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# EFFECT OF FUEL ADDITIVE AND CRUDE JATROPHA OIL ON EMISSION CHARACTERISTICS OF SMALL DIESEL ENGINE

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## ABSTRACT

The using of vegetable oils with edible and non-edible as diesel blends is prove as an alternative to diesel since they are renewable and has similar properties. Even despite of many years did in improvement, they still issue using this vegetables oil-based fuels which is oxidation, stoichiometric point, bio-fuel composition, antioxidants on the degradation and much oxygen with comparing to diesel gas oil. Thus, the improvement of emissions exhausted from diesel engines with the adding of bio-additive in the blended crude jatropha oil can be replaced as the requirement to meet the less emission regulations in the future. Purpose of this study is to investigate the effects of using bio-additive on combustion process of the exhaust emissions of small diesel engine fuelled by diesel blends derived from crude jatropha oil with different ratio. The engine speed was varied from 1500~2500 rpm, the volume for the bio-additive added are 0.2 ml and 0.4 ml while for the crude jatropha oil blending ratio with diesel is from 5~15vol% (CJO5~CJO15). Decreased of NOx emission and fuel consumption rate found in the combustion process as the increased of volume of bio-additive or booster additive added. The experimental results proved that the used of crude jatropha oil with booster additive in diesel engines was a perfect substitute to diesel.

**Keywords:** alternative fuel, crude jatropha oil, diesel engine, booster additive, emissions.

## INTRODUCTION

In this modernized era, biodiesel has becomes an alternative fuel in order to overcome the fossil fuel leakage and environmental pollution. However, by using this bio fuels even have more attractive and economical, it also creates problems of higher emission compared with petroleum based diesel. For the example, problems of emitting NOx and Particulate Matter (PM) into the atmosphere because of the oxidation stability, cetane number, stoichiometric point, bio-fuels composition and antioxidants on the degradation extremely viscous. Thus, the improvement of exhaust emission from biodiesel fuel of the engines is urgently required to meet the future stringent emission regulations. It was reported that the properties of bio-additive affects the fuel properties which thus influence combustion on fuel quantity, injection timing and spray pattern, cause longer injection duration due to change in the start of injection [1-2]. This bio-additive improves cetane number of the fuel, and thus contains less sulfur and more oxygen by weight. These characteristics of fuel are environmental friendly and can reduce the emissions of Hydrocarbon (HC), Carbon monoxide (CO), and Particulate matter (PM) in the exhaust gas [3-4]. With these reasons, they are different studies conducted on biodiesel which blends with diesel fuel shows emission concentration (CO, $CO_2$, HC, PM, NOx) varies and it all depends on sources of biodiesel and also engine combustion system.

In this study, the effects of bio-additive on fuel properties of crude jatropha diesel blends are important that it affect the emission characteristics. Study on bio-additive and crude jatropha oil is carried out to study the effects toward each other. The low proportion of crude jatropha oil (CJO) in biodiesel resulted in lower specific fuel consumption when compared with the high proportion of crude jatropha oil diesel blends and the mineral diesel in the performance of engine[5]. While for the emission of the engine, the low proportion of crude jatropha oil as in biodiesel show in less CO and $CO_2$ emission compared with the diesel [6]. This had proved that the addition of small quantities of CJO to mineral diesel fuel as strategy for increasing alternative fuel consumption is accepted. Thus the additive is discovered to enhance the alternative fuel. The metal based additive and alcohol based additive are both found to have lower emission of CO compared with diesel fuel[7]. However the alcohol based additive is result in higher specific fuel consumption when compared with mineral diesel and the metal based additive cannot show better performance of engine compared with diesel without additive[8]. The formulated diesel additive is resulted in improvement of cetane number but not necessary for the performance of the engine[9]. However, the CO emission of the formulated diesel additive also lower compared with the biodiesel without additive[10-11]. Hence the formulated diesel additive is used to add in the biodiesel that derived from crude jatropha oil to identify the emission of the diesel engine using this biodiesel will be same as the result that had reviewed.

The purpose of this research is to investigate the effects of using diesel fuel blends with CJO and the bio-additive on the emissions characteristics of small diesel engine. The engine speed was varied from 1500-2500rpm without load conditions, CJO blending ratio from 5-15 vol% (CJO5-CJO15) and the volume of bio-additive added are 0.2ml and 0.4ml (BR2-BR4).

