Jurnal
Teknologi

Full Paper

# Effects of Palm Oil Methyl Ester (POME) on Fuel Consumption and Exhaust Emissions of Diesel Engine operating With Blended Fuel (Fossil Fuel + Jatropha Oil Methyl Ester (JOME))

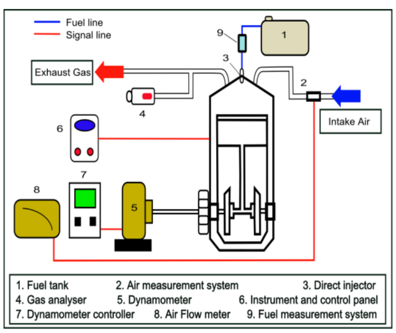
N. R. Abdullah[a]*, Z. Michael[b], A. R. Asiah[a], A. J. Helmisyah[c], S. Buang[a]

[a]Faculty Of Mechanical Engineering, Universiti Teknologi MARA,40450 Shah Alam, Selangor, Malaysia
[b]Faculty Of Mechanical Engineering, Universiti Teknologi MARA, 81750 Pasir Gudang, Johor, Malaysia
[c]Faculty Of Mechanical Engineering, Universiti Teknologi MARA, 23200 Bukit Besi, Dungun, Terengganu, Malaysia

**Article history**
*Received*
*16 February 2015*
*Received in revised form*
*30 April 2015*
*Accepted*
*9 June 2015*

*Corresponding author
nikrosli@salam.uitm.edu.my

**Graphical abstract**




**Abstract**

Biodiesel is used widely as an alternative fuel for diesel engine due to biodegradable, oxygenated, renewable and compatible with diesel engines . In fact, biodiesel emission has decreased the levels of potentially carcinogenic compounds. However, a certain biodiesel such as Jatropha Oil Methyl Ester (JOME) has resulted in the increase of specific fuel consumption and higher $NO_x$ emissions. Therefore, the objective of this study is to investigate the effects of Palm Oil Methyl Ester (POME) in the blended fuel (Fossil fuel + JOME) on the fuel consumption and exhaust emission. Experiments were carried out at a constant engine speed (2000 rpm) with variable of engine loads. Results show that the addition of POME leads to the significant reduction in brake specific fuel consumption (BSFC), Total hydrocarbons ($THC_s$), carbon monoxide (CO) and nitrogen dioxide ($NO_x$) emissions. This study shows a huge difference for Total hydrocarbons emission of blends with 5% POME compared to blends with 10% and 15% of POME. Carbon monoxide emission for blends with 15% POME is the lowest at constant engine speed with various engine loads which in average is 53% lower than blends of 5% POME. This is because blends with higher percentage of POME has higher cetane number hence shortened the ignition delay resulted in the lower possibility of formation of rich fuel zone and thus reduces CO emissions. Moreover, the higher percentage of POME also resulted in lower $NO_x$ emission regardless of engine loads. The blends with 15% POME had the lowest $NO_x$ emission which is 25% less compared with the blends of 5% POME. The study recommended that, additional POME to the blended fuel can be considered as a good initiative to improve blended fuel property for diesel engine due to its potential to improve engine emissions and reduce brake specific fuel consumption. In conclusion, the blends of POME into (Fossil fuel + JOME) improves engine emission without significantly increasing fuel consumption.

*Keywords*: Jatropha Oil Methyl Ester (JOME), Palm Oil Methyl Ester (POME), Fuel consumption, Total Hydrocarbons ($THC_s$) and Carbon Monoxide(CO)

## 1.0 INTRODUCTION

A number of researches have been carried out on biodiesel [1-4] due to the depletion of fossil fuels and environmental pollution. One of the most important properties of biodiesel is the trade-off between oxidation stability and cold flow properties. Biodiesel produced from vegetable oils is higher in esters of unsaturated fatty acids and biodiesel from animal fats is higher in esters of saturated fatty acids [5,6]. The higher proportion of saturated fatty acids havegood oxidation stability but poor cold temperature properties. Whereas, the higher proportion of unsaturated fatty acids will enhance low temperature properties but poor in oxidation stability [7]. A balance composition of different fatty acids is important to improve the combustion and emissions characteristics of biodiesel.

In Europe, the common source of commercial biodiesel is from rapeseed oil, while in USA a soybean oil becomes as a primary source of biodiesel [8,9]. Currently, the demand on biodiesel continuously increases due to their advantages. The fuel has several advantages such as lower sulphur content, higher flash point and lower aromatic content. However, certain biodiesel resulted in higher BSFC than fossil fuel due to lower calorific value [1-2].

