 50% oil. The oil yields from village ghanis and in oil expellers are 20-30% and 34-37% respectively. The expelled cake is relevant to recover the residual oil. Fresh oil is yellow in colour, while commercial oil is generally greenish yellow with disagreeable odour and taste. As this tree grows mainly in forest area and also in waste and fallow land, its cultivation would not produce any impact on food production but would in long way improve the environmental condition by massive afforestation. Therefore an attempt is made in this paper to study the feasibility of mahua methyl ester and its blends with diesel fuel for a compression ignition engine.

2. EXPERIMENTAL PROCEDURE

Tests were conducted at the Department of Farm Machinery and Power, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa. A 2-cylinder, four stroke, direct injected, water cooled and 7.4 kW power at 1500 rpm with injector pressure of 17640 kPa diesel engine was selected for the test. Tests were done on a laboratory test bench which consisted of a hydraulic dynamometer, a water tank, exhaust gas temperature measuring system and engine mounting elements as shown in Fig.1. Mahua methyl ester from non-edible mahua oil (*Madhuca indica*) was selected for the study. Esterification of mahua oil is composed of heating of oil, addition of KOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water. Mahua oil was esterified using the esterification system developed in the laboratory of Farm Machinery and Power Department, O.U.A.T., Bhubaneswar. The fuel properties of mahua oil, mahua methyl ester and diesel have been presented in Table 1. The basic composition of any vegetable oil is triglyceride, which is ester of three fatty acids and one glycerol. Blends of mahua methyl ester with diesel fuel were prepared on volume basis. The ester was mixed with the diesel in the proportion of 20, 40, 60 and 100 % on volume basis. For example, B0 indicates blend mahua methyl ester (0%); diesel (100 %), B20 (Mahua methyl ester 20% and diesel 80%), etc. and B100 (Mahua methyl ester 100% and diesel 0 %) on volume basis. An electrical heating unit was used to heat the fuel and its blends to the desired temperature to reduce the viscosity of vegetable oil which is more viscous than diesel resulting in poorer atomization. Constant speed short-term performances tests were conducted to compare the suitability of the blend fuels with diesel fuel.

