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Partially Hydrogenated Waste Cooking Oil as a Fuel in the Diesel Engine

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Abstract: ***This research aims to analyse the opacity value of diesel engines from seven types of fuel. The fuels used are diesel (D100), mixture of biner diesel 90-biodiesel of waste cooking oil (WCO) 10 %v/v (B10),mixture of biner diesel 80-biodieselWCO 20 %v/v (B20), mixture of biner diesel 70-biodiesel WCO 30 v/v% (B30), mixture of biner diesel 90-partially hydrogenated biodiesel 10 %v/v (PH10), mixture of biner diesel 80-partially hydrogenated biodiesel 20%v/v (PH20), mixture of biner diesel 70-partially hydrogenated biodiesel 30% v/v (PH30), Then an opacity value test was carried out using a pressure variation of 1900 to 2100 Psi with an increase of 50 Psi for each type of fuel. The research results show that the use mixture of biner diesel-partially hydrogenated biodiesel produces lower exhaust gas emissions compared to diesel and a binary mixture of diesel-biodiesel. Insignificant changes were produced by diesel fuel and diesel-biodiesel binary mixtures above 2000 Psi.***

Keywords: opacity value, partially hydrogenated biodiesel, waste cooking oil

1.Introduction

Recent progress on reducing fossil fuel use in the transportation sector increases rapidly to overcome the green energy environment and anticipate fossil fuel depletion. At this point, biodiesel becomes popular as a fuel in the internal combustion engine such as diesel engines. Some organic resources have been investigated actively, such as Calophyllum inophyllum oil [1], Jatropha oil [2], palm oil [3], and other potential resources.

Use of palm oil, normally, intended as frying oil for cooking. In rural areas, the oil has been used repeatedly many times, and the remaining used oil can be categorized as waste cooking oil (WCO), which is in Indonesia, it is called Jelantah oil. Impact of high temperature while cooking and longtime utilization produces pyrolysis effluent, oxidation, and significant increases in polymerization [4]. In addition, in certain worst conditions levels, it may cause cancer due to carcinogenic potential [5]. However, the WCO can proceed to biodiesel with the appropriate esterification [6] and transesterification processes [7]. Adding some catalysts can be used to accelerate biodiesel production, such as bio-based heterogeneous catalyst [8], green catalyst [9], and/or other catalysts.

Biodiesel has some advantages compared to diesel fuel such as lower toxicity, higher flash point, and ability to naturally be decomposed. On the other hand, the lack of cold flow characteristics and oxidation stability limit are some of the disadvantages of biodiesel, due to the high concentration of unsaturated fatty acids of methyl ester[10]. Oxidation stabilization primarily can be caused by unsaturated fatty acids and natural oxidants [11]. Moreover, a high concentration of unsaturated fatty acids of methyl ester results in a higher risk of oxidative degradation leading to a shortening induction period and increasing cold flow characteristics of biodiesel [12]. The rest of the saturated fatty acids will result in a higher cetane number and increasing oxidation stability, but it can reduce cold flow characteristics. Therefore, it will produce a lower heating value, but higher viscosity [13]. This phenomenon can reduce the performance of the diesel engine in a lower environmental temperature, especially in winter. To overcome these weaknesses, partial hydrogenation of biodiesel could be an appropriate method should be applied [14].

Partial hydrogenation of fatty acid methyl ester can cut the double bond of biodiesel (Quaranta et al., 2022). In addition, the process is also able to reduce cold flow characteristics and fog and pour points. To reduce the number of poly-unsaturated esters, such as linoleate methyl and linolenic methyl, the dehydrogenation process can reform them to oleate methyl by using hydrogen gas and catalysts at a lower temperature of less than 140^{o}C [15]. However, it should be noted that some parameters can affect the partial hydrogenation process such as the process length time, stirring speed, catalyst types, catalysts loaded mass, hydrogen flow rate, and precursor quality [16].

Besides the complexity of the partial hydrogenation process, it can be promoted as the best process to increase oxidation stability and cut the double bond of biodiesel. Therefore, in this paper, the study of the partial hydrogenation process applied to WCO to produce biodiesel will be presented. In addition, the utilization of the produced biodiesel in the diesel engine will also be demonstrated including smoke opacity testing with various fuel nozzle pressures.