A series of research work at Universiti Teknologi MARA (UiTM) is being carried out with collaboration with other universities and industries [1-4]. The selected biodiesel-diesel blends for this study are Jatropha Methyl Ester (JME) and Palm Oil Methyl Esters (POME). Therefore, the objective of the current study was to investigate the effects of Palm Oil Methyl Esters (POME) to the fuel consumption and exhausts emissions when operating with blended fuel (Fossil fuel + JOME) under varying engine loads at constant engine speed. The fuel consumption was calculated from brake specific fuel consumption (BSFC), while the exhaust emissions ($THC_s$, CO and $NO_x$) were measuredby using portable gas analyzer.

## 2.0 EXPERIMENTAL

POME was blended into 3 different composition of blended fuel (Fossil fuel + JOME). First fuel consists of blended fuel (5% JOME + 90% Fossil fuel + 5% POME), second test fuel (5% JOME + 85% Fossil fuel + 10% POME) and the third test fuel (5% JOME + 80% Fossil fuel + 15% POME).

Figure 1 shows a single cylinder four stroke diesel engine (DY-23-014135) with 5 kW electric dynamometer (model: PS-DEC-1) was used in this research. The experiments were carried out at constant engine speed (2000 rpm) with various engine loads (1Nm, 2 Nm, 3Nm, 4 Nm and 5 Nm).

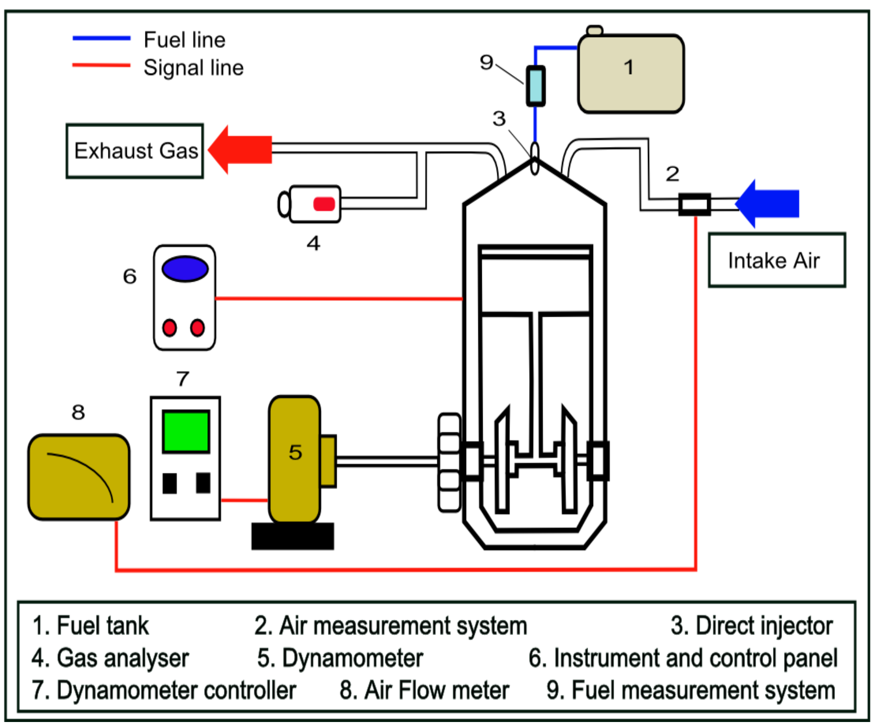



**Figure 1** Experimental set up of Diesel engine

## 3.0 RESULTS AND DISCUSSION

### 3.1 Brake Specific Fuel Consumption (BSFC)

Figure 2 shows that at constant speed of 2000 rpm and 1 Nm, the blend with 5% of POME has the highest brake specific fuel. At lower engine load, blends with higher percentage of POME consume less fuel. This is more related to the fuel viscosity, density, lower heating value and evaporation rate that resulted in complete combustion. Cetane number is an important parameter to show the seif-ignitability of fuel. The results showed higher cetane number contributes to complete combustion due to improved self-ignitability of fuel [10]. The higher cetane number promotes ignition reaction and accelerate fuel burning rate. When the engine load continues to increase to 5 Nm, the blend with 15% of POME has lower brake specific fuel consumption compared to 10% of POME. This is due to higher combustion temperatures with higher engine load that lead to improved fuel evaporation rate, resulting in higher fuel amount during the combustion process.