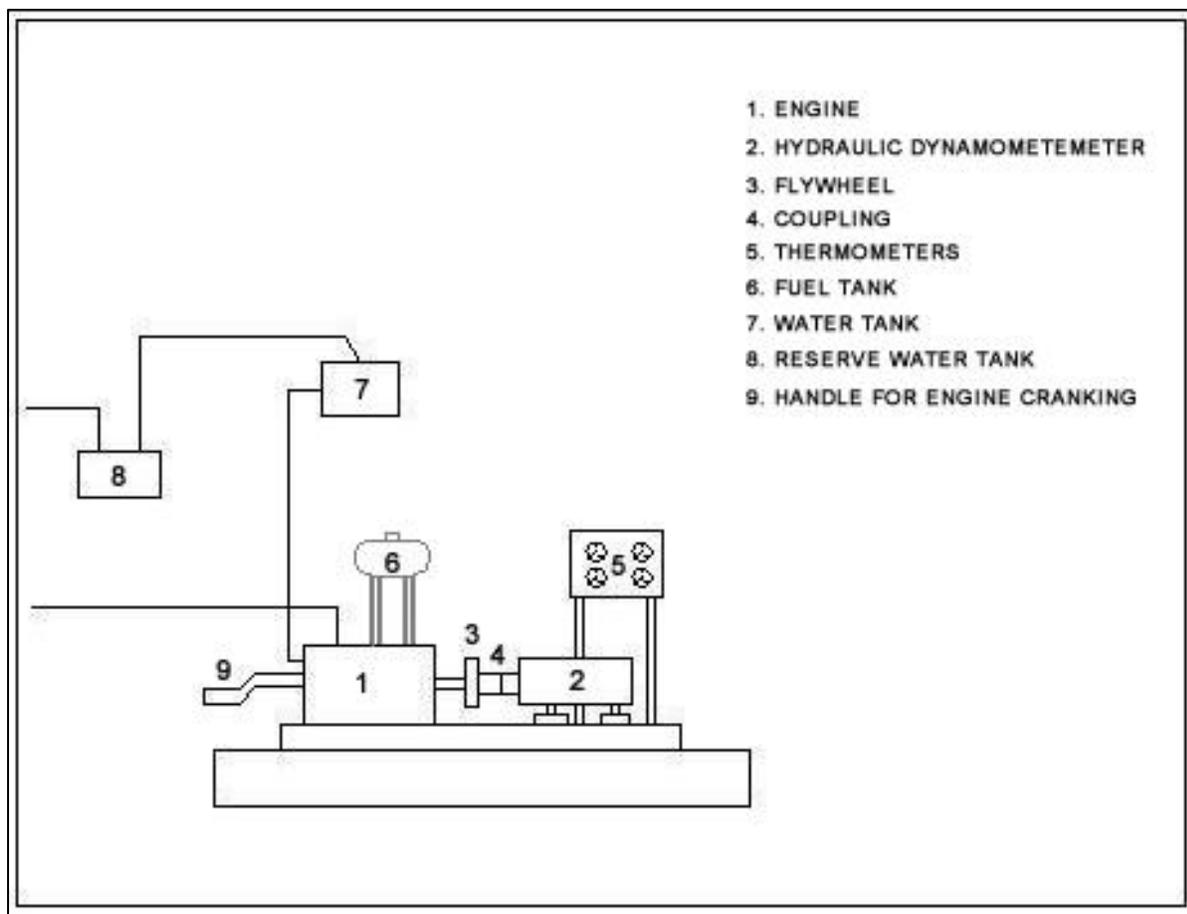


Figure 1. Schematic layout of experimental set up

The baseline test was conducted using diesel fuel alone for its comparison with the performance of alternative fuel blends. The following parameters were selected for the study: engine speed, 1500 r/min; fuel temperature, 30⁰C, 50⁰C and 70⁰C; injection pressure, 17640 kPa and 24010 kPa. The three ranges of fuel temperatures like low (30⁰C), medium (50⁰C) and high (70⁰C) were taken to study the engine performance with the increasing fuel temperatures as viscosity of vegetable oil decreases with increase in temperature resulting good atomization of fuel. The engine was started and run till it attained the speed little higher than 1500 rpm. Then the speed was adjusted exactly to 1500 rpm by adjusting the fuel control lever. The load on the engine was gradually applied with the help of a spring balance (100 g x 20 kg). The speed for all the observations was kept constant at 1500 r/min. For the stabilization of measuring parameters at each load change and at the start of each test a time period of 10 minutes and 20 minutes was respectively allowed. Three readings were taken for each set of observations at minimum of three load settings to get a reasonable value. One set of observations consists of measurements relating to (i) net weight on the torque arm, (ii) time for 50 cc of fuel consumption, (iii) reading for the exhaust temperature, (iv) coolant temperature, (v) fuel temperature and fuel injection pressure. The ambient air temperature and barometric pressure were also recorded. From the

recorded set of observations, the following parameters were calculated to predict and compare the engine performance such as (i) brake power output in kW, (ii) engine specific fuel consumption (ESFC) in kg/kW-h and (iii) exhaust gas temperature (ExGT) in °C. These performance parameters were compared for all fuel blends at three-fuel temperatures and two-injection pressures. The original injection pressure of the injector of the engine is 17640 kPa. The engine created problem in proper atomization of the fuel during testing and that was why the injection pressure was changed to 24010 kPa for improved atomization. The engine test was done according to BIS: 5994-11 (Anon, 1979).

Table 1. Fuel properties of mahua oil, mahua methyl ester and diesel (IS: 548). 1997.

Fuel	Kinematic Viscosity at 38 °C (cS)	Density at 21 °C (kg/m ³)	Flash point (°C)	Pour point (°C)	Heating value (MJ/kg)
Mahua oil	44.3	0.901	276	14	34.3
Mahua methyl ester	10.4	0.861	170	11	36.7
Diesel	6.8	0.849	74	- 4	47.4

3. RESULTS AND DISCUSSION

The power output for the blends (B0, B20, B40, B60 and B100) at two different fuel injection pressures (17640 kPa and 24010 kPa) has been presented in Figs. 2 and 3. The power output increased with the increase of operating temperatures and pressures for all the blends. But the power output showed a decreasing trend from B20 to B100 at a particular temperature and pressure. The maximum power output at 70⁰-C and 24010 kPa was found to be 7.20 kW in B20 and followed by 7.13 kW for B40, 7.10 kW for B60, 7.0 kW for B0 and minimum (6.90 kW) for B100. However the power outputs in case of B20 and B100 were found to be respectively 3% more and 1.5% less than the reference diesel fuel. The increased power output with the increase of temperatures may be due to the better atomization of the blends because of their reduced viscosities at higher temperatures. The increase in power output with the increase in injection pressure may be due to the improved atomization. The decreasing trends in power output is from B20 to B100 for the increase in the percentage of mahua methyl ester oil in diesel because of lower energy input of vegetable oils than that of diesel. It may also be due to poor atomization of vegetable ester for its higher viscosity.