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## EXPERIMENTAL SETUP

### Fuel

The Crude Jatroha Oil (CJO) which blended with diesel and standard diesel fuel were used in test project. The CJO is blends with different ratio which are 5(CJO5), 10(CJO10), 15vol% (CJO15) of jatropha oil with the standard diesel fuel. Three blended fuel is prepared for each ratio that the bio-additive or booster additive is added with 0.2ml and 0.4ml that indicated by BR2 and BR4 respectively while the blended fuel that no booster additive added is indicated by BR0. The kinematic viscosity of CJO blend was measured by Viscolite700 model VL700-T15. The density properties measured by Metter Toledo Diamond Scale modeled JB703-C/AF. The flash point measured by Pensky-Martens PMA4. While the engine fuel consumption measured by Ono Sokki mass flow rate meter modeled FM2500. The properties of the tested fuel are detailed in Table-1.

**Table-1.** Properties of the tested fuels.

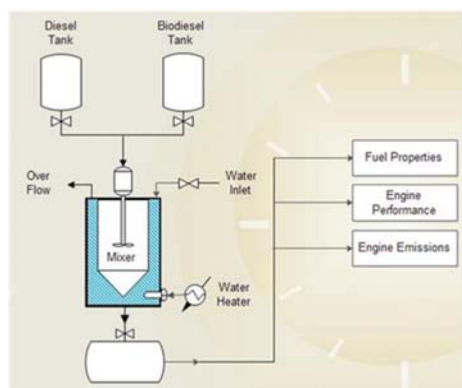
| Fuel type | Fuel Properties | | | |
|---|---|---|---|---|
| | Density ($g/cm^3$) | Kinematic Viscosity (Cp) | Flash point (°C) | Acid value (mg KOH/g) |
| DIESEL | 0.83551 | 3.7 | 83.0 | 0.1138 |
| CJO5BR0 | 0.85129 | 3.8 | 118.3 | 0.2104 |
| CJO5BR2 | 0.85845 | 3.9 | 116.3 | 0.1823 |
| CJO5BR4 | 0.85947 | 4.1 | 115.5 | 0.1683 |
| CJO10BR0 | 0.85630 | 4.2 | 129.3 | 0.3506 |
| CJO10BR2 | 0.86218 | 4.3 | 127.0 | 0.3418 |
| CJO10BR4 | 0.86824 | 4.6 | 124.5 | 0.3342 |
| CJO15BR0 | 0.85825 | 5.2 | 131.2 | 0.5189 |
| CJO15BR2 | 0.86672 | 5.7 | 128.2 | 0.4909 |
| CJO15BR4 | 0.87392 | 6.0 | 125.4 | 0.4726 |

The crude jatropha oil was blended with standard diesel in various concentrations for preparing bio-fuels. During the blending process, the blending machine was operated at 60 °C and the mixture was stirred at 70 °C for one hour. The rotating blade speed was adjusted to maintain the same speed at 270 rpm. The schematic diagram of blending process is shown in Figure-1(b) and the blending machine used show in Figure-1(a).

**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 | 80/69mm |
| Displacement | $347 cm^3$ |
| 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 | 17.5Nm |
| Weight | 40kg |

(a) Blending apparatus




(b) Schematic of blending process

**Figure-1.** Illustrating the blending process of producing crude jatropha oil blended fuel.

### Engine specification

The small diesel engine, HATZ diesel engine 1B30 with 1 cylinder engine was tested in this project. This engine have diesel 2467cc with four-cylinder four stroke cycle with model code S-L049GV-NTD. This engine is design with compact installation dimensions and in all applications with a power requirement up to 8kW due to its low weight. The maximum torque is 17.5Nm. The engine specification including the operating parameter with fuel injection were summarize in the Table-2. Fuel test is essential for evaluating the fuel consumption pattern of an engine operation.

