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*Research Paper*

# Diesel-Biodiesel Blend on Engine Performance: An Experimental Study

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## Abstract

This article discusses engine performance using diesel oil and biodiesel obtained from the reaction of vegetable oils with alcohol through the process of alcoholysis. Tests carried out on variations of diesel oil 100% (B0), 10% biodiesel (B10), 20% biodiesel (B20) and 30% biodiesel (B30). Engine performance testing is carried out at 1500 rpm to 4000 rpm at intervals of 500 rpm. The highest torque is obtained at 2000 rpm using B0, B10 and B20 of 310.3 Nm, 306 Nm and 308.1 Nm, respectively. The highest power is obtained at 3000 rpm using B0, B10 and B20 of 114.7 hp, 115.1 hp and 114.9 hp, respectively. The average fuel consumption with B0, B10 and B20 is 1.42 ml/s, 1.54 m/s, and 1.74 ml/s, respectively. B30 fuel cannot be tested on a vehicle due to detonation so that combustion does not occur completely and B30 fuel properties are incompatible with the vehicle being tested.

**Keywords:** Transesterification reactions, Biodiesel, Diesel engines, Torque, Power

## Abstrak

Artikel ini membahas performa mesin menggunakan minyak diesel dan biodiesel yang diperoleh dari reaksi minyak nabati dengan alkohol melalui proses alkoholisis. Pengujian dilakukan variasi minyak diesel 100% (B0), biodiesel 10% (B10), biodiesel 20% (B20) dan biodiesel 30% (B30). Pengujian performa mesin dilakukan pada putaran mesin 1500 rpm sampai 4000 rpm dengan interval 500 rpm. Torsi tertinggi diperoleh pada putaran 2000 rpm menggunakan bahan bakar B0, B10,dan B20 masing-masing sebesar 310,3 Nm, 306 Nm, dan 308,1 Nm. Daya tertinggi diperoleh pada putaran 3000 rpm pada B0, B10 dan B20, masing-masing sebesar 114,7 hp, 115,1 hp dan 114,9 hp. Rata-rata konsumsi bahan bakar dengan B0, B10, dan B20, masing-masing sebesar 1,42 ml/s, 1,54 m/s, dan 1,74 ml/s. Bahan bakar B30 tidak dapat diuji pada kendaraan dikarenakan terjadi detonasi sehingga pembakaran tidak terjadi secara sempurna dan propertis bahan bakar B30 yang tidak sesuai dengan kendaraan yang diuji.

**Kata Kunci:** Reaksi transesterifikasi, Biodiesel, Mesin diesel, Torsi, Daya

## 1. Introduction

The depletion of oil reserves is triggered by overuse, which causes problems such as fuel scarcity and price fluctuations. During the last few years, world oil reserves have experienced unstable conditions as the primary energy source, including in Indonesia [1]. It must be reduced by finding alternative fuels that can reduce the excessive use of fossil fuels. Efforts to find alternative energy sources, even renewable energy, are needed to substitute fuel oil.

One alternative renewable fuel is biodiesel that is compatible with diesel engines. Biodiesel is one of the most promising substitutes for diesel fuel that can be produced from vegetable oils, animal fats and waste oils [2]. Biodiesel is a fatty acid ester derived from vegetable or animal oils through the transesterification or esterification reaction [3]–[5]. Biodiesel can also be produced from animal fats and wastes so that diesel fuel is non-toxic, biodegradable, and environmentally friendly [6].

There are several limitations of biodiesel as a fuel in diesel engines such as cold flow and oxidation stability. The use of biodiesel depends on the environmental temperature and the specific nature of biodiesel which is influenced by the composition of fatty acids [7]. Biodiesel composed of the primary molecule namely fatty acid methyl esters (FAME) has been proven to be effective in reducing levels of pollution to the environment and able to increase the value of energy efficiency in the transportation sector [8]. Roy [9] investigated the performance of diesel engines at 1800 rpm with variations in three effects, namely low, medium and high, which used three variations of fuel: biodiesel-diesel, biodiesel-diesel-additive and biodiesel-kerosene. The results showed that the average reduction in CO and HC was 20% and 35% respectively, while the average increase in NOx was 13% with diesel using B100.