Similarly the effect of fuel temperatures on engine specific fuel consumption (ESFC) for the blends at above mentioned injection pressures has been depicted in Figs. 4 and 5. The results showed that with the increase in the fuel temperatures and injection pressures, ESFC decreased in all the blends of fuel. But ESFC showed a increasing trend from B20 to B100 at a particular temperature and pressure. The minimum ESFC at 70⁰C and 24010 kPa was found to be 0.23 kg/kWh in pure diesel and followed by 0.25 kg/kWh for B20, 0.26 kg/kWh for B40, 0.26 kg/kWh for B60 and maximum (0.27 kg/kWh) for B100. Similarly the ESFC in case of B20 and B100 were found to be respectively 9% and 17% more than the reference diesel fuel. The ESFC increase may be due to the lower heat content of the mahua methyl ester oil than diesel fuel. Increasing in injection pressure decreases the ESFC and it might be due to the improved burning quality of finer injection sprays. By increasing the fuel temperatures, viscosity decreases and enhances flowability and finer atomization of blends, which results in decreased ESFC.

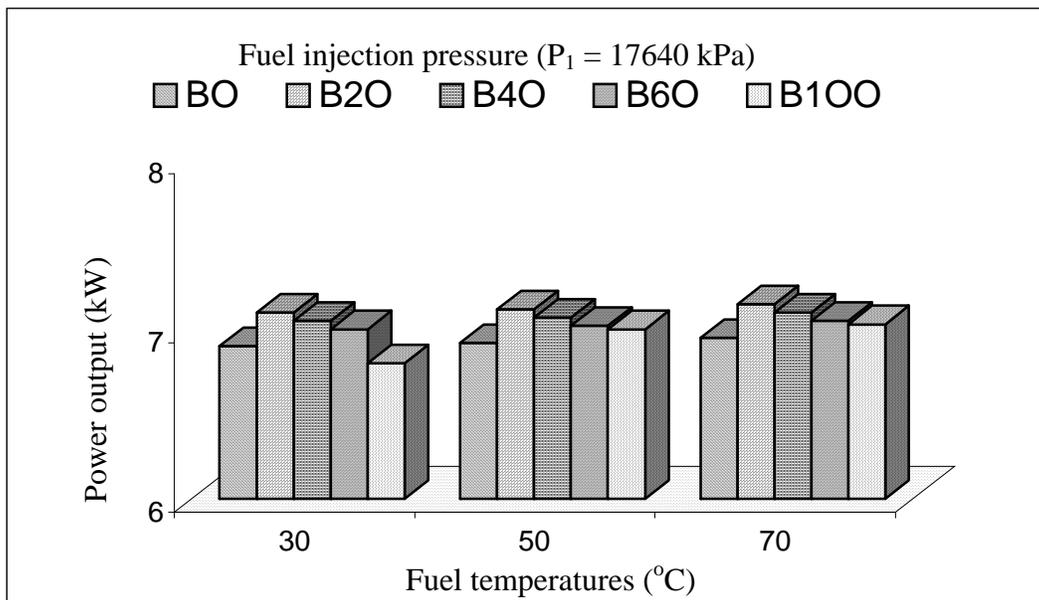


Figure 2. Effect of fuel temperature on power output for different blends of mahua methyl ester with diesel at 17640 kPa injection pressures

