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Comparative Analysis of Performance and Emission Characteristics of Biodiesels from Animal Fats and Vegetable Oils as Fuel for Common Rail Engines

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Abstract: Currently, solving global environmental problems is recognized as an important task for humanity. In particular, automobile exhaust gases, which are pointed out as the main cause of environmental pollution, are increasing environmental pollutants and pollution problems, and exhaust gas regulations are being strengthened around the world. In particular, when an engine is idling while a car is stopped and not running, a lot of fine dust and toxic gases are emitted into the atmosphere due to the unnecessary fuel consumption of the engine. These idling emissions are making the Earth's environmental pollution more serious and depleting limited oil resources. Biodiesel, which can replace diesel fuel, generally has similar physical properties to diesel fuel, so it is receiving a lot of attention as an eco-friendly alternative fuel. Biodiesel can be extracted from various substances of vegetable or animal origin and can also be extracted from waste resources discarded in nature. In this study, we used biodiesel blended fuel (B20) in a CRDI diesel engine to study the characteristics of gases emitted during combustion in the engine's idling state. There were a total of four types of biodiesels used in the experiment. New Soybean Oil and New Lard Oil extracted from new resources and Waste Soybean Fried Oil and Waste Barbecue Lard Oil extracted from waste resources were used, and the gaseous substances emitted during combustion with pure diesel fuel and with the biodiesels were compared and analyzed. It was confirmed that all four B20 biodiesels had a reduction effect on PM, CO, and HC emissions, excluding NOx emissions, compared to pure diesel in terms of the emissions generated during combustion under no-load idling conditions. In particular, New Soybean Oil had the highest PM reduction rate of 20.3% compared to pure diesel, and Waste Soybean Fried Oil had the highest CO and HC reduction rates of 36.6% and 19.3%, respectively. However, NOx was confirmed to be highest in New Soybean Oil, and Waste Barbecue Lard Oil was the highest in fuel consumption.

Keywords: biodiesel; CRDI engine; new soybean oil; waste soybean fried oil; new lard oil; waste barbecue lard oil; PM; CO; NOx; HC; fuel consumption

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1. Introduction

The practice of carbon neutrality to overcome the problem of global warming caused by environmental pollution is leading to governments strengthening various air environment policies. In particular, among various pollutants, toxic engine combustion gases emitted from automobiles are pointed out as the main cause of global environmental destruction [1–3]. In particular, if an engine is in an idling condition while a car is stopped and not driving, there is a risk of the engine overheating, and the unnecessary fuel consumption generates a lot of fine dust and nitrogen dioxide [4,5]. According to the Ministry of Environment, based on a passenger car with a fuel efficiency of 12 km per liter, idling for 10 min a day consumes about 138 cc of fuel, which is equivalent to driving 1.6 km [6]. According to a release from the Korea Automobile Environment Association, 50% of the causes of fine dust and nitrogen dioxide emissions are due to idling and, compared to driving conditions, 6.5 times more carbon monoxide and 2.5 times more hydrocarbons are emitted. Therefore, interest in biodiesel as an eco-friendly energy source that can replace petroleum resources is increasing [7,8]. These eco-friendly alternative fuels utilize various energy resources on Earth, and various research is being conducted in an effort to reduce the toxic gases emitted during engine combustion [9–11]. Biodiesel can be extracted from vegetable and animal materials and can also be manufactured from various waste resources discarded in nature. The biodiesel recycling project, which reuses waste resources, is highly valued because it can be implemented at a low cost while protecting the global environment and responding to rapidly rising oil prices. When examining research papers, there are many separate studies on vegetable biodiesel and animal biodiesel, but there are not many studies that directly compare and analyze the combustion characteristics of the two types of biodiesels during idling conditions and that additionally study biodiesel using vegetable and animal waste resources. In order to optimize the idling combustion of biodiesel, the combustion characteristics of various types of biodiesels must be more accurately identified. It is believed that more systematic and extensive research is needed through various experimental conditions to determine how biodiesel affects exhaust gases under idling combustion conditions compared to pure diesel.

