Comparative Analysis of Fuel Economy of B30 and B20 Fuels in Passenger Vehicles

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The higher biodiesel content blended into diesel fuel gives the lower calorific value that may affect the fuel economy. To determine the effect of using 30 % biodiesel mixed in diesel fuel (B30) compared to B20, especially on fuel economy in automotive vehicles, a road test was conducted using 4 brands of passenger vehicles for 50,000 km. The daily route of this road test consisted of 10.6 % of general road, 49.9 % of climbing-downhill road, and 39.5 % of highway road, which covers a distance of 560 km per day. The method used in this study for fuel economy analysis is the full-to-full method, by comparing the fuel consumption of B30 and B20 in two vehicles in each brand (8 cars in total). Based on the test results, statistically, in testing the fuel economy with full to full method, population of data used has been normally distributed and homogeneous. In Passenger1 and Passenger4 vehicles, the average fuel economy value of B30 is 6.7 % and 3.7 % higher than the B20’s, while in vehicles Passenger2 and Passenger3, the average fuel economy value of B20 is 1.5 % and 3.9 % higher than those of B30. In addition, the results of the one way ANOVA test on data of passenger vehicles B20 and B30 shows p-value <0.05, which states the average value of fuel economy in each passenger vehicle is different based on statistical analysis. However, based on the difference of engine technology, the fuel consumption of B30 and B20 does not have a significant difference.

Key Words
Biodiesel, B30, Fuel economy, Full-to-full, Passenger vehicles

1. Introduction

Biodiesel has become a favorable fuel for diesel fuel substitute because it is a renewable fuel that has other advantages such as lower emissions, high cetane number, low sulfur content, and improvement of lubricity 1) ~ 3). The utilization of biodiesel can promote the achievement of United Nation’s Sustainable Development Goal especially in a sustainable and renewable energy 4) ~ 6).

Biodiesel is defined as mono-alkylesters of fatty acids produced from trans-esterification reaction of vegetable oil or animal fats with short-chain alcohol, such as methanol. Biodiesel has been used as blended fuel with conventional diesel fuel. However the maximum blending of biodiesel is still limited by its disadvantages such as its calorific content, cold flow properties, and impurities such as monoglycerides 3) 7). The higher biodiesel content blended into diesel fuel gives the lower calorific value 8) 9) that may affect the fuel economy that describes as mileage (km) per volume of fuel (liter) for vehicles. This effect has become an obstacle for commercialization of biodiesel in higher blending portion.

In Indonesia, the implementation of biodiesel fuel has been regulated by the government 10) to improve from 20 % of blending (B20) at 2016 to reach 30 % of blending (B30) in 2020. The effect of B20 in diesel fuel vehicles has been investigated and compared with diesel fuel (B0) in a durability testing on a road test covering 40,000 km 11) 12). Due to its lower calorific value, for an average distance traveled, the consumption of fuel of B20 was around 0.5 % higher compared to B0.

The result from previous research shows that the effect from using B20 compared to B0 is not significantly
different in passenger vehicles. However, with the increase the percentage of biodiesel to B30, the effect needs to be clarified. To determine the effect of B30 compared to B20, especially on consumption of fuel in automotive vehicles, a road test was conducted before the implementation of B30.

2. Methodology

The road test was conducted for 50,000 km using 8 vehicles of 4 different brands, notified as P1, P2, P3, and P4. All vehicles were equipped with diesel common rail engine. Specifications of vehicles are presented at Table 1. Each brand was tested using B20 and B30, running at the same daily route as described in Fig. 1, started at 3:00am from Lembang, West Java, Indonesia (1500 m above sea level) to Guci, Central Java, Indonesia (1330 m above sea level) then ended in Lembang at 8:00pm to stay overnight. The daily route of this road test consisted of 10.6% of general road, 49.9% of climbing-downhill road, and 39.5% of highway road, which covered a distance of 560 km per day.

