Performance of Small Diesel Engine with Pertadex and Biodiesel Mixed Fuel from Kemiri Seeds

Digdo Listyadi Setyawan, Nasrul Ilminnafik, Hary Sutjahjono, Moh. Wafir
Mechanical Engineering Department, University of Jember,
Jl. Kalimantn 37 Jember 68121, East Java,
Indonesia

***Abstract*:- The decline in fuel oil production has led to the development of alternative fuels that are renewable and more environmentally friendly. An alternative fuel that can be developed is biodiesel. In this study aims to develop alternative biodiesel fuels as a substitute for fossil oil fuels that are feasible applied to diesel engines. This study conducted a diesel engine performance test using mixed fuel from pertadex and candlenut biodiesel with a variation of biodiesel mixture B10, B20, and B30. The diesel engine used is a single cylinder MDX-170F air-cooled 211 cc. The diesel engine is connected to the ST-3 Generator 1 phase 220 Volt 1500 rpm which is given a load in the form of a lamp 4000 W. From the test results using a mixture of biodiesel, the effective power and torque produced by the engine decreases compared to using pure pertadex. Among the three variations of the biodiesel mixture, the best effective power produced by B10 fuel is 1537 Watt and the best torque produced by B10 fuel is 5,84 Nm. Specific fuel consumption in all biodiesel blends is increased compared to pure pertadex. Among the three variations of the biodiesel mixture, the average best specific fuel consumption produced by B30 fuel is 236,24 g/kWh. The thermal efficiency in all biodiesel blends is increased compared to pure pertadex in B20 and B30 blends. Among the three variations of the biodiesel mixture, the best thermal efficiency produced by B20 fuel is 45,97 %. The opacity of the engine exhaust gas produced in all biodiesel mixes is getting better compared to using pure pertadex. The best opacity of the engine exhaust gas produced in the use of B30 fuel is 2,3% HSU.**

Key Words: Candlenut Biodiesel, Pertadex, Performance of diesel Engine, Oppacity

1. INTRODUCTION

Biodiesel is a liquid fuel converted from vegetable oil contained in plants, so that this biodiesel can be renewed. Biodiesel is environmentally friendly because it produces much better exhaust emissions than diesel oil. This fuel also has many advantages, including: free from sulfur content, small smoke number, high cetane number, and biodegradable fuel [1].

Biodiesel can be made from vegetable oil through esterification and transesterification processes, also known as alcoholysis [2]. Biodiesel requires vegetable oil as raw material which can be produced from plants containing fatty acids. These plants include: candlenut seeds (Aleurites Moluccana), oil palm (Elaeis guineensis), jatropha (Jatropha Curcas), used cooking oil, cotton seeds, coconut, rubber trees, and many other types of plants [3].

Candlenut seeds are a source of vegetable oil raw materials that are prospectively developed as raw material for biodiesel [4]. Candlenut is a plant that has a high oil content reaching 57-69% of the total weight of the nutmeg seeds. Candlenut oil has flammable properties so it can be used as fuel. In addition, the oil contained in candlenut seeds has a low free fatty acid (FFA) content of 0.1-1.5% [5].

Biodiesel has been widely applied as a mixture of diesel fuel, because the combustion results are more environmentally friendly than fossil fuels. The use of Candlenut did not significantly improve performance aginst Brake Specific Fuel Consumption (BSFC), Brake Power (BP), Brake Thermal Efficiency (BTE), and Exhaust Gas Temperature (EGT), but reduced HC and CO along with increased NOx emissions [6]. The use of candlenut biodesel improves the knocking value than the the use of High Speed Diesel (HSD) [7]. The use of a mixture of candlenut biodiesel and soapnut can be used in VCR engine [8]. Therefore, this research was conducted with the aim of developing biodiesel which is suitable for application in diesel engines. This study tested the performance of diesel engines using a mixture of Pertamina dex fuel [with cetan number 53] and biodiesel from candlenut seeds (Aleurites Moluccana). Pertamina dex [Pertadex] is used as a mixture because pertadex is a type of fossil diesel fuel that produces the best performance compared to other fossil diesel fuels [9].

2. METHODOLOGY

The research method used is an experimental method. This method is used to test the performance of diesel engines with biodiesel fuel, Pertamina dex, and a mixture of Pertamina dex and candlenut biodiesel. Pertadex (Pertamina DEX – Diesel Environtment Extra) is a type of diesel oil produced by PT Pertamina Indonesia with a cetane number of 53 and the lowest sulfur content of 300 ppm.