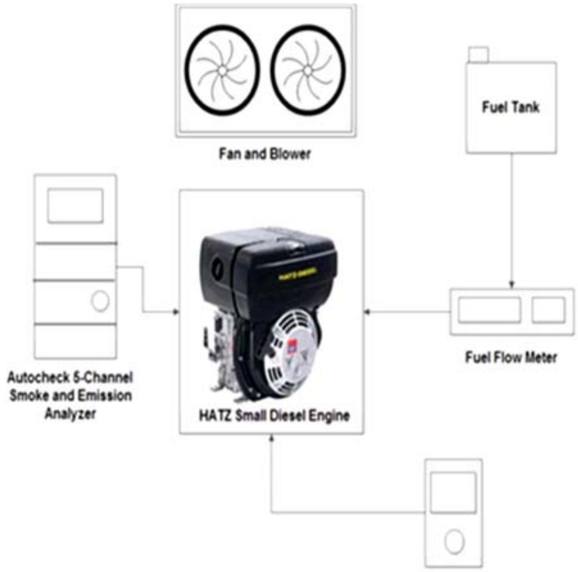



**Figure-2.** Experimental condition.

For this experiment, the running speeds were simulated at 1500, 2000, and 2500rpm. Measurements data comprise fuel consumption rate (kg/hr) togethre with the exhaust emissions such as hydrocarbon (HC), oxygen ($O_2$), carbon dioxide ($CO_2$), carbon monoxide (CO), nitrogen oxides (NOx) and smoke opacity by using autocheck 5 channel gas emossion analyzer. For this research, CJO5BR0, CJO10BR0, CJO15BR0, CJO5BR2, CJO5BR4, CJO10BR2, CJO10BR4, CJO15BR2, CJO15BR4 and standard diesel are used for running under similar engine in a manner similar operation conditions that run for 3 hours. With this, the comparison of the difference fuels were needed by repeating about 3 cycles per each conditions and the analysis and presentation of data is based on average of measurement. The schematic diagram of the experiment setup is shown in Figure-2.

## RESULT AND DISCUSSIONS

Based on the experiments, there are ten types of fuels which are standard diesel (DIESEL), CJO5BR0, CJO10BR0, CJO15BR0, CJO5BR2, CJO5BR4, CJO10BR2, CJO10BR4, CJO15BR2 and CJO15BR4 are used. The emission test for all ten types of fuel was tested under engine speed from 1500, 2000, and 2500 rpm. The effects of booster additive volume on emissions of small diesel engine as the blending ratio increases are discussed on Figure-3. As the blending ratio and the volume of booster additive increases the content of CO also increases. The content of CO is higher compared to standard diesel for CJO10 and CJO15. This is due to the incomplete burning process of the diesel blends. While for the graph of NOx has show that as the volume of booster ratio increase the emission of NOx decreases. The decline of NOx can be seen is same as the decline of the oxygen content and the exhaust temperature. Since the production of NOx is under a medium of high temperature and high oxygen content.

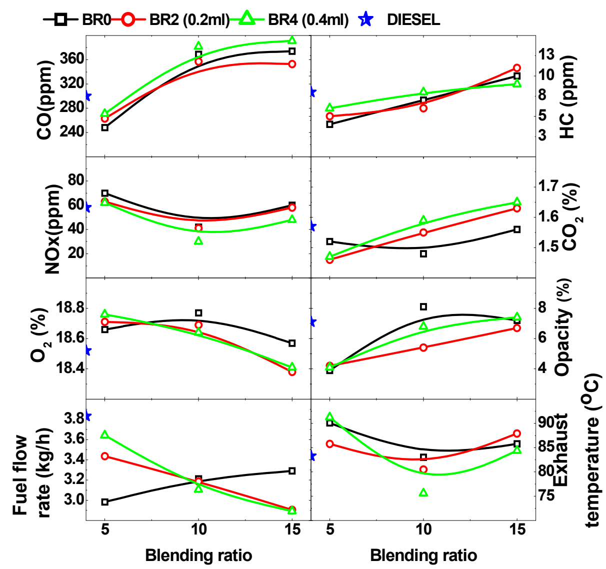



**Figure-3.** Emission characteristics of biodiesel blending ratio with booster additive volume at engine speed 1500rpm for the first hour of engine operation.

By referring to Figure-4, the effects of blending ratio under constant booster additive volume at different engine speeds are discussed. It shows that the increasing of blending ratio will cause the emission of HC, CO and $CO_2$ to be rise at 1500rpm without any bio-additive. This had always due to the poor atomization of the high viscosity that in the diesel blends that cause the incomplete combustion which affects these emissions to be increase. Besides the emission of NOx is found to be decreases as the blending ratio increases that due to the decrease of oxygen content and exhaust temperature. In addition the less of oxygen content also is the cause of incomplete combustion. While smoke opacity also increases as the blending ratio increases.