Engine vibration and engine noise can also be reduced by using biodiesel [10]. Heidary [11] examined the mixing ratio between biodiesel and diesel fuels. Based on the results of the analysis, it was concluded that the fuel mixture has a significant effect on the vibration produced. As a difference from the studies previously mentioned, this study aims to investigate the performance of diesel engines with diesel-biodiesel blends and how much fuel consumption is used.

## 2. Method

### 2.1. Biodiesel preparation

First, material for biodiesel is put into a container which includes: palm oil (1 liter), a mixture of methanol (200 ml) with a catalyst (NaOH) (3.5 grams). Then, stirring for ±20 minutes. The determination of the amount of biodiesel is presented in Figure 1.

Second, the conditioning process of the reaction between the separation of fatty acids/biodiesel and glycerin in a closed container for ± 12 hours Figure 2a. Third, pouring biodiesel into a new container to separate the glycerin precipitate with biodiesel which is above the glycerin (Figure 2b). Purification of biodiesel is carried out for ± two days until it is clear yellow and then biodiesel can be used for mixing with diesel fuel. The results of biodiesel produced are presented in Figure 2c.

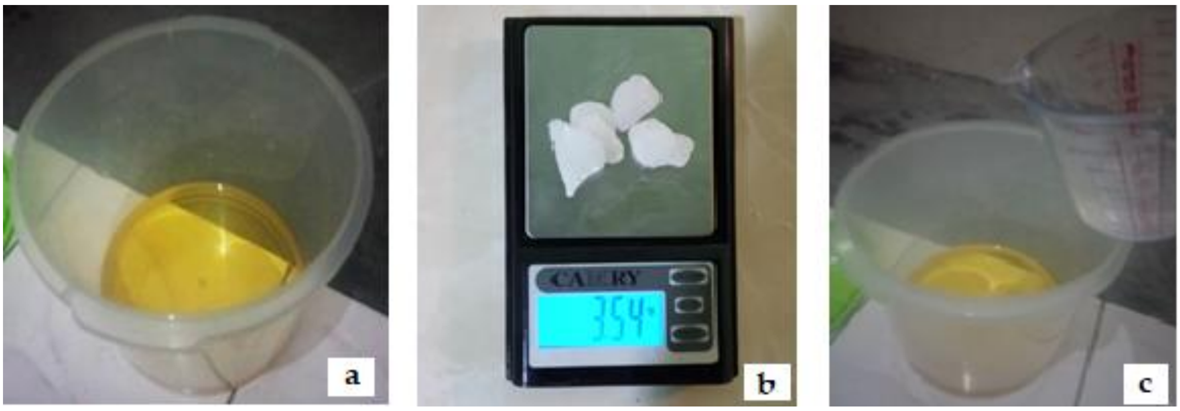


**Figure 1.** Determination of material for biodiesel: (a) palm oil, (b) catalyst, (c) the basic materials mixing

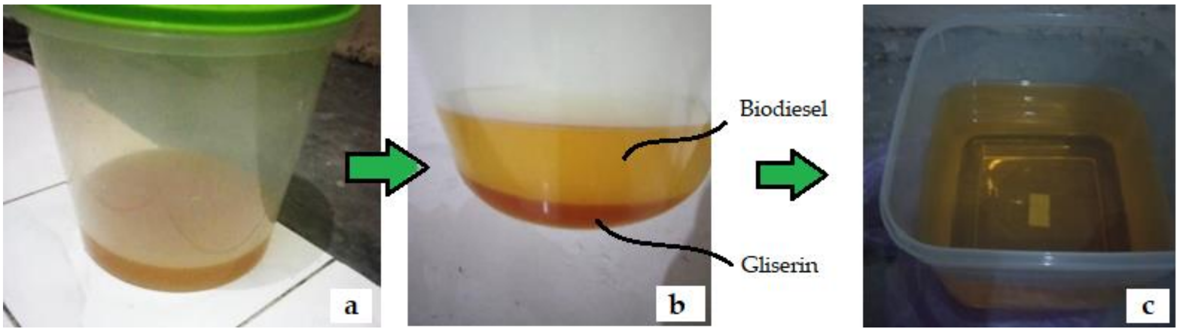


**Figure 2.** The process of separation reaction between fatty acids/biodiesel and glycerin

### 2.2. *Fuel mixing*

The process of mixing diesel fuel with biodiesel is carried out with the following steps. First, the process of making a fuel mixture is done with a measuring cup, using a ratio of 100% diesel (B0), 10% biodiesel + 90% diesel (B10), 20% biodiesel + 80% diesel (B20) and 30% biodiesel + 70% (B30). Second, the measuring cup is placed in a flat. Biodiesel and diesel are mixed in a measuring cup at a volume of 450 ml for diesel with 50 ml of biodiesel as a variation of B10, 400 ml of diesel with 100 ml of biodiesel as a variation of B20 and 350 ml of diesel with 150 ml of biodiesel as a variation of B30. The measurement of the mixture is shown in Figure 3.

### 2.3. *Set up experiment*

The study begins with the preparation of the tested vehicle, with the specifications shown in Table 1. For engine performance tests, the vehicle is mounted to a dynamometer that has been connected to a computer. Engine performance testing is carried out from 1500 rpm to 4000 rpm at intervals of 500 rpm, to produce torque, power and fuel consumption. The set up of experiments is presented in Figure 4.

