

## Emissions Characteristics of Small Diesel Engine Fuelled by Waste Cooking Oil

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**Abstract.** Biodiesel is an alternative, decomposable and biological-processed fuel that has similar characteristics with mineral diesel which can be used directly into diesel engines. However, biodiesel has oxygenated, more density and viscosity compared to mineral diesel. Despite years of improvement attempts, the key issue in using waste cooking oil-based fuels is oxidation stability, stoichiometric point, bio-fuel composition, antioxidants on the degradation and much oxygen with comparing to diesel gas oil. Thus, the improvement of emission exhausted from diesel engines fueled by biodiesel derived from waste cooking oil (WCO) is urgently required to meet the future stringent emission regulations. The purpose of this research is to investigate the influences of WCO blended fuel and combustion reliability in small engine on the combustion characteristics and exhaust emissions. The engine speed was varied from 1500-2500 rpm and WCO blending ratio from 5-15 vol% (W5-W15). Increased blends of WCO ratio is found to influences to the combustion process, resulting in decreased the HC emissions and also other exhaust emission element. The improvement of combustion process is expected to be strongly influenced by oxygenated fuel in biodiesel content.

### 1 Introduction

Biodiesel is an alternative fuel that receiving a lot of attention nowadays due to its availability sources and renewability. In Malaysia, Green Technology and Climate Change Council (MTHPI) involved in reducing the CO<sub>2</sub>, emissions up to 40% between 2005 and 2020. For that reason, the vehicle run by Bio-diesel Fuel (BDF) has been a potential option. Thus, the alternative sources of fuel are receiving a lot attention in the automotive industry. The key issue in using waste cooking oil (WCO) based fuel is oxidation stability, stoichiometric point, biofuel composition, antioxidants on the degradation and much oxygen with comparing to diesel gas oil[1-4]. However, the application of the BDF in the diesel engines offer not only attractive and more economical fuel but also creates problems of higher emissions compared with petroleum based diesel. BDF diesel engines still have problem of emitting NO<sub>x</sub> and Particulate Matter (PM) into the atmosphere because of the oxidation stability, cetane number, stoichiometric point, bio-fuel composition and antioxidants on the degradation extremely viscous [5-6]. Thus, the improvement of emissions exhausted from BDF engines is urgently required to meet the future stringent emission regulations. It was reported that the implementation of boost pressure, swirl velocity and injection pressure has a great effect on the mixture formation, ignition delay, turbulence, ambient density and ambient pressure, and then affects to the flame propagation, combustion characteristics and emissions production[7-9]. Biodiesel has higher cetane number than

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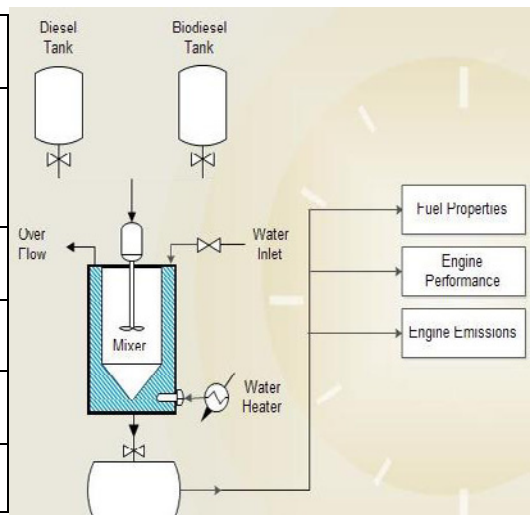
diesel fuel, no aromatics, almost no sulfur, and contains 10 to 11% oxygen by weight. These characteristics of the fuel reduce the emissions of carbon monoxide (CO), hydrocarbon (HC), and particulate matter (PM) in the exhaust gas [10]. For that reason, numerous emissions studies using the bio diesel and its blends shows emissions concentration (CO, CO<sub>2</sub>, HC, PM, NO<sub>x</sub> as well as deposit) varies depend on source of bio-diesel and engine combustion system. The purpose of this research is to investigate the influences of WCO blended fuel in small engine on the combustion characteristics and exhaust emissions. The engine speed was varied from 1500-2500 rpm without load conditions and WCO blending ratio from 5-15 vol% (W5-W15).