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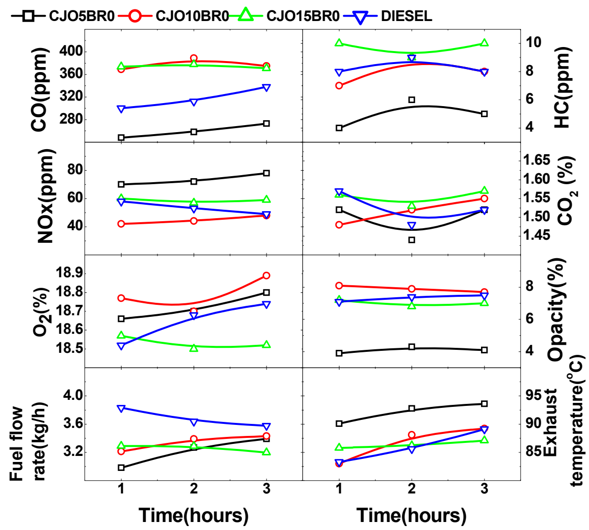


**Figure-4.** Emission characteristics of no additive added with different biodiesel blending ratio at engine speed 1500 rpm by the increasing of time.

Next on Figure-5, the smoke opacity is also showing an increase as the blending ratio increases under the 0.2ml volume of booster additive at 2000rpm. The oxygen content however is decreasing as the blending ratio increasing which in case causes the emission of the NOx also to be decrease. The fuel flow rate of the diesel blends had depicts that the blending ratio increases will cause the fuel flow rate to be decrease. The emission of HC and CO is increases as the blending ratio of CJO increases. This is due to the incomplete combustion. However the emission of $CO_2$ is different with the emission of CO that it decreases as the blending ratio increases.

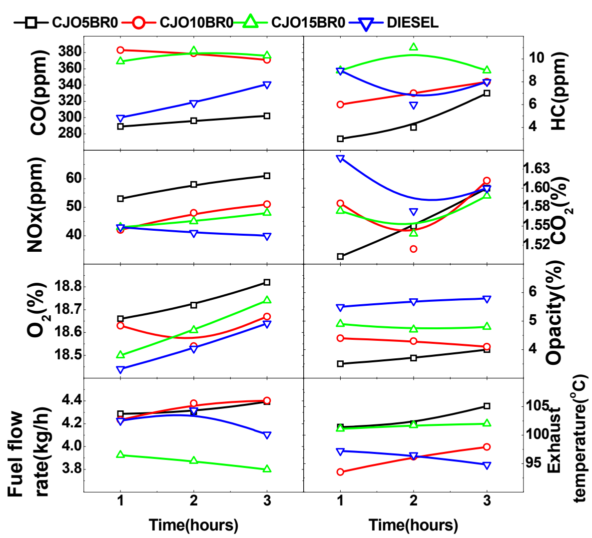


**Figure-5.** Emission characteristics for no additive added with different biodiesel blending ratio at engine speed 2000 rpm by the increasing of time.

As seen in Figure-6, the content of oxygen seems to be increases as the volume of the booster additive increases. However the NOx did not show the same trends with the oxygen content which due to the decrease of exhaust temperature that reduce the emission of NOx. Besides that, the emission of CO increases when the booster additive volume increases and the emission of CO for diesel are much higher than the others CJO5. While the fuel flow rate of diesel blend show that the booster additive volume does have effect on it that it reduce the fuel flow rate for CJO10 and CJO15. However for CJO5 the fuel flow rate is increases as the booster additive volume increases.

