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Effect of Candlenut Seed Biodiesel on Diesel Engine Emissions

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ABSTRACT

Growing concern for environmental sustainability has increased interest in alternative fuels such as biodiesel. This study investigated the effect of candlenut seed biodiesel on diesel engine emissions. Biodiesel derived from candlenut oil was produced through a transesterification process and tested on a single-cylinder diesel engine with an engine speed of 1500 Rpm. The diesel engine was connected to a generator set and given an engine load using lamps with variations of 1000 watts, 2000 watts, and 3000 watts. The fuel used was a mixture of 40% candlenut seed biodiesel with 60% diesel. The results showed that at low engine loads NOx, CO2, and Opacity emissions increased, but at high engine load conditions of 3000 watts NOx emissions decreased by 34.21%, and CO2 emissions decreased by 20.24%, and Opacity decreased by 17.14% compared to using pure diesel. This research highlights the potential of candlenut seed biodiesel as a sustainable alternative fuel.

Key words : Candlenut Seed, Biodiesel, Diesel Engine, NOx Emissions.

1. INTRODUCTION

Diesel engines are widely used in transportation and industry due to their high efficiency and durability [1]. However, their emissions contribute significantly to air pollution and greenhouse gas accumulation [2]. The growing global emphasis on environmental sustainability has driven researchers to explore renewable energy alternatives to fossil fuels [3]. Among these alternatives, biodiesel derived from plant-based sources stands out due to its potential to reduce harmful emissions and promote energy security [4].

Biodiesel is a biodegradable renewable fuel, and has the potential to be a promising alternative to petroleum diesel [5]. Among the various biodiesel feedstocks, candlenut seed has received attention due to its high oil content and availability in tropical regions [6, 7]. Candlenut seed biodiesel offers several advantages as a biofuel. Its high oil content and non-edible status make it an attractive feedstock for biodiesel production, as it avoids competing with food crops [6, 8].

This study aims to evaluate the emission characteristics of diesel engines using candlenut seed biodiesel. By comparing emission data from conventional diesel fuel and candlenut seed biodiesel, this research is expected to provide insight into the environmental benefits and potential trade-offs that may occur.

2. LITERATURE REVIEW

2.1 Biodiesel

Biodiesel is an alternative renewable fuel obtained from vegetable or animal resources, such as palm oil, soybean oil, jatropha oil, and algae oil [9]. The use of biodiesel as a diesel engine fuel has been widely studied, especially in relation to its impact on exhaust emissions [10, 11]. Based on previous research, biodiesel has a number of advantages, including reduced emissions of greenhouse gases such as carbon dioxide (CO2), as well as lower emissions of particulate matter (PM) and carbon monoxide (CO), compared to fossil diesel fuels [12, 13]. In addition, biodiesel can also reduce dependence on fossil fuels, which are becoming increasingly limited. Some studies show that biodiesel use can reduce CO, HC, and PM emissions, but can increase NOx emissions, which can be detrimental in terms of air quality and health [12].

2.2 Diesel Engine Emissions

Diesel engines are known for their higher fuel efficiency compared to gasoline engines, but their emissions are often a major concern regarding environmental impact and human health [14]. Diesel engines produce a number of harmful exhaust gases, including carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HC), and particulate matter (PM) [15, 16]. Carbon monoxide (CO) is formed due to incomplete combustion, while hydrocarbons (HC) are the result of incomplete combustion of fuel [16, 17]. Nitrogen oxide (NOx) emissions, which consist of nitrogen dioxide (NO2) and nitrogen monoxide (NO), contribute to the formation of smog and acid rain, and can increase the risk of respiratory problems [18]. Meanwhile, particulate matter (PM) emissions mainly consist of soot produced by incomplete fuel combustion, which can degrade air quality and pose a high risk to human health, especially the respiratory system [19].

Therefore, controlling diesel engine emissions is a top priority in an effort to reduce negative environmental impacts. Various technologies, such as more efficient fuel injection systems, the use of particulate filters, as well as the development of alternative fuels such as biodiesel, have been studied to reduce the level of harmful emissions from diesel engines [20].

2.3 Previous Research

Research by M. A. Salam et al. (2016): This study examined the effect of biodiesel from Jatropha oil on the exhaust emissions of motor vehicles. The results show that the use of biodiesel can reduce CO, HC, and NOx emissions compared to conventional fossil fuels. However, reducing NOx emissions is still a challenge that needs to be addressed further [21].

Research by B. R. Pradhan et al. (2017): This study investigated the effect of biodiesel from used oil on diesel engine emissions. The results showed a decrease in CO and HC emissions, while NOx emissions increased slightly. The study also found that biodiesel from used oil can be an environmentally friendly alternative with the benefit of reducing greenhouse gas emissions [22].