The composition of the candlenut seed biodiesel mixture uses a mixture of variations of B10 (90% pertadex and 10% biodiesel), B20 (80% pertadex and 20% biodiesel), and B30 (70% pertadex and 30% biodiesel). The performance of the tested diesel engines were: Effective power, torque, specific fuel consumption, thermal efficiency, and opacity. The diesel engine used is a single cylinder MDX-170F air-cooled 211 cc. The diesel engine is connected to the ST-3 Generator 1 phase 220 Volt 1500 rpm which is given a load in the form of a lamp 4000 W. The stages of testing carried out are as follows:

1) The diesel engine is connected to the generator.
2) Put fuel into the diesel engine fuel line.

3) Turn on the diesel engine without loading.
4) Set the load on the diesel engine at 4000 watts by providing 5 incandescent lamps at the generator output.
5) Adjust the engine speed using the speed lever. Variations of engine speed 1600 rpm, 1800 rpm, 2000 rpm, 2200 rpm, 2400 rpm, 2600 rpm, 2800 rpm and 3000 rpm
6) The load was kept constant at 4000 watts for all tests.
7) Retrieval of data in each engine speed includes: fuel consumption time every 10 ml, electric voltage (V), electric current (I), and diesel engine opacity.
8) Repeating the test using a variety of different fuel mixtures, namely: Biosolar, B0 (Pertadex), B10, B20, and B30.

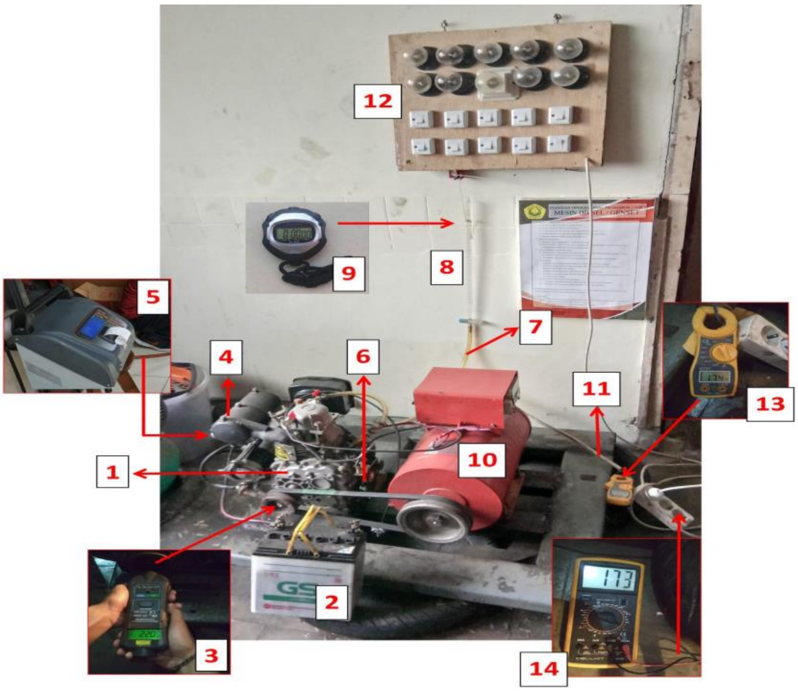

Fig. 1. Schematic of Machine Performance Testing Equipment

1) Diesel engine	8) Fuel gauge tube
2) Accumulator (Battery)	9) Stopwatch
3) Digital tachometer	10) Generator
4) Engine exhaust gas line	11) Generator output cable
5) Smokemeter	12) Loading lights
6) Engine speed control lever	13) Ammeter
7) Fuel inlet	14) Voltmeter

3. RESULTS

3.1. Characteristics of Candlenut Seed Biodiesel

Table 1 are the results of testing the characteristics of candlenut biodiesel compared to the biodiesel quality standard. The biodiesel quality standard used as a reference in this study is the biodiesel quality standard according to SNI 7182-2015 [10].