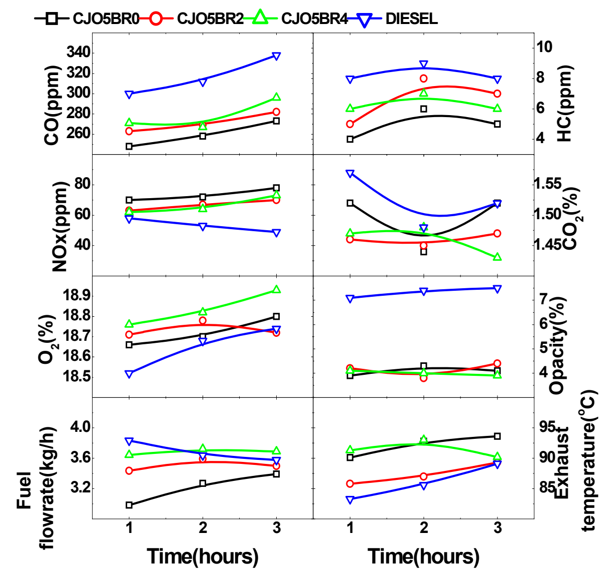


**Figure-6.** Emission characteristics of biodiesel blend CJO5 with different booster additive volume at engine speed 1500rpm by the increasing of time.

From Figure-7, the emission of CO, $CO_2$ and HC are reducing for CJO5 as the booster additive volume is increases at 2000 rpm. This may be due to the booster additive volume had enhance the cetane number that suit the cetane number of the small diesel engine which let the combustion process become more sufficient. The increase of the booster additive volume did not show a significant effect on the smoke opacity since the trends of the graph for the three different booster additive volumes are almost the same. The emission of NOx is also decreases as the volume of the booster additive increases due to the low oxygen content and the low exhaust temperature. The fuel flow rate however show rising as the volume of booster additive increases from 0.2ml to 0.4ml. This is due to the increases of viscosity of the fuel with the present of the booster additive that decreases the energy produced.

At 2500 rpm, the fuel flow rate is increasing as the booster additive volume increase that show in Figure-8. The oxygen content and the emission of NOx also decrease as the booster additive volume increases that the exhaust temperature also shows the decline. While the

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emissions of $CO_2$ and HC of the diesel blends are always higher than the standard diesel. The increases of volume for booster additive did not affect the smoke opacity of the exhaust since the smoke opacity is almost the same for all the CJO5 blends. The emissions of HC and CO are increase as the volume of the booster additive increases due to the less of oxygen content which in case causing incomplete combustion. However the low content of oxygen in exhaust had cause the emission of $CO_2$ become lower as the volume of booster additive increases.

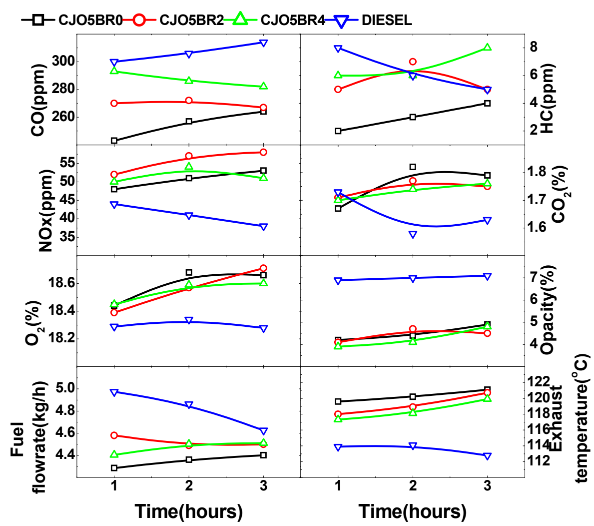


**Figure-7.** Emission characteristics of biodiesel blend CJO5 with different booster additive volume at engine speed 2500rpm by the increasing of time.

## CONCLUSIONS

In this case of study, the ratio of blended (CJO5,CJO10,CJO15) and STD were tested under diesel engine with engine speeds at 1500, 2000, 2500, 3000 rpm. The summary as follows:

i. The properties test for all blended fuel that carried out have given the different of fuel properties due to the existence of the booster additive. However due to the small volume of the booster additive, the influences are not significant.
ii. The higher the blending ratio in diesel blends will cause the emission of HC and smoke opacity to be higher at all engine speeds. The reason of causing this phenomenon to be happened is the high viscosity of the diesel blends. The high viscosity will cause the poor atomization that will cause the incomplete combustion take place in the diesel engine.
iii. The NOx emission is shows decline as the booster additive volume increases. There is sign that show the decline of NOx emission that are the low oxygen content and the exhaust temperature. Since NOx formed under high temperature and pressure with a high oxygen content area thus the decline of NOx emission is reasonable and due to the existence of the booster additive.

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