In this study, changes in the characteristics of exhaust gases were studied using the biodiesel blended fuel B20 in a 3800 cc Common Rail Direct-Injection (CRDI) diesel engine. Biodiesel was tested with a total of four fuels: New Soybean Oil using new vegetable materials, New Lard Oil from animal sources, Vegetable Waste Soybean Fried Oil, and Animal Waste Barbecue Lard Oil were used as fuel for the CRDI diesel engine under no-load idling conditions. The emission components generated during idling combustion were compared and analyzed with regular diesel oil by changing the engine speed in the absence of fuel.

2. Biodiesel Research Review

To understand the emission and performance characteristics of Waste Soybean Fried Oil, New Soybean biodiesel, Waste Barbeque Lard Oil, and New Lard oil biodiesel, it was essential to consider the impact of different feedstocks on emissions and engine performance. McCormick et al. (2001) conducted a study examining biodiesels produced from various real-world feedstocks and found that the source material and chemical structure significantly impact the emissions of criteria pollutants from heavy-duty engines [12]. Additionally, Wahlen et al. (2012) found that high oleic acid soybean biodiesel led to lower NOx emissions compared to regular soybean biodiesel, indicating an influence of fatty acid composition on emissions [13]. Furthermore, Ghobadian et al. (2009) revealed that blends of waste vegetable oil methyl ester with diesel fuel provided better engine performance and improved emission characteristics [14].

Moreover, a study by Vellaiyan and Partheeban (2018) focused on the emission analysis of a diesel engine fueled by soybean biodiesel and its water blends, providing insights into the emission characteristics of soybean biodiesel [15].

While there is limited direct information on Waste Soybean Fried Oil and New Soybean biodiesel, the references provide valuable insights into the influence of feedstock on emissions and engine performance. The studies highlight the importance of considering the chemical composition and source material of biodiesel feedstocks in evaluating their emission and performance characteristics.

2.1. Impact of Biodiesel Blends on Engine Performance

The impact of biodiesel blends on engine performance is a topic of significant interest in the field of alternative fuels. Ali et al. (2016) found that increasing the biodiesel ratio in blended fuel had a statistically significant effect on engine brake power [16]. Similarly, Çanakçı and Gerpen (2003) investigated the effect of biodiesel produced from high free fatty acid feedstocks on engine performance and emissions. They found that the source material significantly influenced engine performance and emissions [17]. Furthermore, Emaish et al. (2021) conducted a study on the effects of blending waste frying oil (WFO) biodiesel with diesel fuel on the performance of a diesel engine, aiming to reduce the environmental impact of gas emissions [18].

In addition, Pramudito et al. (2022) studied the impact of high-speed diesel fuel–biodiesel blends on diesel engine performance and found a decrease in power and torque as well as a reduction in emission opacity [19]. Moreover, Zaher and Gad (2018) conducted extensive research on the effect of blending biodiesel produced from waste cooking oil with regular diesel fuel on the performance characteristics of a diesel engine and the temperature of the combustion exhaust. Their findings provide valuable insights into the impact of biodiesel blends on engine performance [20].

While there are numerous studies on the impact of biodiesel blends on engine performance, it is evident that the choice of feedstock and blend ratios significantly influences engine performance and emissions. The studies provide valuable insights into the complex relationship between biodiesel blends and engine performance, highlighting the need for further research to optimize the use of biodiesel blends in internal combustion engines.