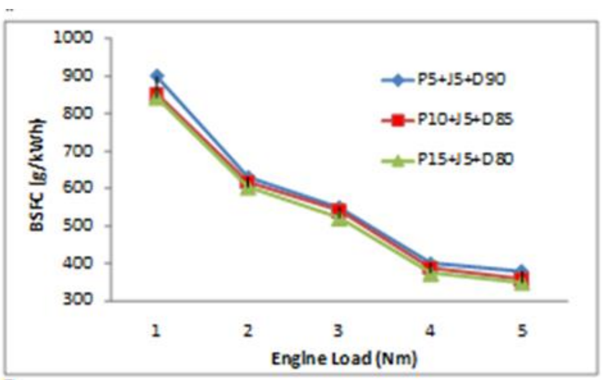



**Figure 2** BSFC (g/kW.h) against Variation of Engine Load (Nm) at Constant Engine Speed of 2000 rpm

### 3.2 Total Hydrocarbons (THCs) Emissions

Figure 3 shows the $THC_s$ emissions at variation of engine loads with constant engine speed. THCs is a result of incomplete combustion due to insuffient oxygen and poor fuel distribution. The results showed a huge differences for Total hydrocarbons emission of blends with 5% POME compared to blends with 10% and 15% percent of POME. The blends with 15% POME have lower THCs emission than blends with 10% POME at almost all engine loads. This is because the blended fuel with 15% of POME had higher oxygen content, leading to complete combustion, thus reducing Total hydrocarbons emissions [1, 3, 11]. Complete combustion with 15% of POME also assists in localized burning process and promotes oxidation of $THC_s$.

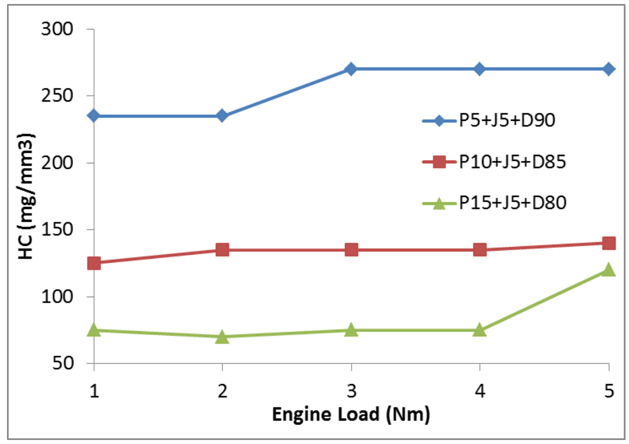



**Figure 3** THCs (mg/m3) against Variation Engine Load (Nm) at Constant Engine Speed 2000 rpm

### 3.3 Carbon Monoxide (CO) Emissions

Figure 4 shows the CO emissions at variation of engine loads with constant engine speed. CO is the intermediate product of combustion for hydrocarbon fuels. The results showed that blend with lowest percentage of POME have the highest emission of carbon monoxide. The higher emissions of CO are related to the low oxygen concentration, low reaction temperature and short reaction time. At lower engine load, the cetane number plays a major role in carbon monoxide emission. Blends with higher percentage of POME had higher cetane number , hence shortened the ignition delay, leading to lower possibility of rich fuel zone formation and CO emissions reduction [12]. As the load increases, the oxygen content will be the major decider on carbon monoxide emission as extra oxygen content promotes complete combustion, thus leading to the reduction of CO emissions but causing the formation of carbon dioxide to increase [13,14].

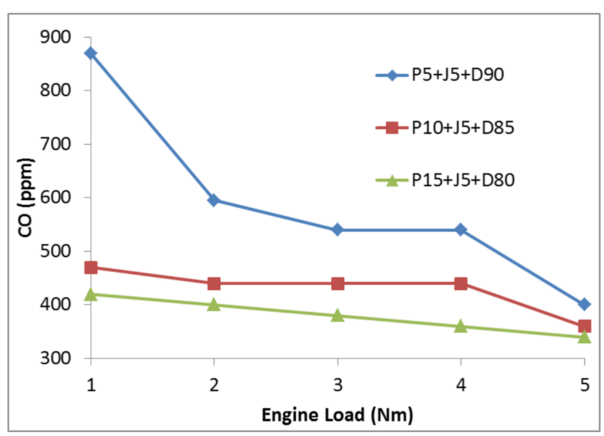



**Figure 4** CO (ppm) emissions against Variation Engine Load (Nm) at Constant Engine Speed 2000 rpm

### 3.4 Nitrogen Oxide (NOx) Emission

Figure 5 shows the $NO_x$ emissions at variation of engine loads with constant engine speed. The results at lower engine load showed that the blends with 15% POME has the lowest nitrogen oxide emission which was 14% less than blends with 10% POME and 25% less than blends with 5% of POME. However, at the higher engine load, blends with 5% POME shows the lowest nitrogen oxide emission which is 18% less than other fuels. There are two major arguments regarding factors that influenced the emission of nitrogen oxide.

