



# Performance and emission characteristics of a direct injection diesel engine fueled with palm oil-based biodiesel blends

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## Abstract

The availability of fossil fuels is increasingly depleting, so it is necessary to develop alternative fuels that are environmentally friendly. This study aims to evaluate biodiesel as an alternative to fossil fuels and examine the performance and exhaust emissions of this fuel in motor vehicles. One of the alternative fuels evaluated is a mixture of biodiesel derived from pure palm oil (B100) and fuel oil, with compositions ranging from B0 to B60. The mixing procedure was carried out using a stirrer at a certain rotational speed. Performance testing was carried out using the dyno test method, while exhaust emission testing (opacity) was carried out using a smoke meter on a four-cylinder direct injection diesel engine. The fuel variations studied included: B0, B30, B40, B50, and B60. Performance testing was carried out at engine speeds between 2000 rpm and 6000 rpm, in multiples of 1000 rpm. The results of the B40 fuel test produced optimal performance, achieving a maximum torque of 101.6 Nm and a maximum power of 53.1 Hp. Exhaust gas opacity tests showed that B40 exhibited a low opacity of 2.1% at low engine speeds. This demonstrates B40's potential as an effective and environmentally friendly alternative fuel for direct-injection diesel engines.

## Keywords

Palm oil biodiesel, Renewable energy, Diesel engine performance, Exhaust emission, Sustainable fuel

## Introduction

Efforts to meet the fuel needs in the automotive world and the increasing development of vehicles in Indonesia are inversely proportional to the availability of natural fuels in Indonesia, with the problem of fossil fuels being increasingly depleted, this requires research to become a breakthrough in renewable fuels derived from plant-based materials because of the abundant and renewable raw materials and the periodic production volume in Indonesia [1], [2].

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One type of engine used in Indonesia is the diesel engine, which is widely used due to its high fuel efficiency and power compared to gasoline engines. This makes diesel engines widely used as propulsion in heavy vehicles and transportation equipment in the industrial and automotive industries [3], [4]. Another advantage of diesel engines is the flexibility of the types of fuels that can be used, such as dexlite, jatropa, and renewable energy butanol, methanol, and ethanol. This is because the combustion that occurs does not require spark control.

In previous research [5], [6] entitled has conducted research on diesel engine performance testing with B20 and B40 used cooking oil fuel which produces property values that indicate according to Dexlite standards and performance testing to see torque and power shows the best results in the B40 variation. Because previous research variations that were tested were only two variations, namely B20 and B40. Similar things also need to be carried out the same research with different fuel variations with more comparison variations with palm oil materials. With the amount of palm oil being a large commodity in Indonesia, it creates a big opportunity for Indonesia to be independent in renewable fuels that do not depend on natural fuels (fossils) whose availability is increasingly depleted.

In general, vegetable biodiesel can be decomposed biologically and more completely (more than 90% in 21 days) than petroleum biodiesel fuel (around 20% in 21 days). In addition, the use of vegetable biodiesel as fuel is expected to provide economic value in the agricultural sector. One vegetable biodiesel that has the potential to be used as an alternative fuel is palm oil biodiesel [7].

The selection of palm oil biodiesel as an alternative energy source is very appropriate in Indonesia because Indonesia is the second largest palm oil biodiesel producer in the world after neighboring Malaysia. In 2010, Indonesian palm oil biodiesel production is projected to reach 12 million tons/year. In addition, the production of fuel from palm oil biodiesel is more environmentally friendly because it is free of nitrogen and sulfur. Palm oil biodiesel has a long hydrocarbon chain that allows it to be used as a biofuel. The highest fatty acid composition in palm oil biodiesel is oleic acid at 55%. This high oleic acid content is also the basis for consideration for use as a raw material in research on biofuel production from palm oil biodiesel [8], [9].

Based on the above problems, it is necessary to conduct research with the title The Effect of Biodiesel Fuel Mixture on Performance, Fuel Consumption, Exhaust Gas Emissions in Direct Injection Diesel Engines In this case, it is necessary to mix fuel from Palm Biodiesel with Dexlite Pertamina. This research aims to determine the effect of Biodiesel fuel mixture on Performance, fuel consumption and exhaust gas emissions in direct injection diesel engines.

## Method

This study used a comparative blending method between palm oil biodiesel fuel and Dexlite, which tested the performance and exhaust gas opacity of a direct-injection diesel engine. The mixture composition calculation for producing palm oil biodiesel fuel is shown in Table 1.