## 2 Experimental Setup

The biodiesel used was waste cooking oil (WCO) biodiesel which blended form automotive lab and the particular of the tested fuel are detailed in Table 1. The fuel tested were grade II diesel and blends of 5(W5), 10(W10) and 15 vol%(W15) WCO with the diesel fuel. The grade II diesel designated as standard diesel (Dsl). The kinematic viscosity of WCO blend was measured by Viscolite 700 model VL700-T15. The density properties measured by Metter Toledo Diamond Scale modeled JB703-C/AF. The water content in biodiesel sample is measured by Volumetric KF Tirator model v20. The flash point measured by Pensky–Martens PMA 4. The engine fuel consumption measured by Ono Sokki mass flow meter modeled FM2500

Fuel type	Properties				
	Density (g/cm <sup>3</sup> )	Kinematic viscosity (Cp)	Flash point (°C)	Water content (%)	Acid value (mg KOH/g)
Dsl	0.8394	3.0	83.0	0.050	0.423
W5	0.8430	3.0	89.9	0.009	0.120
W10	0.8435	3.2	102.2	0.010	0.320
W15	0.8456	3.2	110.0	0.013	0.480

**Table 1.** Properties of tested fuels



**Figure 1.** Blending process of producing biodiesel

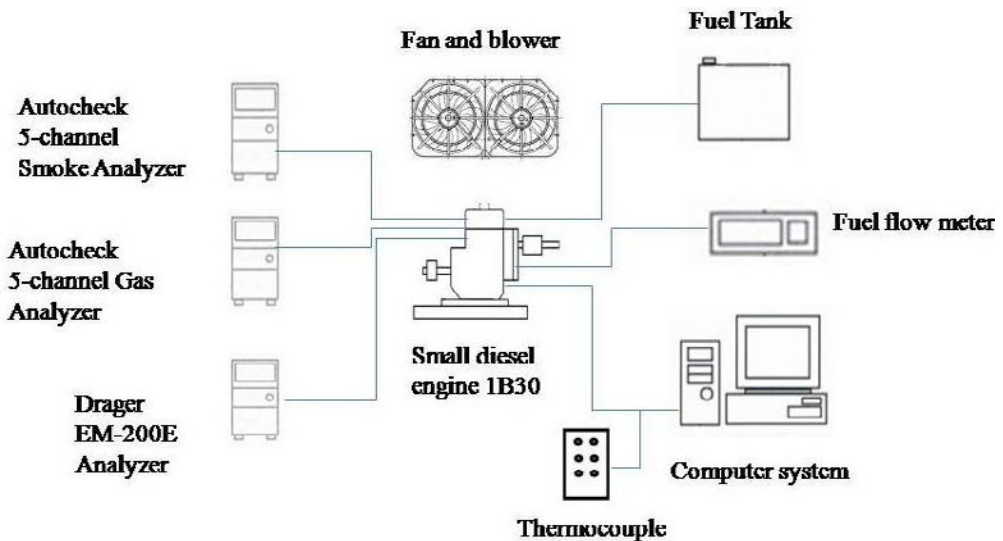
Schematic view of blending process is shown in Figure 1. The WCO was blended with Dsl in various concentrations for preparing a biodiesel blend. During blending process, the laboratory scale blending machine was operated at 60°C and the mixture was stirred at 70°C for 1 hour. The rotating blade speed was adjusted to maintain the same speed at 270 rpm.

A schematic view of the emission test and summarizes the engine specification including the operating parameter shown in Fig. 2 and Table 2, respectively. The tested engine that used is small diesel engine, Hatz diesel engine 1B30 with 1 cylinder engine. This engine 1B30 series was design with compact installation dimensions and in all applications with a power requirement up to 8 kW due to its low weight. The maximum torque is 17.5 Nm. For this experiment, the running speeds were simulated at 1500, 2000, and 2500 rpm. Measurements data comprised fuel consumption rate (kg/hr) together with the exhaust emissions like hydrocarbon(HC), oxygen(O<sub>2</sub>), carbon dioxide(CO<sub>2</sub>), carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) and smoke opacity by using autocheck 5 channel gas emission analyzer and dragger MSI. For this research Dsl, W5, W10 and W15 are used for running under similar engine in a manner similar operation conditions. To compare the difference, the measurement

process was repeated for 3 cycles per each condition. Further analysis and presentation of data is based on the average of measurement.

**Table 2.** Engine specifications

Engine Specification	
Model	Hatz Diesel Engine 1B30
Type	Air-cooled four stroke diesel engine
Combustion system	Direct injection
Number of cylinder	1
Bore/Stroke	80/69 mm
Displacement	347 cm <sup>3</sup>
Sense of rotation on power take-off side	left
Engine oil pressure at oil temperature of 100°C	2.5 bar at 3000 rpm
Maximum torque	17.Nm
Weight	40 kg



**Figure 2.** Schematic of Emission test setup

### 3 Results and Discussion

The emission characteristic on different blending ratio and engine speed was shown in Figure 3. The discussion also based on relationship between the emission characteristic of standard diesel (DsI), W5, W10 and W15, engine speed of 1500, 2000, and 2500 rpm and simulated the engine run without load condition. As seen in Figure 3, the increasing of blending ratio for all engine speed will influences the decreasing of the HC and smoke opacity.