Some researchers said that higher cetane number will not lead to higher nitrogen oxide emission because higher cetane number will not only lead to burn early, but also lead to lower premixed combustion, which will lead to softer changes in pressure and temperature, thus it causes lower NO formation [15]. Secondly, most authors agree that the increase in oxygen content is the cause for the increase of nitrogen oxide emission [16]. The main factors contributed to the $NO_x$ formation are $O_2$ concentration, local temperature and reaction time. The lower cetane number led to longer ignition delay hence resulted in increase of temperature therefore caused an increased nitrogen oxide emission [17].

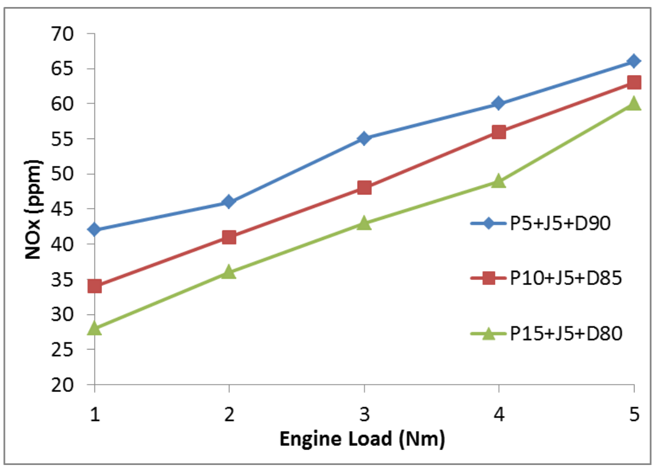



**Figure 5** $NO_x$ (ppm) against Variation Engine Load (Nm) at Constant Engine Speed 2000 rpm

## 4.0 CONCLUSION

Experimental work was carried out by using a single cylinder diesel engine to investigate the effect of POME ratio (5%,10% and 15%) on the BSFC and engine emission of diesel engine fuelled with blended fuel (Fossil fuel + JOME). The main conclusions are as follows:

1. The BSFC decreased with the increase of POME ratio in the blended fuels. The blend with 15% POME shows the lowest BSFC for all engine test conditions. These results are due to the higher cetane number of POME leading to shorter ignition delay and promotes complete combustion. Besides that, the addition of POME provides better lubricity for fuel atomization for complete combustion hence; it has reduced the fuel consumption.
2. $THC_s$ emission is decreased asPOME ratio in the blended fuels is increased. The blends with 15% POME shows the lowest $THC_s$ emission for all engine test conditions. This is due to higher oxygen content in the blend with 15% POME that led to complete combustion. As a result, the hydrocarbon emission is reduced.
3. The CO emission is decreased with the increase of POME ratio in the blended fuels. The blend with 15% POME shows the lowest CO emission for all engine test conditions. Additional POME gives extra oxygen content in the blended fuels and promotes a complete combustion. Therefore, the extra Oxygen reduces the CO emission. Also the CO emission is decreased as the engine load is increased because of the higher oxidation process at the higher combustion temperature.
4. The emission of $NO_x$ is decreased as the POME content in the blended fuel is increased. The blend with 15% POME shows the lowest $NO_x$ emission for all engine test conditions. It is found also the lower cetane number with 5% of POME increase the ignition delay. Subsequently, the combustion temperature is incrased and it has increased the $NO_x$ formation.

The overall results show that the BSFC is improved with the introduction of POME into the blended fuel. The exhaust emission shows significant reduction in $THC_s$, CO and $NO_x$ emission. It can be concluded that the addition of POME into the blended fuel (Jatropha + Fossil fuel) can enhance the engine performance and reduce harmful emissions.