2.2. Knowledge Gaps and Research Needs

To reduce the exhaust emissions of compression ignition (CI) engines, it is essential to understand the knowledge gaps and research needs of various B20 biofuels made from animal and plant oils. The demand for grains and oilseeds as biofuel feedstocks has been cited as the main cause of the price rise, but there is little direct evidence for this contention [21]. Biofuels produced from vegetable oils and animal fats have become attractive due to their capability of being used in commercial CRDI diesel engines [22]. Promising plant-based feedstocks for future aviation biofuels include jatropha, camelina, and algae [23]. Hemp, a versatile crop, can be used to produce biofuels and animal feed, among other products [24]. Research into the feasibility of using plant cell walls in the production of cost-effective biofuels is desirable [25]. Additionally, biofuels made from vegetable oils and animal fats have great potential as an alternative to traditional fuels to reduce environmental pollution [26].

Biodiesel, a long-chain fatty acid ester made from renewed and biological raw materials such as used cooking oil, animal fat, vegetable oil, and algae, is a viable option for reducing exhaust emissions [27]. Enormous attention has been focused on triglycerides from animal fats and vegetable oils as abundant biomass resources for the generation of biofuels [28]. Furthermore, experimental investigations into the exhaust emission characteristics of a gardener CI engine fueled by rapeseed methyl ester (RME) and fossil diesel under lean equivalence ratios have been conducted, shedding light on the potential of biofuels to reduce emissions [29]. The utilization of liquid biofuels is capable of reducing CO and CO_2 emissions [30]. First-generation biofuels, made from sugar crops, starch crops, oilseed crops, and animal fats, have the potential to reduce exhaust emissions [31].

The role of biofuels in reducing greenhouse gas emissions and their association with rising protein-rich animal feed production highlight the potential for biofuels to mitigate environmental impacts [32]. Examples of biofuels such as ethanol, biodiesel, green diesel, and biogas derived from various sources offer promising avenues for reducing exhaust emissions [33]. Algal biofuel, derived from burning cellulosic plant material and residual woody parts, presents an environmentally friendly alternative fuel option [34]. Comprised of mono-alkyl esters of long fatty acids, biofuels derived from animal fats or vegetable oils offer the potential to reduce exhaust emissions [35]. Additionally, waste vegetable oil methyl ester can decrease biofuel dependency, contributing to emission reduction [36].

The synthesis of these references highlights the potential of biofuels made from animal and plant oils to reduce the exhaust emissions of CI engines. The research gaps and needs in this area include further investigation into the direct evidence of the impact of biofuel feedstocks on food prices, the potential of various biofuel sources to reduce emissions, and the development of cost-effective and environmentally friendly biofuel production technologies.

3. Methodology

3.1. Biodiesel Fuel Productions

The biodiesels used in this experiment were fuel extracted from new oil and fuel extracted from waste oil, respectively. New oil was extracted from New Soybean Oil (NSO) and New Lard Oil (NLO), respectively. As a waste oil, biodiesel was additionally extracted from Waste Soybean Fried Oil (WSFO) left over from frying chicken and Waste Barbeque Lard Oil (WBLO) from the process of grilling pigs. A total of four types of biodiesel were used in the experiment, and the NSO extraction process is shown in the pictures in Figure 1. For the esterification transition required in the biodiesel production process, 2.5 g of potassium hydroxide per 135 mL of methanol was diluted and mixed with 500 mmL of soybean cooking oil. The mixed raw materials were set to 55 °C in a magnetic stirrer and rotated at 700 rpm for about 2 h. Afterwards, they were stored at room temperature for about 24 h and the glycerol produced as a by-product was removed. Since the biodiesel remaining after the removal contained moisture and methanol components, it was washed 5 to 6 times with water at 70 °C and then all foreign substances were removed and pure biodiesel was extracted. Biodiesel from NLO, WSFO, and WBLO was also manufactured using the same method.