Table 1 Characteristics of Candlenut Biodiesel

Parameter	Biodiesel standards	Test results	Test Method
Density at 15 ^{O}C (kg/m^3)	850 - 890	890,3	ASTM D-1298
Viscosity at 40 ^{O}C (cSt)	2,3 - 6,0	4,113	ASTM D-445
Flash point (^{O}C)	Min. 100	174	ASTM D-93
Calorific value (kal/g)	8956,725 – 9601	9621,19	Bomb Calorimetry

Source: Pertamina (2020)

3.2. The Calorific Value of the Fuel

The result of testing the characteristics of all diesel fuels used in this study showed on Table 2, include density, viscosity, flash point, and calorific value.

Table 2 Characteristics of Diesel Fuel

Parameter	Bio solar	Pertadex	B10	B20	B30	Test Method
Density at 15 ^{O}C (kg/m3)	823,6	819,5	828,2	834,4	838,7	ASTM D-1298
Viscosity at 40 ^{O}C (cSt)	2,0-4,5	2,0-4,5	2,743	2,604	2,631	ASTM D-445
Flash point (^{O}C)	min 52	min 55	69	70	73	ASTM D-93
Calorific value (kal/g)	10787,9	11280,6	10967,8	10480	10464	Bomb Calorimetry

Source: Pertamina (2020)

3.3 Power

Based on Figure 2, it can be seen that the more engine speed increases, the effective power value continues to increase. This is because the higher the engine speed, the fuel and air consumption that enters the combustion chamber is enlarged. So that the mixture of air and fuel approaches the stoichiometric mixture which causes combustion to take place nearer to completion and results in an increase in the effective power generated by the engine.

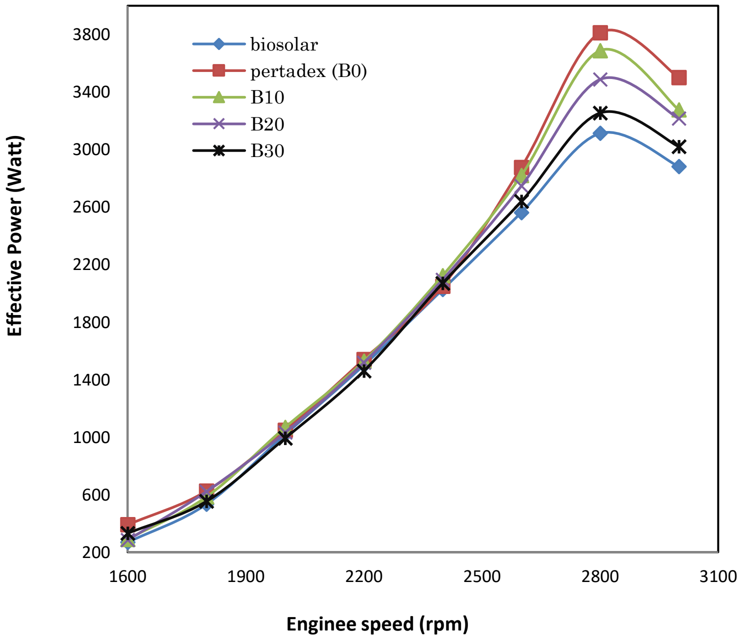

Figure 2. Effect of engine speed on Effective Power

Combustion that takes place getting closer to perfect makes the crankshaft rotation faster and results in the effective power generated by the engine to increase. The effective power is influenced by the rotation of the crankshaft which occurs due to the piston thrust which is generated due to the combustion of fuel with air [11]. Figure 2 shows that the effective power at engine speed from 1600 rpm to 2800 rpm tends to increase. This is because the resulting torque increases so that volumetric efficiency also increases

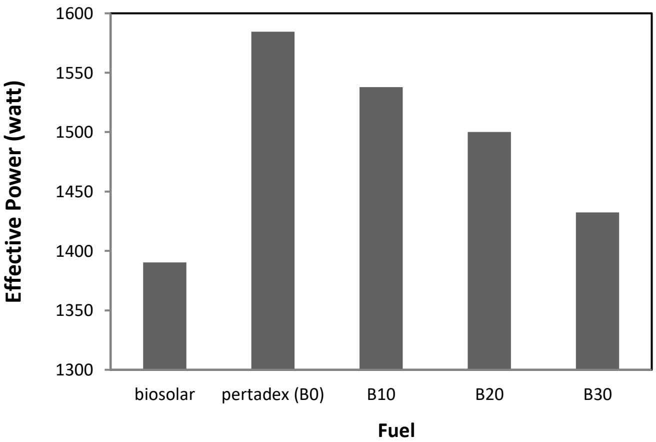

Figure 3. Effect of fuel composition on Effective Power

The mixture of air and fuel that enters the combustion chamber approaches the stoichiometric mixture so that combustion takes place near completion and results in an increase in the effective power generated by the engine. This also causes the engine speed to increase so that it causes the pressure in the combustion room to increase as well, so the power generated increases. At 2800 rpm to 3000 rpm, the effective power has decreased. This is because the torque decreases at high rotation, so that the piston does not have enough time to suck the air and fuel mixture, as a result, the volume of fuel sucked in decreases and the compression pressure decreases.