Research by S. A. L. Zubair et al. (2018): This study examined biodiesel from algae oil and its impact on vehicle emissions. The results show that biodiesel from algae has great potential to reduce greenhouse gas and particulate emissions compared to conventional diesel. NOx emissions increased slightly, but could be addressed by modifying engine technology [23].

Research by L. Zhang et al. (2020): This study addresses the use of biodiesel blends (B20) in diesel engines and its effect on emissions. The results show that biodiesel blends reduce greenhouse gas (GHG) emissions, especially CO2 and HC, but there is still a small increase in NOx emissions [24].

In general, the use of biodiesel has the potential to reduce CO, HC, and particulate matter (PM) emissions, but there are still challenges related to NOx emissions that need to be addressed, either through the use of oil feedstocks with certain characteristics, or the addition of certain additives in biodiesel, as well as more efficient engine technology or the use of biodiesel [25].

3. RESEARCH METHODOLOGY

This study was conducted using a standard single-cylinder direct injection diesel engine, which was tested with pure petrodiesel and biodiesel produced from candlenut seed oil. Biodiesel was synthesized through a transesterification process, using methanol and potassium hydroxide catalyst. The engine was operated at various load conditions (0 watt, 1000 watt, 2000 watt, and 3000 watt) with a constant engine speed of 1500 rpm.

Emissions were measured using an exhaust gas analyzer and a smoke meter to determine CO2, NOx, and opacity levels. The engine was tested for each fuel type at each load condition, and the emission levels were recorded and analyzed to determine the effect of using candlenut seed biodiesel on diesel engine emissions. The research scheme is shown in **Figure 1** below.

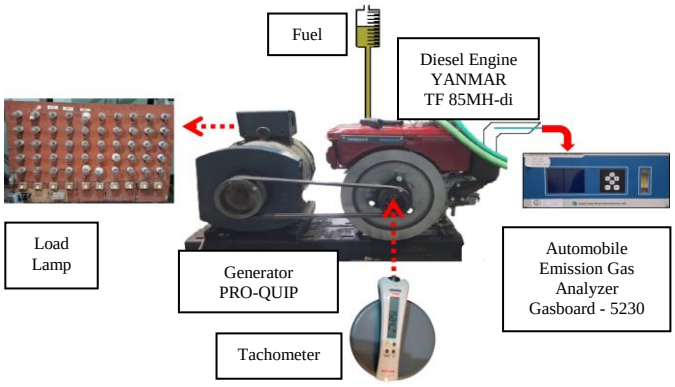

Figure 1: Research Scheme

4. RESULT AND DISCUSSIONS

4.1 Fuel Characteristics

Testing the characteristics of biodiesel is carried out to evaluate the physical and chemical properties of biodiesel that can affect the performance and emissions of diesel engines. In this study, the biodiesel used was derived from candlenut seed oil processed through the transesterification method. Test results show that biodiesel has several different characteristics compared to conventional diesel fuel. The viscosity of biodiesel is slightly higher than that of fossil diesel, which can affect the fuel injection and combustion process in the combustion chamber of a diesel engine [26, 27]. In addition, the lower heating value of biodiesel compared to conventional diesel may affect fuel efficiency, although this difference is relatively small [28, 29]. The results of the fuel characteristics test can be seen in **Table 1** below.

Table 1: Fuel Characteristics Test Result

No	Parameter	Test Result		Test Method
		Petro Diesel	B40	
1	Density (kg/m^3)	822	841	ASTM D -1 298
2	Viscosity (cSt)	2,98	3,24	ASTM D -4 45
3	Flash Point (^OC)	61	68	ASTM D - 93
4	Caloric Value (kal/g)	11681,4	10890,1	Bomb Calorimetry
5	Cetane Number	56,9	> 62,5	Cetane Analyzer

4.2 Diesel Engine Emission Test Results

The results of the NOx Emissions can be seen in **Figure 2** below.

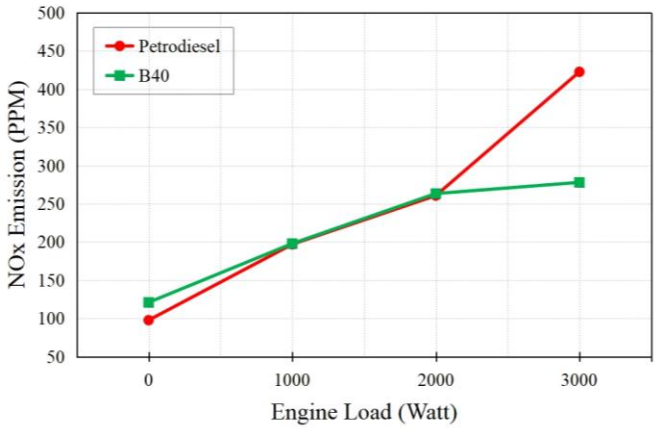

Figure 2: Effect of Candlenut Seed Biodiesel Fuel on NOx Emissions

The results of the CO2 Emissions can be seen in **Figure 3** below.