These phenomenons happen due to the increasing of blending ratio will weaken the fuel ignitibility and prolong ignition delay as well. In addition this behavior associated with the lower combustion temperature and pressure thus predominantly lower HC emission and smoke opacity. It is also found that NO<sub>x</sub> emission is increase inversely proportional with the blending ratio. This may attributed with the low viscosity of fuel due to the higher temperature enhance the fuel-air premixing

thus influence the higher NOx. It seems that the increasing WCO blending ratio influences the reductions of CO2 and CO emissions production.

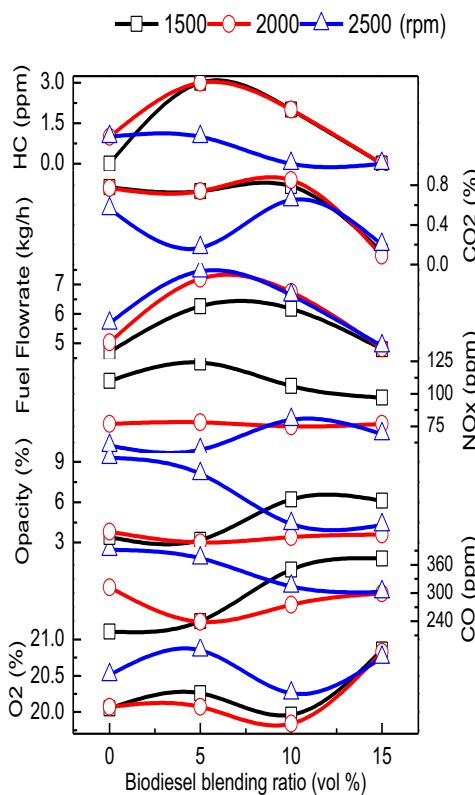


Figure 3. Effects of WCO blending on different engine speed (rpm)

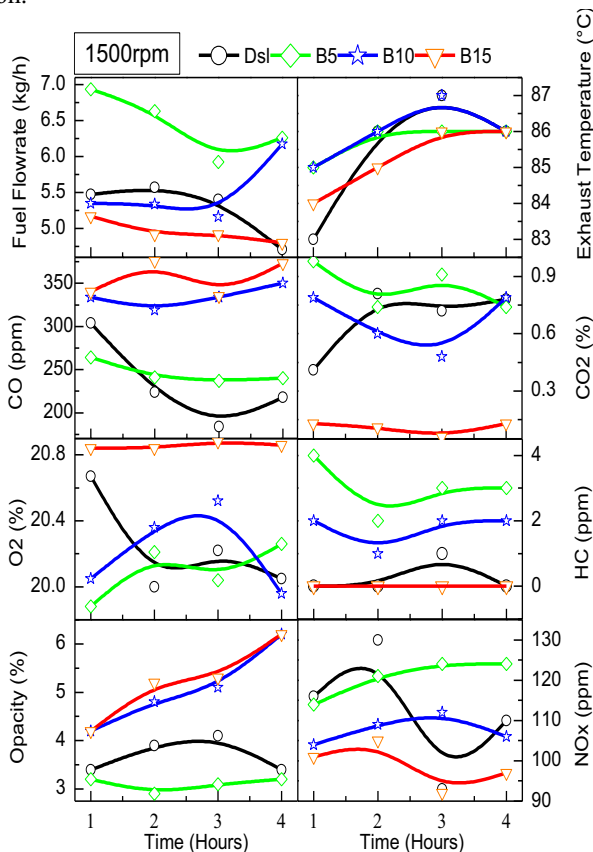
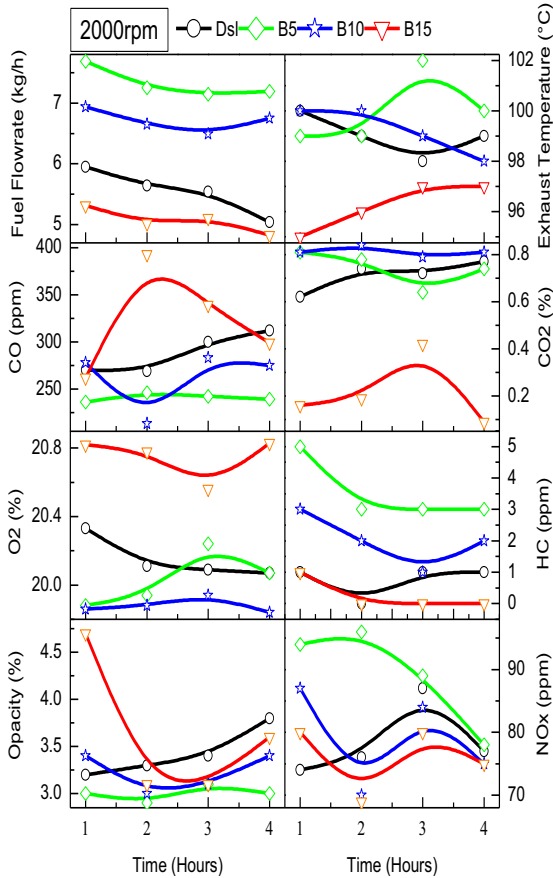
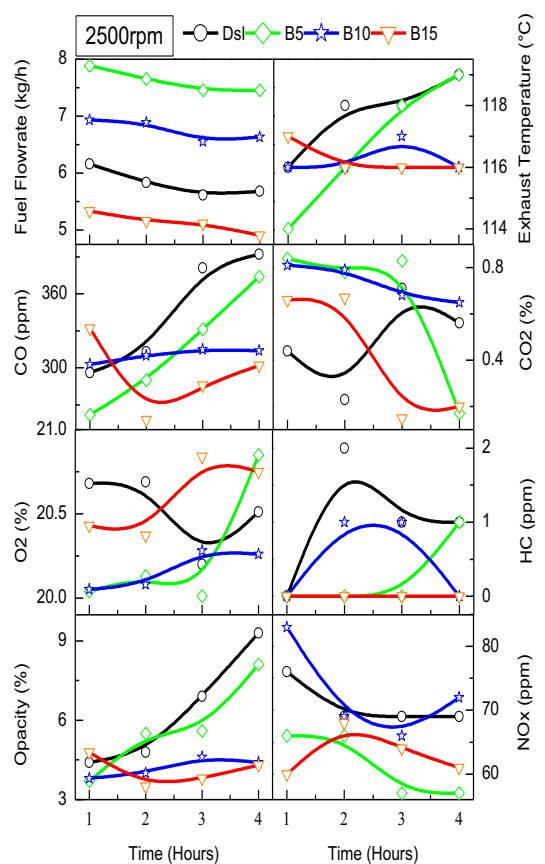