Based on the graph in Figure 3, it can be seen that the average effective power produced by B10 increases by 5.59% of biodiesel and is lower by 3.0% than pertadex [B0], from the figure it is also known that the addition of candlenut biodiesel to the material pertadex fuel (B10, B20, B30), the value of the effective power produced decreases compared to when using B0 (pure Pertadex) fuel. This is because the addition of candlenut biodiesel to pertadex increases the viscosity value of the fuel

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mixture. The viscosity of the fuel mixture B10, B20, and B30 is higher than the maximum viscosity value for fuel B0 (pure Pertadex). The addition of candlenut biodiesel to pertadex also reduces the calorific value of the combustion of the fuel mixture in the combustion room. High viscosity values and low heating values will reduce the resulting effective power output [12].

3.4. Torque

Based on Figure 4, it can be seen that with the addition of candlenut biodiesel to pertadex fuel (B10, B20, B30), the resulting torque value decreases compared to when using B0 (pure Pertadex) fuel, this figure also shows that the torque value the average yield of B10 fuel increased by 9.0% from biodiesel and slightly decreased from pure pertadex of 3.0%. The value of the torque is very much influenced by the calorific value of the fuel. High heating value results in fuel combustion going well. Combustion that goes well will make the crankshaft rotate faster, so that the torque produced by the engine increases. The calorific value of biodiesel blended fuel with pertadex is lower than the calorific value of pure pertadex fuel. So that the torque value generated in the mixture of biodiesel fuel pertadex is also lower than the torque value produced by the fuel pure pertadex.