The fuel used in this test was analyzed according to regulation. Diesel fuel was obtained from PT Pertamina (Persero) (Cilacap, Central Java, Indonesia) while biodiesel was obtained from members of Indonesia Biofuels Producer Association (APROBI). The properties of diesel fuel and biodiesel are presented in Tables 2 and 3. Diesel fuel and biodiesel was blended using a blending plant located in Laboratory for Fuel Technology and Design Engineering (South Tangerang, Indonesia) to produce B20 and B30. The fuels were tested to ensure the characteristic met the standard.

The method used in this study for fuel economy analysis is the full-to-full method, by comparing the fuel consumption of B30 and B20 in two vehicles of each brand. Each day before start the route at Lembang, the fuel tank of each vehicle was filled until full. The volume of fuel was measured using measuring glass and the mileage measured by odometer of the vehicle was recorded. When the testing vehicles arrived at Guci for refueling, the fuel tank of each vehicle was filled until full and the volume was measured. The volume of fuel at full refueling was the volume of

| Specifications | P1 | P2 | P3 | P4 |
|----------------|----|----|----|----|
| Vehicle type   | SUV| SUV| SUV| PICKUP|
| Engine type    | DOHC| DOHC| DOHC| SFD|
| Vehicle Cylinder | 4 - 2,399 cc| 4 - 2,500 cc| 4 - 2,488 cc| 4 - 1,300 cc|
| Max Power      | 109.6 kw @3,400 rpm| 130.5 kw @4,000 rpm| 141.7 kw @3,600 rpm| 56 kw @4,000 rpm|
| Max Torque     | 400 Nm @1,600 - 2,000 rpm| 430 Nm @2,500 rpm| 450 Nm @2,000 rpm| 190 Nm @1,750 rpm|

SUV = Sport Utility Vehicles; DOHC = Double Overhead Camshaft; SFD = Synchronized Fuel Distribution

| Parameter                  | ASTM Test Method | B0 (Average) | Requirement (10) |
|----------------------------|------------------|--------------|------------------|
| FAME content, %            | D7371            | 0            | -                |
| Density at 15 °C, kg/m³    | D4052 (10)       | 864.16       | 815 – 870        |
| Viscosity at 40 °C, mm²/s  | D445 (10)        | 3.62         | 1.8 – 4.05       |
| Total Acid Number, mgKOH/g | D664 (10)        | 0.16         | Max. 0.6         |
| Water content, ppm         | D6304 (10)       | 75.96        | Max. 500         |

| Parameter                  | ASTM Test Method | Biodiesel (Average) | Requirement (10) |
|----------------------------|------------------|---------------------|------------------|
| Density at 40 °C, kg/m³    | D4052 (10)       | 856.56              | 850 – 890        |
| Viscosity at 40 °C, mm²/s  | D445 (10)        | 4.48                | 2.3 – 6.0        |
| Total Glycerol, %mass      | SNI 7182:2015    | 0.17                | Max. 0.24        |
| Free Glycerol, %mass       | SNI 7182:2015    | 0.01                | Max. 0.02        |
| Total Acid Number, mgKOH/g | D664 (10)        | 0.24                | Max. 0.5         |
fuel consumed by each vehicle during the mileage. This activity was repeated every day until the final distance was completed.

To determine the difference between consumption of B20 and B30 at each brand, the data was analyzed with one way ANOVA test. A normality test of Shapiro Wilk and homogeneity test was conducted prior to the ANOVA test.

3. Results and discussion

Each fuel used in this road test was analyzed in several important parameters. The result of fuel analysis is within the requirement, as presented at Table 4.

The fuel consumed by P1, P2, P3, and P4 vehicles up to a distance of 50,000 km was analyzed. The fuel economy is determined as the distance travelled by the vehicle divided by volume of fuels consumed during that distance. Each testing vehicles completed the final distance on target. During the testing, a routine maintenance was conducted by each manufacturer for every 10,000 km.