2.Method

Waste cooking oil that has proceeded to biodiesel was obtained from Lengis Hijau Foundation in Bali, Indonesia. It was collected from the hotels and restaurants in the tourist area of Bali. The 350g of WCO is partially hydrogenated by mixing with 180g of hydrogen donors, 5% w/w of catalyst aluminium oxide (Al_2O_3), and 180g of distilled water as a solvent. A magnetic stirrer is operated in the mixing process at 500 rpm and 80^{o}C of temperature for 90 minutes. The partial hydrogenation of biodiesel is mixed with diesel oil with a variation of 10% (PH10), 20% (PH20), and 30% (PH30) by volume. As a comparison, 100% diesel oil (D100), mixed between

WCO and diesel oil with a variation of 10% (B10), 20% (B20), and 30% (B30) was also tested. While for the diesel engine, a four-stroke, single horizontal cylinder generator set with a maximum power of 8 horsepower was used for the experiments to identify the effect of the biodiesel on the emission, especially for the smoke opacity, which is measured by smoke opacimeter. The specifications of this tool are Model Number: SY-OM501, Measuring Method: Smoke opacity (%), k (m-1): Light absorption coefficient - RPM (option), °C (option): Light extinction method (Partial-flow sampling type). The engine also has an optimal engine rotation of 2600 rpm and a compression ratio of 21-22 can be achieved.

The experiments were conducted based on the Indonesian National Standard (SNI 19-7118.2-2005). The fuel nozzle pressure is varied from 1900 to 2100 psi with 50 psi of increment, with the detailed procedure is, firstly, set the fuel nozzle procedure at 1900 psi by using nozzle tester and when the engine is started, increases the speed of the engine to the maximum of 2600 rpm. Later, hold the engine speed for a while until the read of the value shown on the smoke tester is stable. This procedure is repeated for the other fuel nozzle pressure studied in this experiment.

3.Result and discussions

Smoke opacity testing of diesel engine was carried out using the SNI 19-7118.2-2005. The data taken is the smoke opacity value produced from a diesel engine using D100, B10, B20, B30, PH10, PH20, PH30 with variations in nozzle injection of 1900, 1950, 2000, 2050, and 2100 Psi, respectively.

a. Nozzle injection at 1900 Psi

Table 1 below presents data on the results of smoke opacity testing from a diesel engine at an injector nozzle pressure of 1900 Psi using seven different fuel variations.

Table 1: Smoke Opacity at Pressure of 1900 Psi

Fuel	Opacity					Total (%)	Average (%)
	I	II	III	IV	V		
D100	19.40	19.00	19.10	19.00	19.60	96.10	19.22
B10	16.90	16.30	17.10	16.30	16.80	83.40	16.68
B20	14.40	14.70	14.80	14.50	14.80	73.20	14.64
B30	14.00	13.40	13.50	13.30	13.40	67.60	13.52
PH10	12.90	13.40	13.00	13.10	12.90	65.30	13.06
PH20	8.40	8.20	8.50	8.20	8.00	41.30	8.26
PH30	7.70	7.10	7.00	7.30	7.20	36.30	7.26

The lowest smoke opacity value was produced from a mixture of 70% diesel fuel and 30% v/v partially hydrogenated biodiesel (PH30) which had an average value of 7.26%. Meanwhile, the highest value was shown using diesel fuel (D100) which had an average value of 19.26%. For more details, see Figure 1.