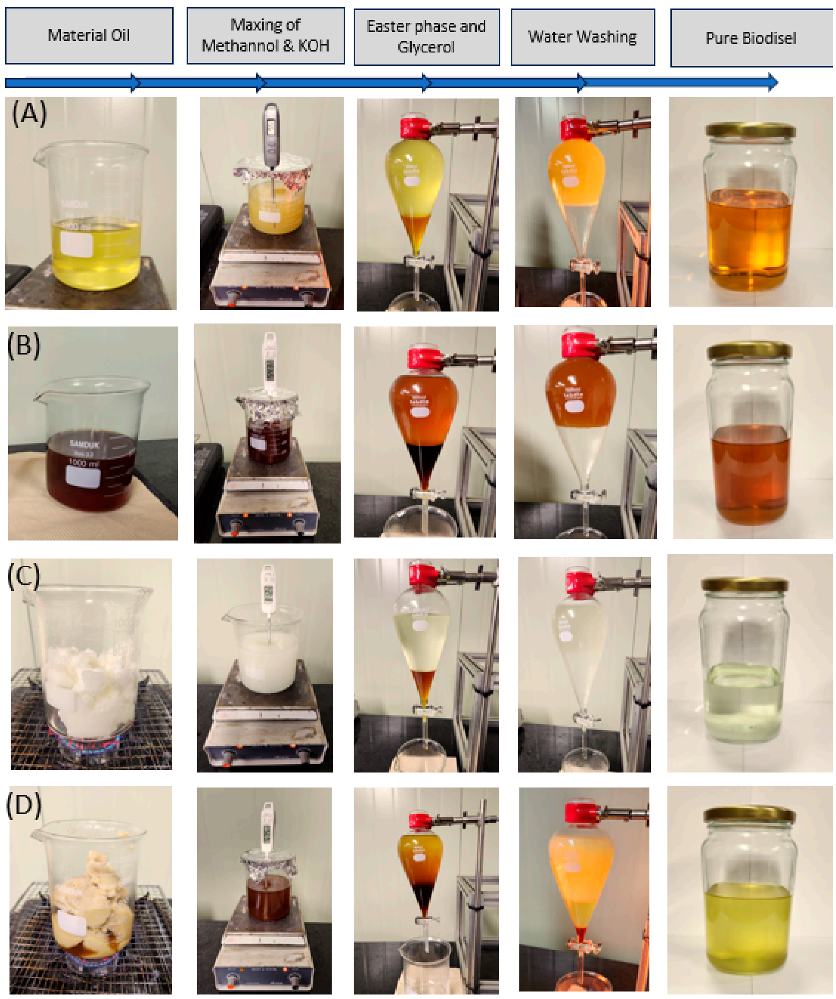

Figure 1. Biodiesel production process: (**A**) New Soybean Oil, (**B**) Waste Soybean Fried Oil, (**C**) New Lard Oil, (**D**) Waste Barbeque Lard Oil.

3.2. Experimental Setup

The engine used in the experiment was an electronic common rail diesel engine that had been mounted on an actual bus and had traveled about 10,000 km on the road. The engine was removed and installed on the experimental bed. The detailed specifications of the experimental engine are shown in Table 1.

Table 1. Test engine specification.

Parameter	Specification
Engine Brand	Cummins ISF3.8
Vehicle Application	Minibus (25 seats)
Fuel Type	Diesel
No. of Cylinders	4
Bore x Stroke	102 × 115
Displacement	3800 cc
Fuel Injection	Common Rail Direct Injection
Fuel Injection Pressure	450~1600 bar
Max. Overspeed Capa.	3900 RPM (1600 bar)
Emission Level	EURO5
Max. Power	168 HP/2600 RPM
Max. Torque	443 ft-lb at 1300 RPM
Intake System	Inter-cooler
Injector Type	Solenoid
No. of Injector Holes	6
Standard Thermostat Range	83 to 95 °C
Post-Treatment Device	SCR only

Figure 2 shows the actual size of the experimental engine. When manufacturing the engine, a 168PS CRDI Diesel 3.8 L was installed on a dedicated engine bed to enable the engine to operate under no-load conditions. The CRDI engine was an electronic diesel fuel system that injected high-pressure fuel directly into the combustion chamber. It was a system that operated through an injector with the injection pressure, injection timing, and injection amount controlled by electrical signals from the ECU. In order to reproduce the operating conditions of the actual vehicle as closely as possible, the same parts as the actual vehicle, such as the radiator, intercooler, and intake/exhaust system, were used.