Table 1. Mixture Composition

No	Concentration variation	Dexlite (%)	Biodiesel (%)
1.	B30	70	30
2.	B40	60	40
3.	B50	50	50
4.	B60	40	60

This study is a mixture of Palm Oil biodiesel fuel with Dexlite and testing the Performance and Opacity of Exhaust Gas on a direct injection diesel engine fueled by biodiesel and Dexlite to determine the Performance and Opacity of Exhaust Gas produced. The Independent Variable in this study is a mixture of Dexlite combined with palm oil biodiesel. The dependent variable in this study is the fuel mixing time and the performance of the diesel engine which includes the amount of power, torque and Exhaust Gas Opacity. The mixing of this study is a mixture of B100 Palm Oil fuel with Dexlite for 60 minutes and heated to a temperature of 40°, the method used in stirring using a magnetic stirrer and power and torque testing is carried out at 2000 rpm to 6000 rpm with an interval of 1000 rpm on the dyno test. Figure 1 shows the fuel mixing scheme.



Figure 1. Fuel mixing scheme

The performance testing method used in this study is a dyno test where power and torque are obtained from the rotation of the rear wheels of the vehicle. According to Figure 2, the Exhaust Gas Performance and Opacity Testing Scheme, this test does not involve any load on the vehicle. Data is obtained from the roll rotated by the rear wheels of the vehicle. Data is taken at engine speeds of 2000 rpm to 6000 rpm using 4<sup>th</sup> gear.

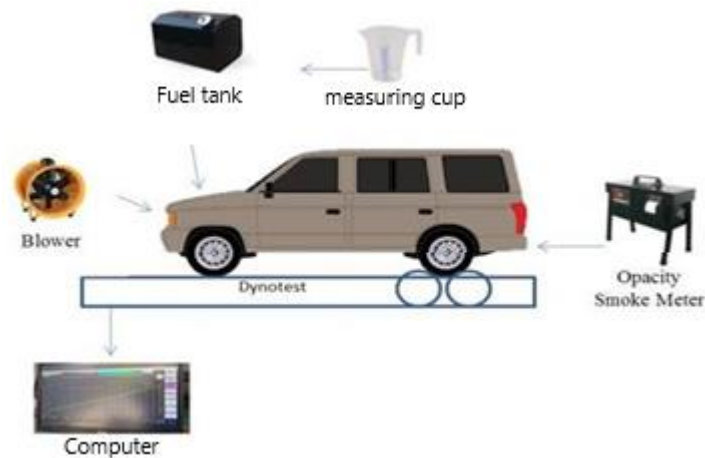


Figure 2. Performance testing scheme

## Results and discussion

Based on Figure 3, the torque versus rpm graph produced from dyno testing with Pertamina Bio Dexlite fuel, B30, B40, B50, and B60 is presented in dark blue, red, purple, and light blue. The lowest torque for Pertamina Bio Dexlite fuel, B30, B50, and B60 is at 2000 rpm, with results of 99.8 Nm, 99.9 Nm, 100.6 Nm, and 101.1 Nm, respectively. As engine speed increases, the torque produced decreases at 6000 rpm. The B40 variation, as shown in the green graph, shows the highest torque produced at 101.64 Nm at 2000 rpm, and as engine speed increases to 6000 rpm, the torque results show a decrease to 64.6 Nm. In the B40 fuel variation, the highest torque test results were shown at the start of the engine rotation because it was caused by a low flash point so that combustion occurred perfectly and produced high torque performance according to research data from [10], [11]. This study showed that the highest torque occurred at low engine rotation, the more the engine rotation increased, the torque produced decreased which was influenced by the combustion speed in the combustion chamber.

Based on Figure 4, the graph above presents the power test data against rpm rotation in the lowest power dyno test produced on Pertamina Bio Dexlite fuel, B30, B50 and B60 at 2000 rpm rotation presented in the graph with dark blue, red, purple and light blue colors showing the results of the power test of 20.5 Hp, 2.7 Hp, 33.1 Hp, and 33.5 Hp. And the more the engine rotation increases, the power produced increases at a peak rpm of 5000 which is shown in the graph with a power value of 50.3 Hp, 51.6 Hp, 52.9 Hp and 53.1 Hp. For B40, the highest power produced is 53.7 Hp at 5000 rpm rotation according to the green graph, the lowest power at 2000 rpm is 33.3 Hp. This occurs an increase in power in B40 because it has a low flash point value so that this fuel burns perfectly and produces maximum power [12], [13].

Based on the graph above at the same rotation so that there is an increase in power in the fuel variations B30, B40, B50, B60 compared to Dexlite, of the four fuel variations that were tested for performance above, the test results according to the graph show a significant increase in power in the B40 fuel variation obtaining a power value of 53.1 Hp at peak rpm, namely 5000 rpm, this is in accordance with the data that has been

carried out by [14] which also presents the highest power data obtained in the B40 fuel variation.