**Figure 3.** Comparison of fuel mixtures in B20 variations

**Table 1.** Vehicle specification

| | | |
|---|---|---|
| Engine | : | 2GD FTV 4 Cylinder In-line, 16 valve DOHC with VNT Intercooler |
| Cylinder | : | inline |
| Bore x stroke | : | 92.0 mm x 93.8 mm |
| Capacity | : | 2393 cc |
| Fuel system | : | Common Rail |
| Transmission | : | Manual |
| Power | : | 102 Ps/3600 rpm |
| Torque | : | 26,5 kgm/2400 rpm |


**Figure 4.** Set up experiment

## 3. Result and Discussion

### *3.1. Testing fuel properties*

Testing the fuel properties includes caloric value, viscosity, density and flashpoint. The results are presented in Table 2 as follows.

**Table 2.** Test results of fuel properties

| Fuel | Properties | | | |
|---|---|---|---|---|
| | Caloric value (cal/g) | Kinematic viscosity at 40°C (cst) | Density at 20°C (g/ml) | Flash Point (°C) |
| B0 | 9597,38 | 2,923 | 0,835 | 48,0 |
| B10 | 8923,71 | 3,632 | 0,840 | 42,0 |
| B20 | 9601,97 | 3,946 | 0,846 | 39,5 |
| B30 | 8946,40 | 4,327 | 0,857 | 41,2 |

From Table 1, it can be seen that the caloric value of diesel fuel mixtures with biodiesel has decreased and increased. Changes in heating value will affect fuel consumption, where the lower the heating value, the higher the fuel consumption. In terms of viscosity, changes occur in the mixture of diesel and biodiesel will affect engine performance, including power, torque and fuel consumption. High viscosity causes poor fuel spray during an injection [12].

The density of the mixture of diesel and biodiesel has increased compared to pure diesel. Density indicates the density of fuel, the higher the density causing high boiling points and difficult to evaporate. The mixture of diesel and biodiesel in Table 1 also shows a low flash point value compared to pure diesel fuel. Flashpoint is the temperature at which the fuel will burn by a heat source.

### *3.2. Engine performance testing*

Engine performance testing is carried out on diesel engines with B0, B10, B20 and B30 fuels. This test aims to measure changes in torque, power, and fuel consumption. Engine torque and power are obtained at full open throttle. B30 was not tested due to a knocking indication. The results of torque tests on the use of B0, B10, and B20 are presented in Figure 5. Meanwhile, the results of the power test are presented in Figure 6.