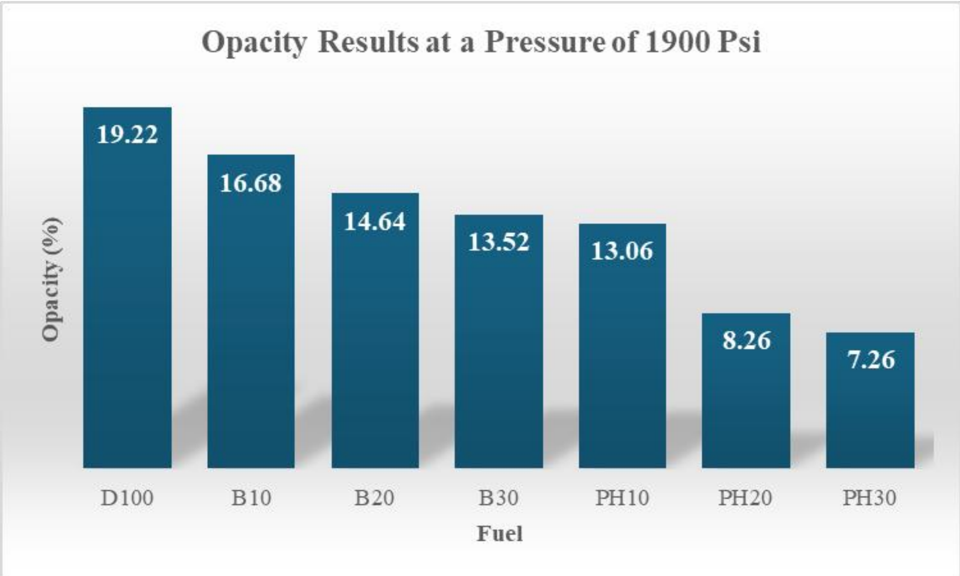

Figure 1: Graph of Smoke Opacity Results at Pressure of 1900 Psi

b. Nozzle injection at 1950 Psi

The opacity test was carried out in the same way where the injection pressure was changed to 1950 Psi, so the results obtained were as in table 2.

Table 2: Smoke Opacity at Pressure of 1950 Psi

Fuel	Opacity					Total (%)	Average (%)
	I	II	III	IV	V		
D100	18.40	18.60	18.40	18.30	18.60	92.30	18.46
B10	17.30	17.50	17.50	17.20	17.30	86.80	17.36
B20	16.70	16.40	16.50	16.50	16.30	82.40	16.48
B30	15.80	15.30	15.70	15.80	15.60	78.20	15.64
PH10	13.40	13.40	13.70	13.30	13.70	67.50	13.50
PH20	10.40	10.40	10.30	10.40	10.30	51.80	10.36
PH30	9.40	9.80	9.70	9.70	9.50	48.10	9.62

Opacity testing in the same way was carried out where the injection pressure was changed to 1950 Psi. Increasing the injection pressure causes the opacity value of to PH30 increase and D100 decrease. The lowest smoke opacity value was produced by PH30 which had an average value of 9.62%. Meanwhile, the highest value was shown using D100 which had an average value of 18.46%. For more details, see Figure 2.

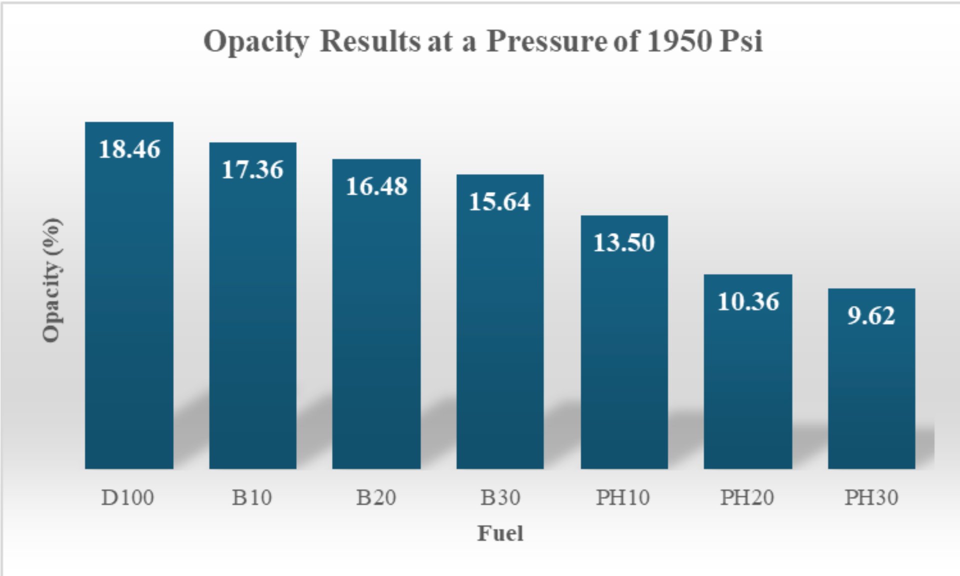

Figure 2: Graph of Smoke Opacity Results at Pressure of 1950 Psi

c. Nozzle injection at 2000 Psi

The injection pressure is increased to 2000 Psi. This pressure was given to seven types of fuel with five repetitions to obtain the average opacity value. The opacity values are shown in table 3.

Table 3: Smoke Opacity at Pressure of 2000 Psi

Fuel	Opacity					Total (%)	Average (%)
	I	II	III	IV	V		
D100	22.90	22.60	23.00	23.20	23.40	115.10	23.02
B10	18.20	18.30	18.60	18.50	18.30	91.90	18.38
B20	16.50	16.80	16.70	16.50	16.70	83.20	16.64
B30	21.70	22.60	22.20	22.40	21.80	110.70	22.14
PH10	12.80	12.60	12.70	12.40	12.60	63.10	12.62
PH20	10.80	10.60	10.30	10.10	10.70	52.50	10.50
PH30	10.00	10.60	9.60	10.10	10.50	50.80	10.16

Increasing the pressure from 1950 to 2000 Psi results in an increase in the opacity value for almost every type of fuel. The lowest smoke opacity value was produced by PH30 which had an average value of 10.16%. Meanwhile, the highest value is shown in the use of D100 which has an average value of 23.02%. For more details, see Figure 3.