Figure 4. Effects of biodiesel blending with different period of times (1500 rpm) conditions.

Figure 4, 5 and 6 show the emission characteristics effects from W5, W10, W15 and compared with the standard diesel (Dsl) under variant in engine speed and time duration. As seen in Figure 4, 5 and 6, W15 contributes to the lowest HC emission and CO2 emissions under all engine speed conditions. The NOx emission starts increasing under 1500rpm of engine speed, but will decrease after 2000rpm and 2500rpm. However, higher blends will result in higher NOx emission such as W5 and W10 during 1500rpm and 2000rpm meanwhile Dsl has the moderate NOx emission among the tested fuels. The B15 shows the lowest at HC, NOx and CO2 emission among other sample biodiesel at all engine speed conditions. On the other hand, the W15 shows the higher value for CO and Smoke Opacity emission at 1500 rpm and 2000 rpm of engine speed. The trend starts decreasing and show the lowest value at 2500 rpm of engine speed. Nevertheless the trend of CO and Smoke Opacity shows the decreasing from 1500 rpm to 2500 rpm. On the other hand, the reduction of smoke opacity may attributed to its oxygen content of the injected fuel at high injection pressure, thus more oxygen content will produce more NOx, then decrease the smoke emission indirectly while increase the CO emission when engine speed increases.



**Figure 5.** Effects of biodiesel blending with different period of times (2000 rpm)



**Figure 6.** Effects of biodiesel blending with different period of times (2500 rpm)

## 4 Conclusion

In this research, the WCO biodiesel with different blending ratio (W5,W10,W15) are obtained in diesel engine and engine speed was adjusted at 1500, 2000, 2500 rpm. The summary as follows:

1. The range W5(5vol%) to W15(15vol %) of blends promotes the reduction of NO<sub>x</sub> and CO<sub>2</sub> emission due to more oxygen present during combustion, thus the combustion will become more complete and in oxygenated fuel.
2. NO<sub>x</sub>, Smoke Opacity, HC, CO, CO<sub>2</sub> emissions and temperature is lower for high blends of WCO (W15), and decrease as the engine speed increases.

## Acknowledgements

The authors also would like to thank the Ministry of Higher Education, Malaysia for supporting this research under Research Acculturation Grant Scheme (RAGS) Vot. R025, COE-MTUN Grant Scheme Vot.C009 and Fundamental Research Grant Scheme (FRGS) vot.1054.

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