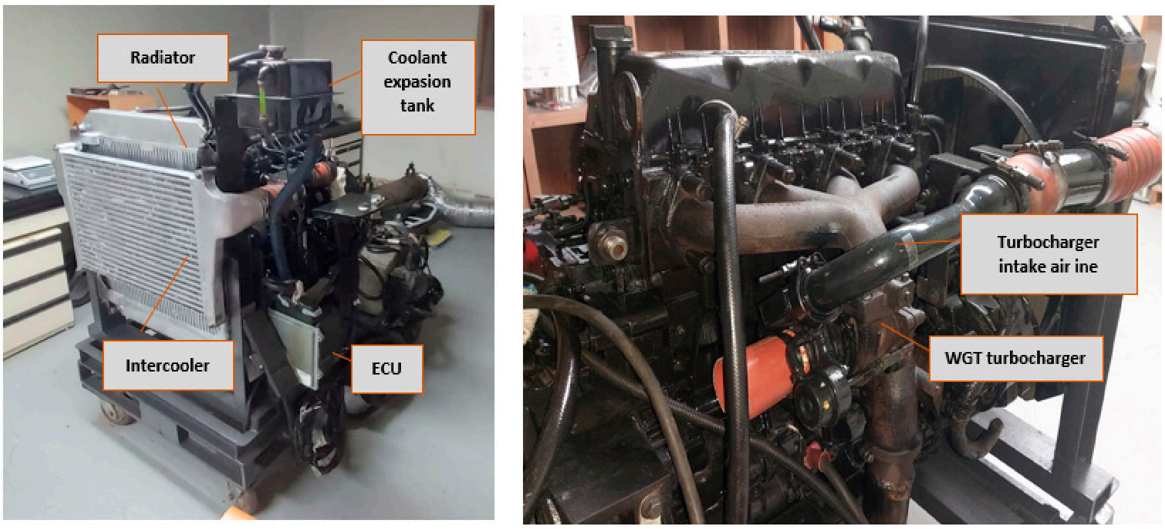

Figure 2. CRDI test engine.

The sensor data acquisition device of the engine used in the experiment collected data using a software tool provided by Cummins INSITE 8.7, and the exhaust gas emissions were measured using the exhaust gas analyzer Hepsiba (HG-550RT), and the diesel smoke tester Zastek (CMS-2300) was used. As shown in Figure 3, the engine's sensing value was measured by connecting the OBD terminal to INSITE, and the two exhaust gas machines were measured by inserting a tube of about 30 cm into the end of the exhaust pipe. In order to directly measure unfiltered exhaust gas components, the post-treatment device was removed from the experimental device. In order to measure fuel consumption, a precision scale was installed in the fuel tank, allowing the amount of fuel consumed to be measured by weight.