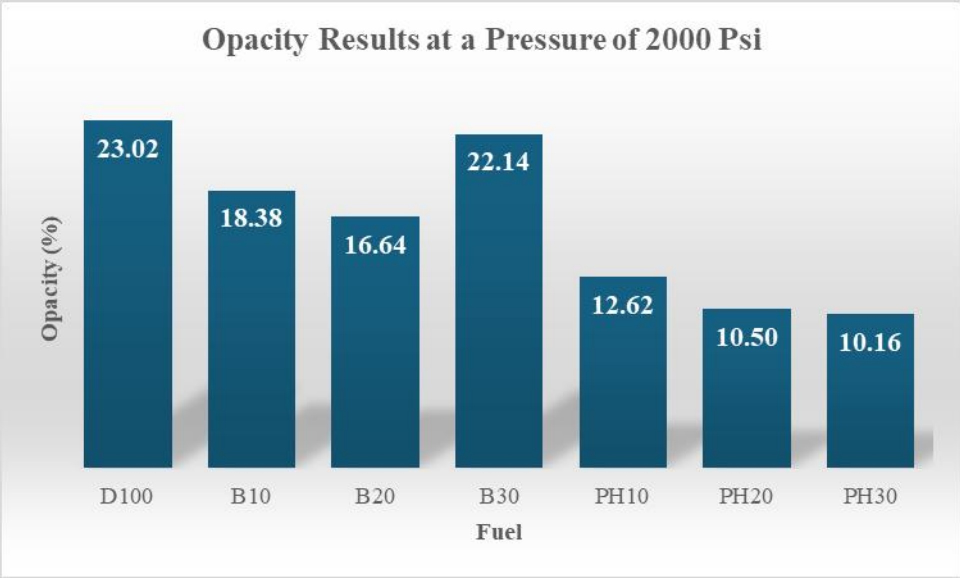

Figure 3: Graph of Smoke Opacity Results at Pressure of 2000 Psi

d. Nozzle injection at 2050 Psi

A pressure of 2050 Psi was given to seven types of fuel with five repetitions to obtain the average opacity value. The opacity value is obtained as in table 4.

Table 4: Smoke Opacity at Pressure of 2050 Psi

Fuel	Opacity					Total (%)	Average (%)
	I	II	III	IV	V		
D100	17.60	17.80	17.60	17.70	17.50	88.20	17.64
B10	16.80	17.00	17.00	17.20	17.10	85.10	17.02
B20	17.00	16.80	16.90	17.10	17.00	84.80	16.96
B30	17.00	17.10	16.80	16.70	16.90	84.50	16.90
PH10	13.80	13.60	13.20	13.80	13.40	67.80	13.56
PH20	10.40	10.60	10.70	10.80	10.60	53.10	10.62
PH30	9.30	9.20	9.60	9.40	9.60	47.10	9.42

The decrease in opacity value obtained in diesel fuel, a mixture biner diesel-biodiesel is not so significant when compared to a mixture biner diesel-partially hydrogenated biodiesel. The lowest smoke opacity value was produced by PH30 which had an average value of 9.42%. Meanwhile, the highest value was shown in the use of the D100 which had an average value of 17.64%. For more details, see Figure 4.