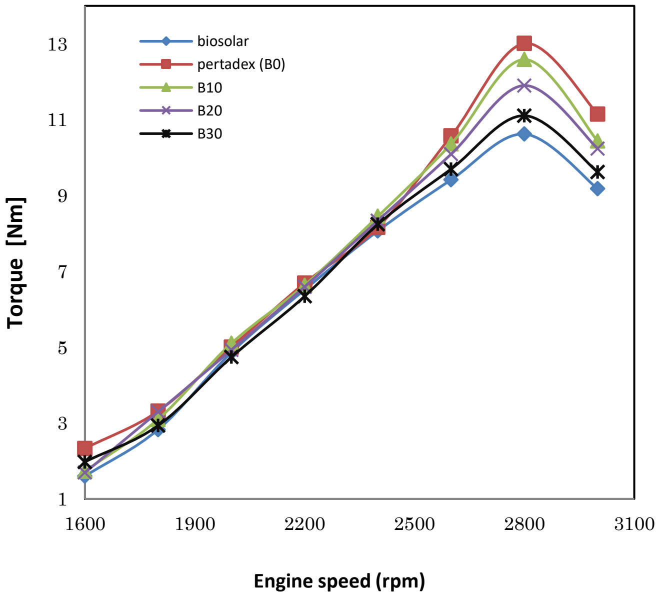

Figure 4.Effect of engine speed on Torque

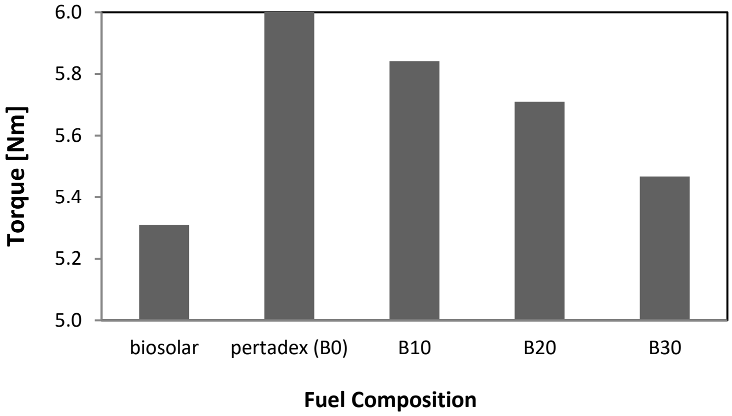

Figure 5. Effect of fuel composition on torque

3.5. Specific Fuel Consumption (SFC)

Based on Figure 6, it can be seen that as the engine speed increases, the value of the specific fuel consumption (SFC) decreases. This is because with increasing engine speed, the turbulence of the flow that enters the combustion chamber increases. So that the air and fuel mixture approaches the stoichiometric mixture, which results in the combustion process being nearly complete. Combustion that is closer to perfection makes fuel consumption better, because almost all fuel burns completely to become the effective power.

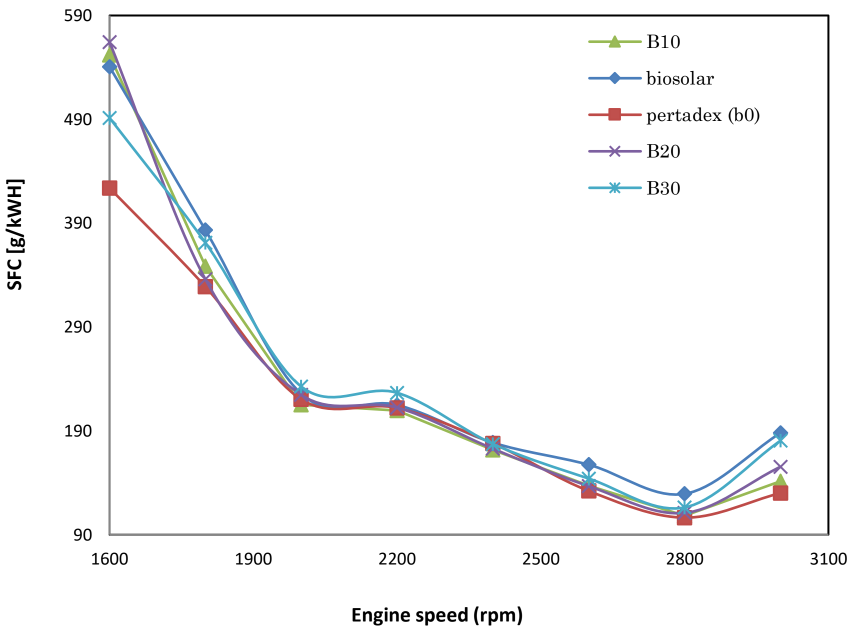

Figure 6. Efect of Engine speed on SFC

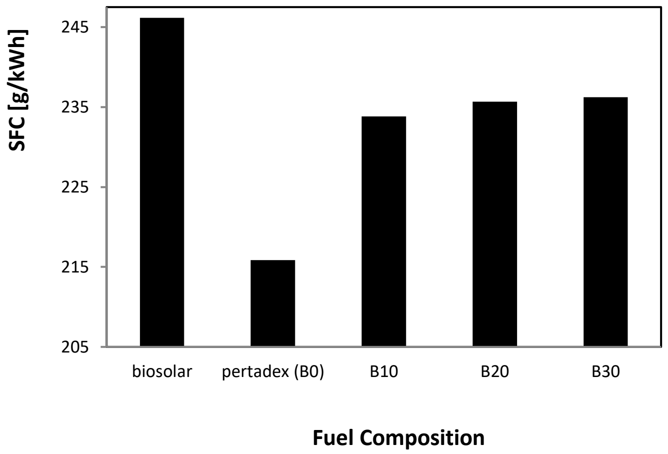

Figure 7. Effect of fuel composition on SFC

Figure 7 shows that the average SFC value produced by B10 fuel decreased 5.27% from biodiesel and increased from pure pertadex by 7.69%, the figure also shows that with the addition of candlenut biodiesel to pertadex fuel (B10, B20 , B30), the resulting SFC value increases compared to when using B0 [Pertadex [B0]] fuel. This is because the addition of candlenut biodiesel to pertadex reduces the calorific value and increases the viscosity value. Increasing the viscosity value and decreasing the calorific value will cause consumption. specific fuel increases [13]. Lower heating value will result in a lean mixture of air and fuel so that to get the desired performance, the air-fuel mixture must be made richer (rich mixture). making the required fuel is more than using pertadex [B0] [14].