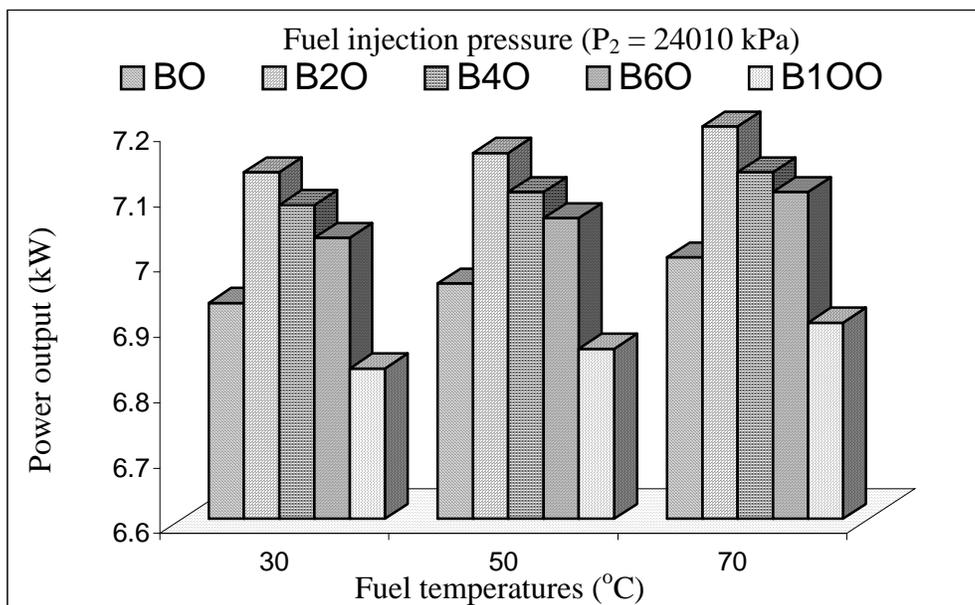


Figure 3. Effect of fuel temperature on power output for different blends of Mahua methyl ester with diesel at 24010 kpa injection pressure

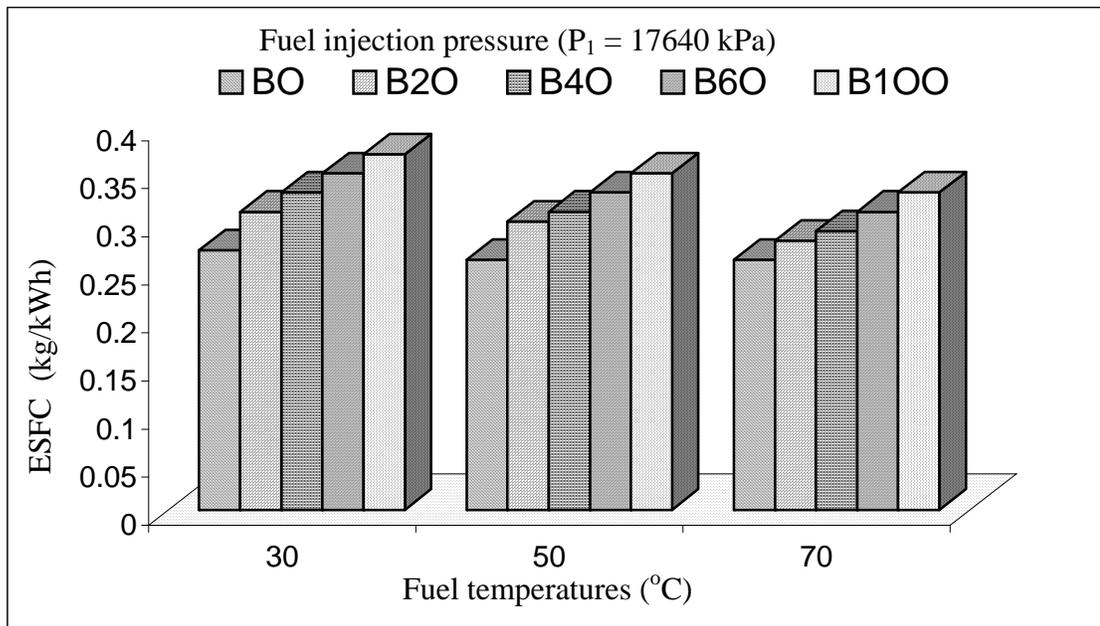


Figure 4. Effect of fuel temperature on engine specific fuel consumption for different blends of mahua methyl ester with diesel at 17640 kPa injection pressure