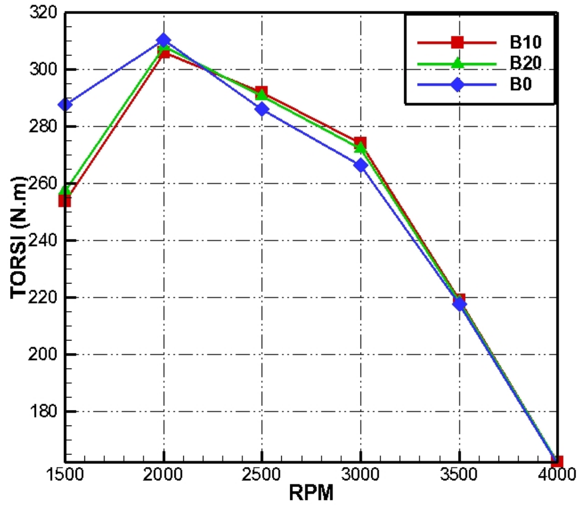


**Figure 5.** Engine torque with B0, B10 and B20.

Figure 5 shows that the highest torque produced by B0 is 310.3 Nm at 2000 rpm. For B10, the maximum torque is 306 Nm and for the B20 composition, the maximum torque is 308.1 Nm at the same rotation. That is, there is a decrease in torque at B10 and B20 with a decrease in percentage of 1.38% and 0.70%, respectively.

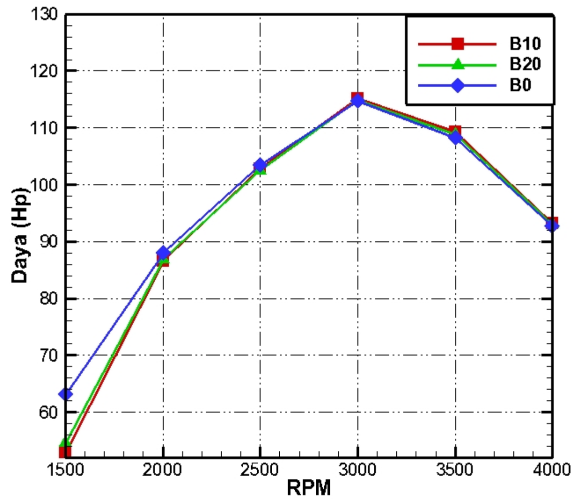


**Figure 6.** Engine power with B0, B10 and B20.

Based on Figure 6, the highest power obtained from B0, B10, and B20 are 114.7 hp, 115.1 hp, and 114.9 hp at 3000 rpm, respectively. There was an increase in power at B10 and B20 by 0.35% and 0.17%, respectively. These results also confirm the results of previous studies, that viscosity, caloric value, and flashpoint affect power output [8], [13].

### 3.3. *Fuel consumption*

In measuring fuel consumption, the test is carried out by calculating the time needed to spend 100 ml of B0, B10 and B20, respectively. The test results show an increase in fuel consumption for the addition of biodiesel concentrations (Figure 7). This increase was due to the caloric value of biodiesel which was lower than diesel oil [14].

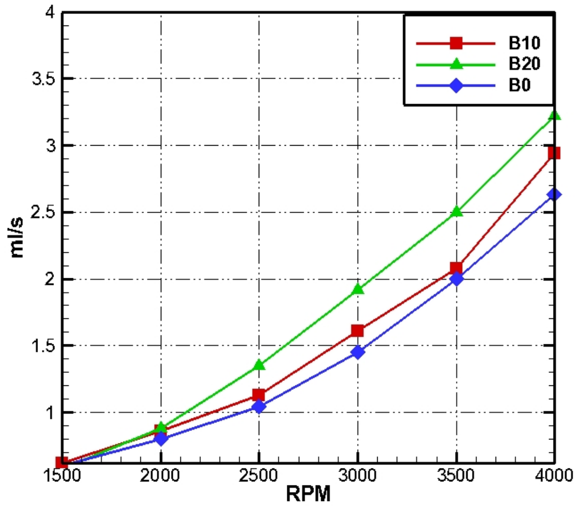


**Figure 7.** Results of fuel consumption testing

## 4. Conclusion

During the research process, we found that the use of B10 and B20 resulted in a decrease in torque of 1.38% and 0.70%, respectively. Also, there is a decrease in power due to the use of B10 and B20 by 0.35% and 0.17%, respectively. We also found that biodiesel consumption is more than diesel oil for the same engine load. Weaknesses of the use of biodiesel are suspected from the caloric value of biodiesel which was lower than diesel oil.

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