3.6. Thermal Efficiency

Based on Figure 8, it can be seen that the more engine speed increases, from 1600 rpm to 2800 rpm, the value of thermal efficiency continues to increase. This is because the higher the engine speed, the turbulence of the flow that goes into the combustion chamber increases so that more work steps are needed at the same time. In this situation, the mixture of air and fuel approaches the stochiometric mixture, resulting in a faster flash point and the combustion process nears completion so that the resulting compression pressure and temperature are higher, resulting in increased efficiency. The value of specific fuel consumption which decreases with the increase in fuel injection pressure also affects the increase in thermal efficiency. Because more and more fuel is converted into the effective power of the engine in the combustion process [15]

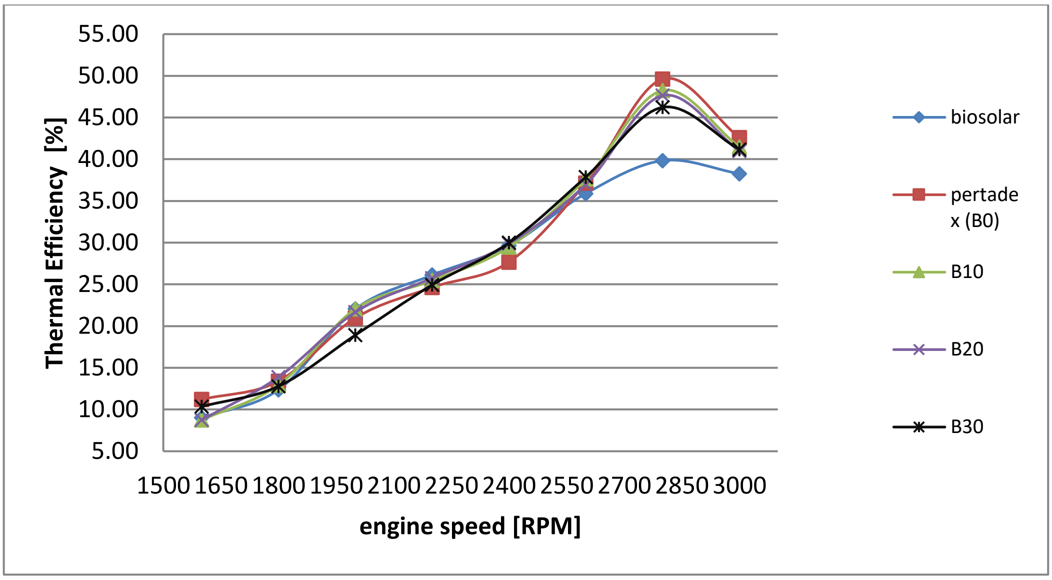

Figure 8. Graph of Thermal Efficiency of Engine Speed

However, at 2800 rpm to 3000 rpm, the value of thermal efficiency tends to decrease. This is because, at this time the piston only has a small amount of time to suck in the air and fuel mixture, so that the volume of fuel sucked in decreases and the compression pressure decreases. In addition, at high rotation, very large friction occurs so that the fuel that is injected is too late and the combustion process is not complete. Another thing that causes the value of thermal efficiency to be lower, because the higher the engine speed causes the engine to experience overload [16].