## Acknowledgement

The research work was supported by the Research Acculturation Grant Scheme (RAGS) from the Malaysia Higher Education Department, UiTM Johor Pasir Gudang Campus and Universiti Teknologi MARA (UiTM) Grant No.600-RMI/RAGS 5/3 (222/2014)).

## References

[1] Syarifah Yunus, Amirul Abd Rashid, Syazuan Abdul Latip, Nik Rosli Abdullah, Rizalman Mamat, Abdul Hakim Abdullah. 2013. Performance and Emissions of Jatropha-Palm Blended Biodiesel. *Applied Mechanics and Materials*. 393: 344-349

[2] Syarifah Yunus, Abdullah, N. R., Mamat, R., Rashid, A. A. 2013. On Overview of Palm, Jathropha and Algae As a Potential Biodiesel Feedstock in Malaysia. *Journal of Materials Science and Engineering*. 50 012055.

[3] Nik Rosli Abdullah, Muhammad izzat Nor, Ismail Nasiruddin, Salmiah Kasolang, Nor Hayati Saad. 2013. Potential Utilization of Biodiesel as Alternative Fuel for Compression Ignition Engines in Malaysia. *Applied Mechanics and Materials*. 393: 475-480.

[4] Rizalman Mamat, Rafidah Rahim, Abdul Adam Abdullah, Amir Aziz, Nik Rosli Abdullah. 2013. Characteristic of Biodiesel Fuel Derived from Palm Oil. *Journal of Biobased Materials and Bioenergy.* 7(4): 457-460.

[5] Tsolakis, A., Megaritis, A. and Yap, D. 2008. Application of Exhaust Gas Fuel Reforming in Diesel and Homogeneous Charge Compression Ignition (HCCI) Engines Fuelled with Biofuels. *Energy Volume*. 33(3): 462-470.

[6] Hess, M. A., Haas, M. J. and Foglia, T. A. 2007. Attempts to Reduce Nox Exhaust Emissions by Using Reformulated Biodiesel. *Fuel Processing Technology.* 88(7): 693-699.

[7] Sharma, Y. C., Singh, B. and N. Upadhyay, S. 2008. Advancements in Development and Characterization of Biodiesel: A Review. *Fuel*. 87(12): 2355-2373.

[8] Canakci, M. 2005. Performance and Emissions Characteristics of Biodiesel from Soybean Oil. Part D: *J. Automobile Engineering, Proc. IMechE*. 219: 8.

[9] Haas, J. M., Scott, K. M., Alleman T. L. and McCormick, R. L. 2001. Engine Performance of Biodiesel Fuel Prepared from Soybean Soapstock: A High Quality Renewable Fuel Produced from a Waste Feedstock. *Energy Fuels*. 15(5): 1207.

[10] Al-Widyan MI, Tashtoush G, Abu-Qudais M. 2002. Utilization of Ethyl Ester of Waste Vegetable Oils as Fuel in Diesel Engines. *Fuel Process Technology.*

[11] Ali, O. M., Mamat, R. Abdullah, N. R., Abdullah, A. A. 2013. Effects of Blending Ethanol with Palm Oil Methyl Esters on low Temperature Flow Properties and Fuel Characteristics. *International Journal of Advanced Science & Technology*. 59.

[12] Ramadhas, A. S. Muraleedharan, C. and Jayaraj, S. 2000. Performance and Emission Evaluation of a Diesel Engine Fueled with Methyl Esters of Rubber Seed Oil. *Journal of Renewable Energy.*

[13] Buyukkaya, E. 2010. Effects of Biodiesel on a DI Diesel Engine Performance, Emission and Combustion Characteristics. *Journal of Fuel.*

[14] Ozsezen A. N., Canakci M., Turkcan A., Sayin C. 2009. Performance and Combustion Characteristics of a DI Diesel Engine Fueled with Waste Palm Oil and Canola Oil Methyl Esters. *Journal of Fuel*.

[15] Kalam, M. A. and Masjuki, H. H. 2004. Emissions and Deposit Characteristics of a Small Diesel Engine When Operated on Preheated Crude Palm Oil. *Biomass and Bioenergy*. 27(3): 289-297.

[16] Deepak Agarwal, Lokesh Kumar and Agarwal, A. K. 2008. Performance Evaluation of a Vegetable Oil Fuelled Compression Ignition Engine. *Renewable Energy*. 33(6): 1147-1156.

[17] Cho, H. M., Maji, S. and Pathak, B. D. 2008. Waste Cooking Oil as Fuel in Diesel Engines. *SAE Paper 2008-28-0013.*