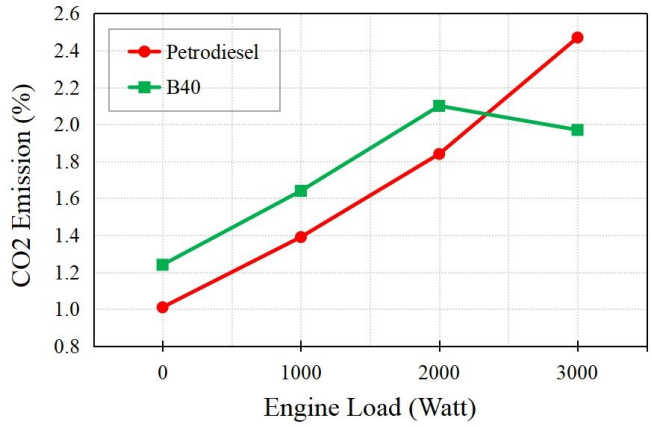

Figure 3: Effect of Candlenut Seed Biodiesel Fuel on CO2 Emissions

The results of the Opacity can be seen in **Figure 4** below.

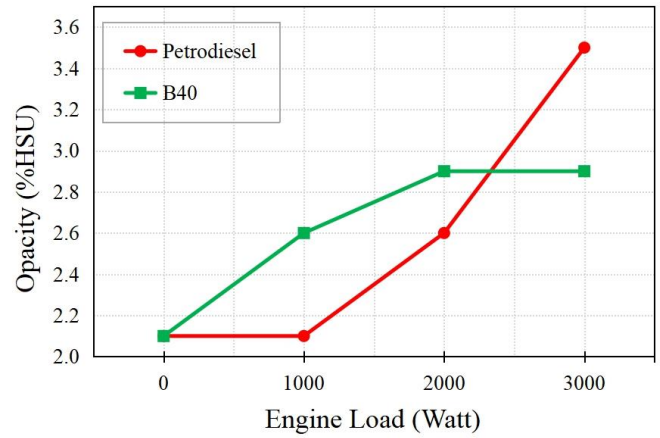

Figure 4: Effect of Candlenut Seed Biodiesel Fuel on Opacity

Biodiesel emission test results based on engine load variations show that changes in load affect the level of emissions produced by diesel engines using biodiesel fuel. At low loads, emissions produced by biodiesel tend to be higher than engines using petrodiesel fuel. This is because biodiesel has a higher viscosity than petrodiesel. At low loads, diesel engines cannot optimally atomize biodiesel, which causes incomplete combustion and increased emissions. Poor atomization causes inefficient combustion, resulting in higher emissions [30].

However, at high load conditions of 3000 watts, NOx, CO2, and Opacity emissions in biodiesel tend to decrease significantly, this is due to more efficient combustion that occurs due to higher combustion temperatures, and better atomization. Better atomization means that the fuel is mixed more completely with the air, which leads to more efficient combustion. More efficient combustion reduces the formation of soot and particulate emissions, which in turn reduces opacity [6, 31].

At high loads, diesel engines operate at higher temperatures and pressures, which generally increase combustion efficiency. Biodiesel has a higher oxygen content compared to petrodiesel, which helps improve the combustion process. With more complete combustion, less unburned fuel is produced, which reduces the formation of NOx emissions resulting from very high combustion temperatures [18, 32]. More complete combustion also results in lower CO2 emissions because less carbon is released as a byproduct of incomplete combustion [33].

At high operating temperatures, because biodiesel has a high flash point, it tends to produce cleaner combustion and reduce emissions, but at low temperature conditions it can cause incomplete combustion at start-up, thereby increasing CO and HC emissions [34].

5. CONCLUSION

Based on the results of the study, it can be concluded that the use of candlenut biodiesel as a mixture of petrodiesel fuel causes an increase in NOx, CO2, and Opacity emissions produced at low engine loads. However, at a high engine load of 3000 watts, the emissions produced by biodiesel fuel decreased significantly compared to the emissions produced by petrodiesel. At a load of 3000 watts, NOx emissions decreased by 34.21%, and CO2 emissions decreased by 20.24%, and Opacity decreased by 17.14% compared to using pure diesel.

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