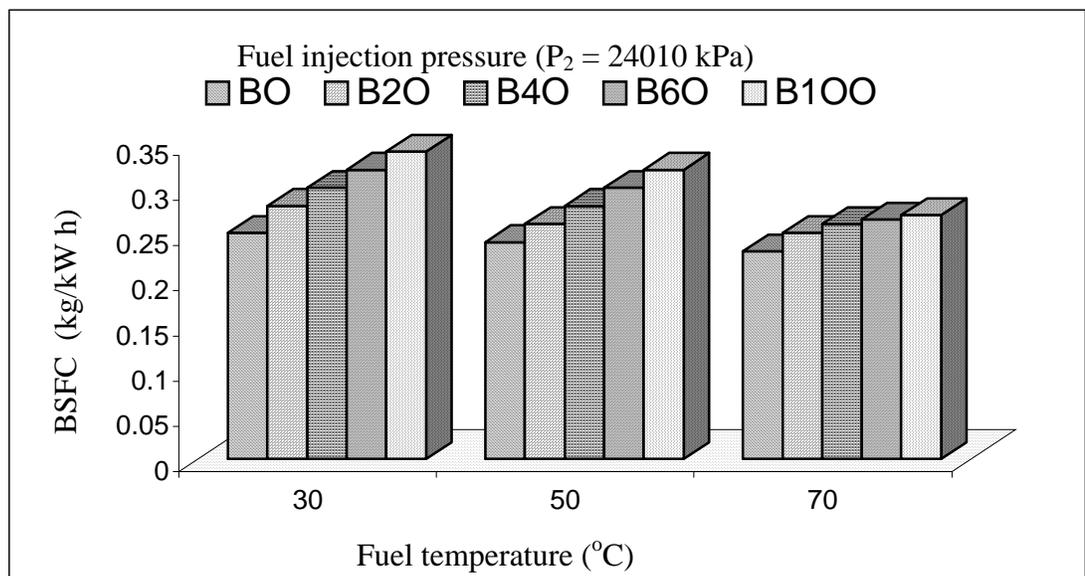


Figure 5. Effect of fuel temperature on engine specific fuel consumption for different blends of mahua methyl ester with diesel at 24010 kPa injection pressure

The relationship between exhaust gas temperature (ExGT) and fuel temperatures for different blends at different fuel injection pressures has been shown in Figs. 6 and 7. The results showed that with the increase in the fuel temperatures and injection pressures, ExGT increased in all the blends of fuel. But ExGT showed an increasing trend from B20 to B100 at a particular temperature and pressure. The minimum ExGT at 70^o-C and 24010 kPa was found to be 156.8^oC in B20 and followed by 157.5^oC for B0, 159.3^oC for B40, 160.5^oC for B60 and maximum (162^oC) for B100. Similarly the ExGT in case of B20 and B100 were found to be respectively 0.5% less and 4% more than the reference diesel fuel. The increase in ExGT with increase in fuel temperature and pressure may be attributed to the increased cylinder pressure due to improved combustion of fuel as a result of improved atomization. The increase in ExGT with increase in the proportion of mahua methyl ester may be due to the delayed combustion. This may also be due to the slower combustion characteristics of mahua methyl ester. The results obtained in this study are in confirmation with the results reported by Shyam et al., 1984 and Bhatt, 1987.