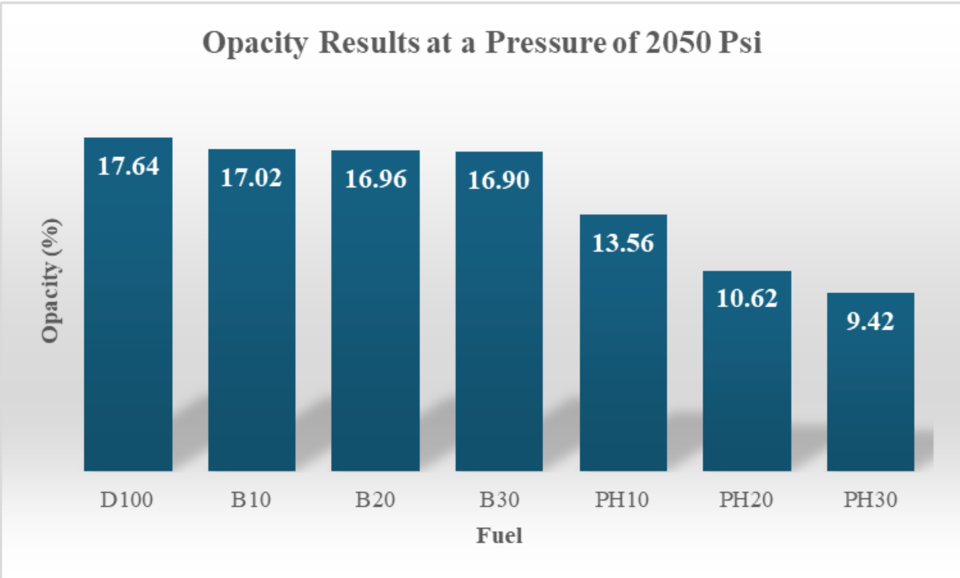

Figure 4: Graph of Smoke Opacity Results at Pressure of 2050 Psi

e. Nozzle injection at 2100 Psi

Injection pressure was changed to 2100 Psi. There are seven types of fuel that are given injection pressure with five repetitions to get the average opacity value. The opacity value is shown in table 5.

Table 5: Smoke Opacity at Pressure of 2100 Psi

Fuel	Opacity					Total (%)	Average (%)
	I	II	III	IV	V		
D100	16.50	16.30	15.90	16.60	16.20	81.50	16.30
B10	15.90	16.10	15.70	16.60	16.80	81.10	16.22
B20	15.80	15.70	15.80	15.70	15.60	78.60	15.72
B30	15.10	15.00	15.40	15.10	15.50	76.10	15.22
PH10	13.60	13.40	13.80	13.70	13.50	68.00	13.60
PH20	11.40	11.60	11.20	11.50	11.50	57.20	11.44
PH30	8.50	8.50	8.00	8.20	8.60	41.80	8.36

In diesel fuel, the mixture of biner diesel-biodiesel obtained opacity values with less significant differences when compared to the mixture of biner diesel-partially hydrogenated biodiesel. The lowest smoke opacity value was produced by PH30 which had an average value of 8.36%. Meanwhile, the highest value is shown when using the D100 which has an average value of 16.30%. For more details, see Figure 5.

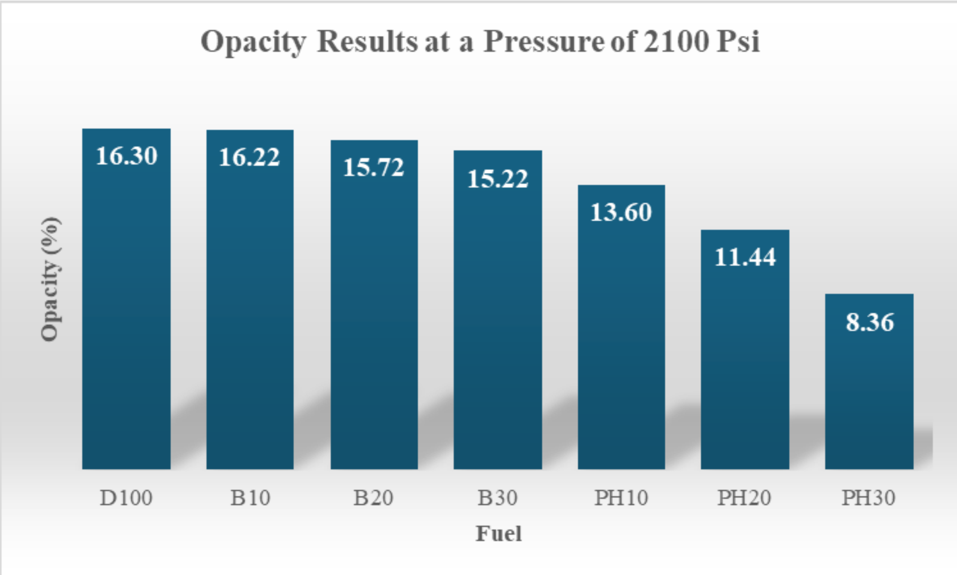

Figure 5: Graph of Smoke Opacity Results at Pressure of 2100 Psi

4.Conclusion

The decrease in opacity value obtained in diesel fuel, a mixture biner diesel-biodiesel is not so significant when compared to a mixture biner diesel-partially hydrogenated biodiesel. The mixture of biner diesel-partially hydrogenated biodiesel is very good for use as alternative fuel.

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