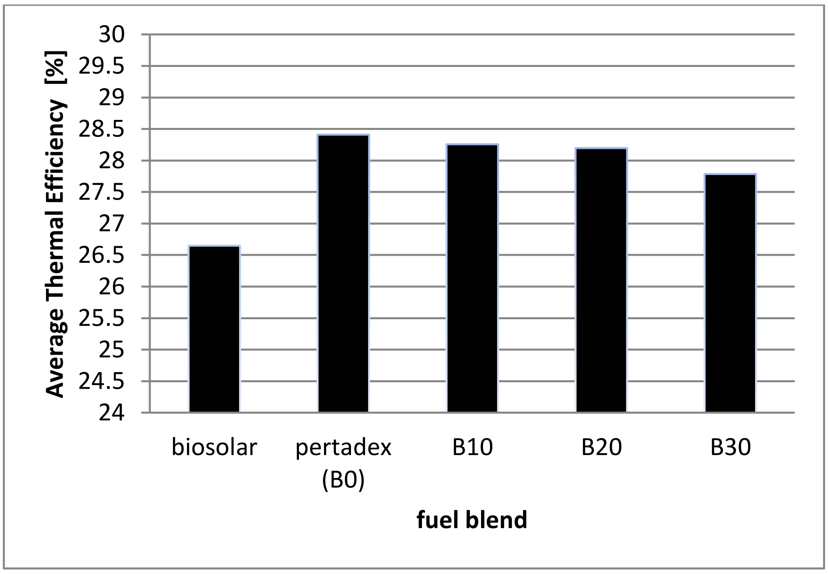

Figure 9. Graph of Average Thermal Efficiency of Fuel

Based on Figure 9, it can be seen that when the use of the B20 and B30 fuel mixture, the resulting thermal efficiency value increases compared to when using B0 (pure Pertadex) fuel, namely the average thermal efficiency value produced by B20 fuel increases by 5, 64% of biodiesel and increased insignificantly from pure pertadex of 1.93%. However, when using the B10 fuel mixture, the thermal efficiency has decreased compared to when using pertadex fuel, this is due to the high viscosity value of B10 fuel so that the fogging process is not perfect. The low viscosity value will facilitate the atomization or fogging process, thus ensuring the perfection of combustion in the diesel engine combustion chamber [17].

3.7. Opacity

Based on Figure 10, it can be seen that the effect of using a mixture of candlenut biodiesel on pertadex fuel reduces the opacity (smoke density) produced by the engine. In the graph, it can be seen that the more biodiesel mixture the smaller the resulting opacity value. This is because biodiesel fuel does not contain sulfur so that the opacity released is more environmentally friendly. This has led to a significant reduction in emissions in the form of opacity. The magnitude of the decrease in opacity in the biodiesel mixture is also due to the sufficient amount of air in the cylinder. So that most of the fuel is mixed ideally when the fuel is in the form of vapor [18]. The amount of opacity produced in biodiesel fuel is generally low. This is because the fatty acids contained in biodiesel are more easily oxidized or burnt completely [19].

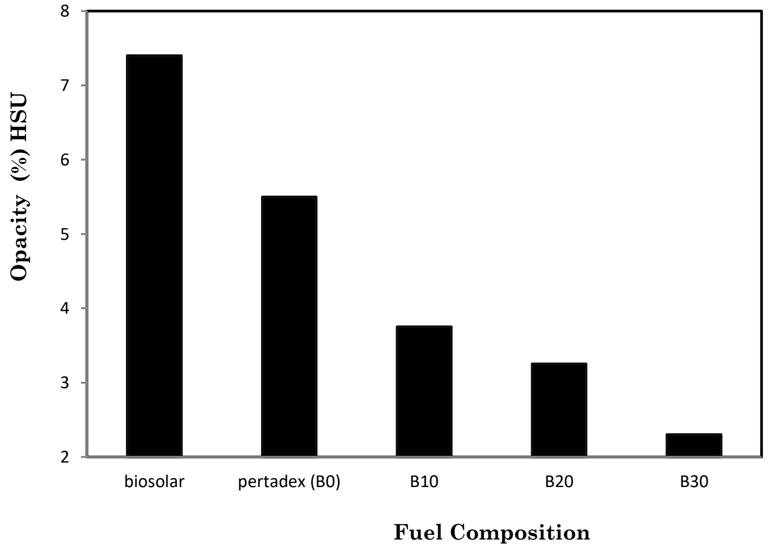

Figure 10. Effect of Fuel composition on Opacity

4. CONCLUSIONS

Based on the results of the research conducted, it can be concluded that the addition of candlenut biodiesel to pertadex affects the performance of the resulting diesel engine as follows:

1. The average effective power in the best fuel mixture is B10. The average effective power produced by B10 increased by 5.59% from biodiesel and lower by 3.0%. from pertadex [B0].
2. The average torque value produced by B10 fuel increased 9.0% from biodiesel and slightly decreased from pure pertadex of 3.0%.
3. The best SFC in the fuel mixture is B30. The average SFC value produced by B30 fuel decreased 9.45% from biodiesel and increased from pure pertadex by 4.02%.
4. The best thermal efficiency of the fuel mixture is B20. The average thermal efficiency value produced by B20 fuel increased by 5.64% from biodiesel and increased insignificantly from pure pertadex of 1.93%.
5. The greater the amount of biodiesel mixture in pertadex the better the resulting opacity value. The best opacity is produced in the B30 fuel mixture, which is 2.3% HSU.

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