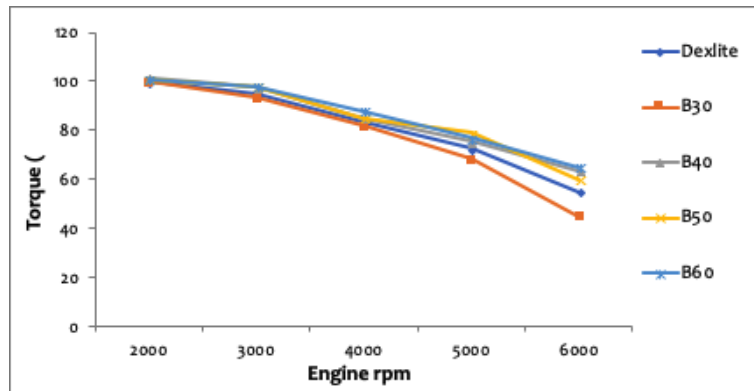


Figure 3. Torque results against rotation

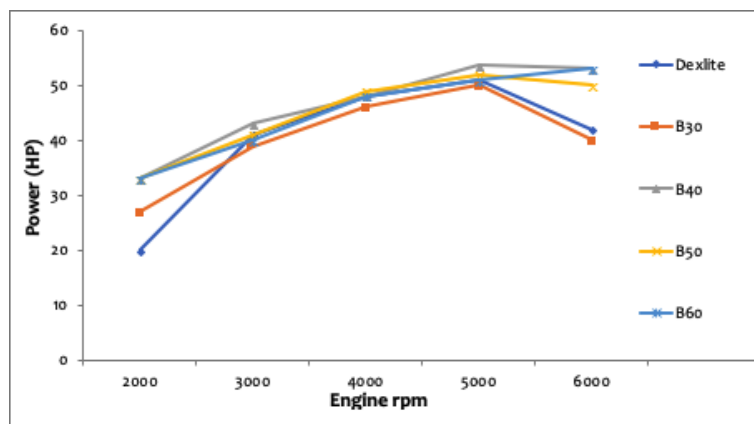


Figure 4. Power results against rotation

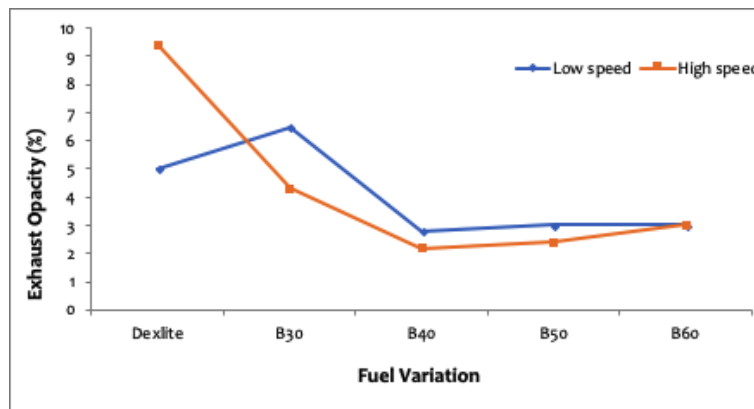


Figure 5. Exhaust Gas Opacity Test Results

Based on the data in Figure 5, the graphic presentation above shows exhaust gas opacity testing for Pertamina’s Bio Dexlite fuel, B30, B40, B50, and B60 palm oil, shown in red for high rpm and blue for low rpm. This indicates the lowest exhaust gas opacity test results for the B40 fuel variation. The opacity value at low rpm is 2.1% and at high rpm is 2.2%. This occurs because the characteristics of B40 fuel comply with Pertamina’s Dexlite standards, and this fuel has a low flash point value, resulting in complete combustion in the combustion chamber, according to data from [15], [16]. The highest exhaust gas opacity is found in Pertamina’s Biodiesel, with an exhaust gas opacity value

at low rpm of 6% and at high rpm of 9.4%. For B30 palm oil, the test results at low rpm produced a value of 5.5% and at high rpm of 9.4%. In contrast, B60 showed a value of 2.8% at low rpm and 3% at high rpm. B50 showed a value of 2.7% at low rpm and 2.4% at high rpm [17].

The exhaust gas opacity test results, based on the graph above, showed a decrease in exhaust gas opacity for the B30, B40, B50, and B60 Palm Oil fuel variations compared to Pertamina's Bio Dextrite. Of the four fuel variations tested, the lowest exhaust gas emission was B40, shown in the graph at 2.1%. This indicates that the exhaust gas emission results meet the standard for category M vehicles, with the maximum exhaust gas emission value at idle engine speed of 4%. This test result shows a value of 2.1%, indicating that exhaust gas emissions fall within the threshold stipulated by the Ministry of Environment of the Republic of Indonesia [16], [18].

## Conclusion

Based on data and analysis on research on the use of B30, B40, B50, B60 Palm Oil fuel on the performance and exhaust gas opacity of direct injection diesel engines, it is concluded that the use of a mixture of Palm Oil Biodiesel fuel with Dextrite shows that the highest torque is obtained at 2000 rpm on a variation of B40 palm oil fuel, which produces 100.6 Nm. The highest power is obtained at 5000 rpm using the same fuel producing a power of 53.7 Hp. And from the results of exhaust gas opacity testing with a variation of B40 palm oil fuel on a low-speed engine which shows an opacity value of 2.1%, this indicates that a variation of the Palm Oil Biodiesel fuel mixture can reduce Exhaust Gas Opacity.

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