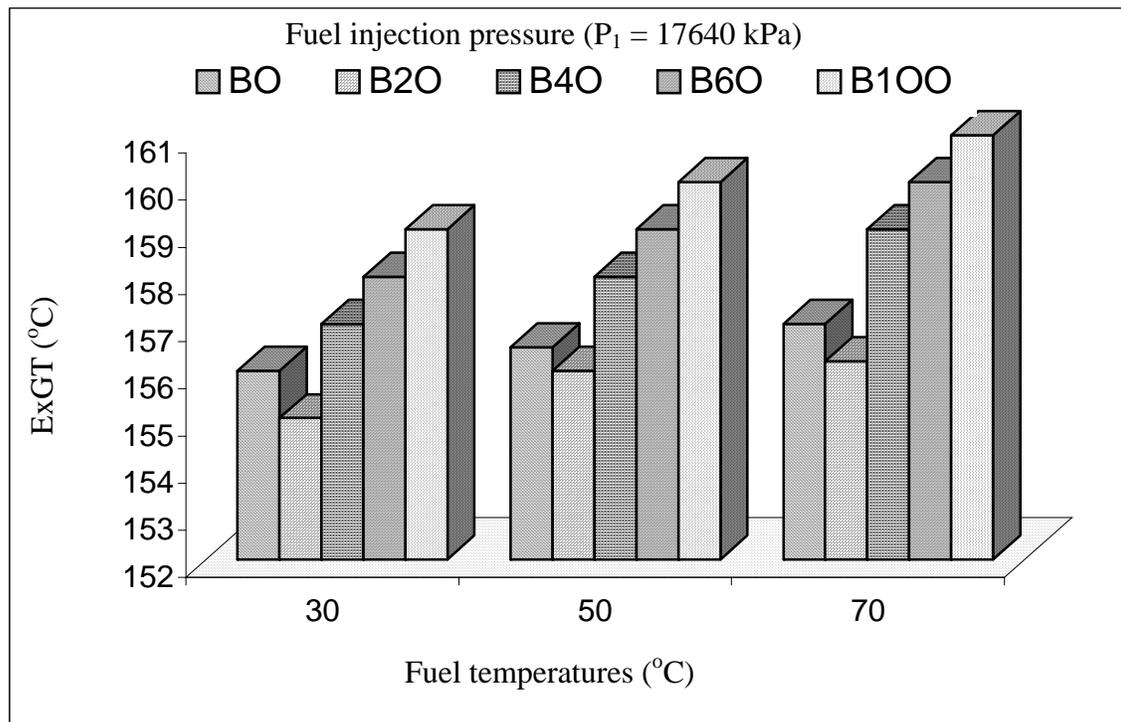


Figure 6. Effect of fuel temperature on exhaust gas temperature for different blends of mahua methyl ester with diesel at 17640 kPa injection pressure

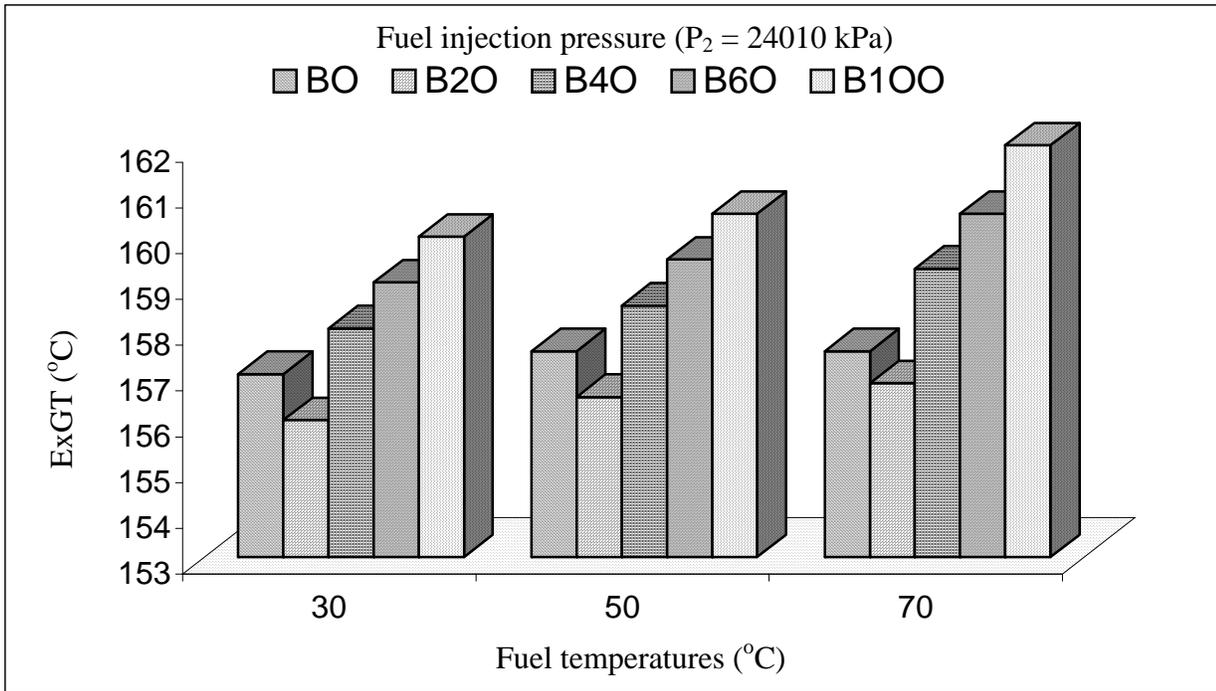


Figure 7. Effect of fuel temperature on exhaust gas temperature for different blends of mahua methyl ester with diesel at 24010 kPa injection pressure

4. CONCLUSIONS

From the results of the experimental investigation, the following conclusions are drawn:

- Injection pressure and fuel temperature were found to have significant effects on the engine performance.
- The power output, engine specific fuel consumption (ESFC) and exhaust gas temperature (ExGT) of the engine under test increased with the decrease, increase and increase respectively of the concentration of mahua methyl ester in the blends.
- The power output, ESFC and ExGT of the engine increased with the increase, decrease and decrease (but non-significant) respectively of the fuel temperatures and operating pressures.
- The performance of the engine with B20 blend fuel was found to be at par with the diesel fuel for short-term engine test.
- On an average, the values of power output, ESFC and ExGT of the blend B20 were found to 3% more, 9% more 0.5 % less than the pure diesel fuel.
- Mahua methyl ester can be used as a substitute for diesel fuel in compression ignition engine with lower percentage of emissions and engine wear compared to diesel.

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