The result of analysis on P1 is shown in Fig. 2. The average fuel economy of P1 B20 vehicles is 12.1 km/L while for P1 B30 is 11.3 km/L. This value shows a significant difference where the average consumption of P1 B30 is 6.7% higher than that of P1 B20. The difference is more than 5% that may be highly affected by the lower calorific value of B30 compared to B20. Fig. 2 also shows a tendency of decreasing. However, the result of normality test of Shapiro Wilk and homogeneity test shows that the data is homogeneous.

Meanwhile, the average consumption of fuel in P2 B20 and P2 B30 does not show a significant difference where P2 B20 is 1.5% higher than P2 B30, as presented in Fig. 3. This result is opposite to the one of P1 although the difference between B20 and B30 is below 5%. The average fuel economy of P2 B20 vehicles is 11.5 km/L while for P2 B30 is 11.7 km/L.

On the other hand, Fig. 4 shows that the average consumption of P3 B20 is 3.9% higher than that of P3 B30. The tendency is similar to P2. The average fuel economy of P3 B20 vehicles is 12.0 km/L while for P3 B30 is 12.5 km/L.

At last, the average fuel consumption of P4 B20 vehicles is 11.9 km/L while for P4 B30 is 11.4 km/L, as presented in Fig. 5. This value shows a significant difference where the average consumption of P4 B30 is 3.7% higher than that of P4 B20. This result is similar to P1 but the difference between B20 and B30 is below 5%.

The data of each passenger vehicle B20 and B30 were tested using one way ANOVA test. The result shows $p$-value < 0.05 which states the average value of fuel economy in each passenger vehicle is different based on statistical analysis. However, Fig. 6 shows that the result

| Parameter            | Test Method | B20 | B30 | Requirement (±) |
|----------------------|-------------|-----|-----|-----------------|
| FAME content, %      | ASTM D7371  | 20.11 | 30.32 | ± 1.5%          |
| Density at 15°C, kg/m³ | ASTM D4052  | 855.76 | 860.16 | 815 – 870       |
| Viscosity at 40°C, mm²/s | ASTM D445  | 3.79  | 3.86 | 1.8 – 4.05      |
| Total Acid Number, mgKOH/g | ASTM D664 | 0.17  | 0.19 | Max. 0.6        |
| Water content, ppm   | ASTM D6304  | 187.56 | 234.74 | Max. 500       |

![Fig. 2 Fuel Economy of P1 B20 and P1 B30](image-url)
**Figure 3** Fuel Economy of P2 B20 and P2 B30

**Figure 4** Fuel Economy of P3 B20 and P3 B30

**Figure 5** Fuel Economy of P4 B20 and P4 B30
is different from one brand and another. In P1 and P4, the vehicle that using B30 consumed more fuel at the same distance compared to that of using B20. On the contrary in P2 and P3 the vehicle that using B20 has higher fuel consumption than that of using B30. This indicates that, besides the calorific value of the fuel, engine technology, engine conditions and setting could be considered to have an important influence in fuel economy, as also mentioned by previous research\(^\text{11)}\).

Therefore, based on the difference of engine technology of each brand, the fuel consumption of B30 and B20 does not have a significant difference.

### 4. Conclusion

A road test has been conducted using 4 brands of passenger vehicles for 50,000 km to compare between B20 and B30. The effect of using 30% biodiesel mixed in diesel fuel (B30), especially on fuel economy in automotive vehicles, has been determined. In Passenger1 and Passenger4 vehicles, the average fuel economy value of B30 is 6.7% and 3.7% higher than the B20's, while in vehicles Passenger2 and Passenger3, the average fuel economy value of B20 is 1.5% and 3.9% higher than those of B30. In addition, the results of the one way ANOVA test on data of passenger vehicles B20 and B30 shows p-value <0.05, which states the average value of fuel economy in each passenger vehicle is different based on statistical analysis. However, based on the difference of engine technology of each brand, the fuel consumption of B30 and B20 does not have a significant difference.

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