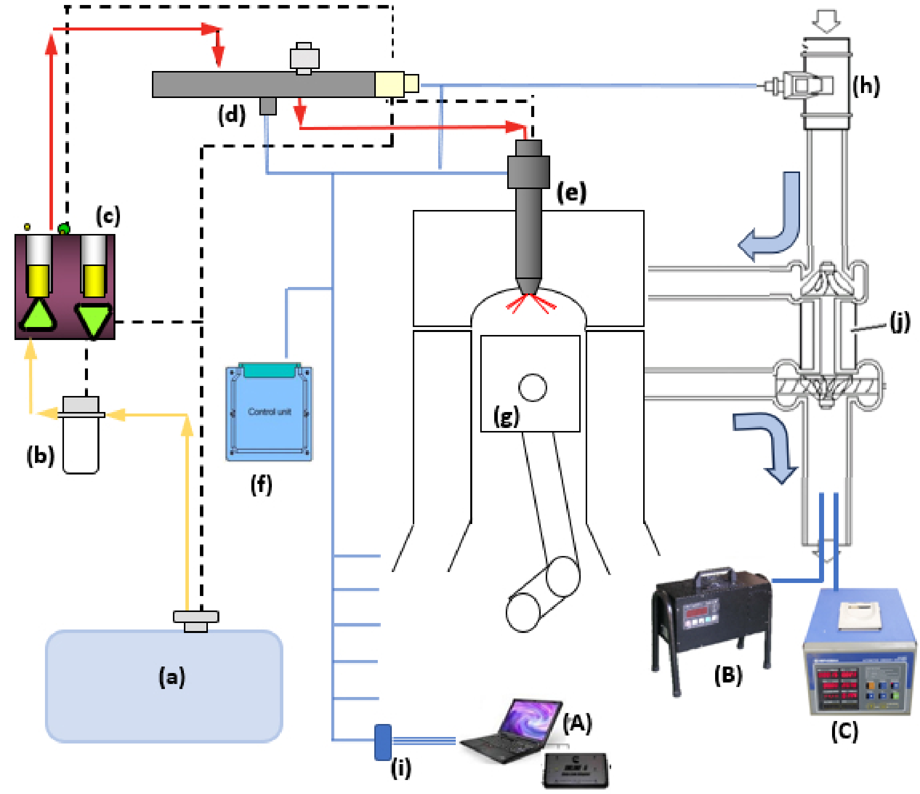

Figure 3. Schematic diagram of measuring apparatus: (a) fuel tank, (b) fuel filter, (c) fuel pump, (d) fuel rail, (e) injector, (f) ECU, (g) engine, (h) air flowmeter, (i) OBD connector, (j) turbocharger, (A) engine scanner, (B) smoke meter, (C) emission analyzer.

3.3. Methodology

A total of five types of fuel were used in the experiment, including pure diesel and biodiesel. Among these, biodiesel was selected as a blend of B20 (biodiesel 20% and pure diesel 80%) to be used as an experimental fuel. In order to stably mix biodiesel and pure diesel, the fuel was diluted for about 30 min in a 60° environment using an ultrasonic machine. Due to the characteristics of the CRDI electronic diesel engine, when testing with 100% biodiesel, there were differences in viscosity and spray conditions depending on the characteristics of the fuel, and the lubrication performance of each part differed from that of pure diesel. In order to protect the experimental engine, a selection experiment was conducted in the B20 area to compare and analyze the exhaust gas components generated during combustion. To obtain stable exhaust emission data, the engine was preheated to about 85° to 95° to warm up the engine. The measurements were made in a total of 5 engine rotation ranges (750 rpm, 1000 rpm, 1200 rpm, 1400 rpm, 1600) and, when each measurement range was reached, the engine was kept in a stable state for 1 min and then data were acquired. In this way, 1 to 5 sections were measured in one cycle, and the average value was calculated by repeating the measurement a total of three times. Finally, the final data were calculated by adding up all the measured values from the five sections. The data measured in this way were compared and analyzed with the emission data using pure diesel fuel in terms of PM, NOx, CO, HC, and fuel consumption values.

4. Results

4.1. Emission Characteristics

4.1.1. Particle Mass (PM) Characteristics

Figure 4 illustrates the total particulate matter (PM) emissions from a diesel engine running on different fuel blends at varying engine speeds. The baseline, represented by D100 (pure diesel), sets the reference point for the PM emissions. The B20 blends, which combined 20% biodiesel with 80% traditional diesel, were shown to reduce PM emissions to varying degrees. Specifically, B20 New Soybean and B20 Waste Soybean Fried Oil blends exhibited significant reductions in PM emissions by 20.3% and 19.9%, respectively. This suggests that incorporating soybean-based biodiesel into diesel can notably diminish particulate emissions, which are a concern for air quality and public health.

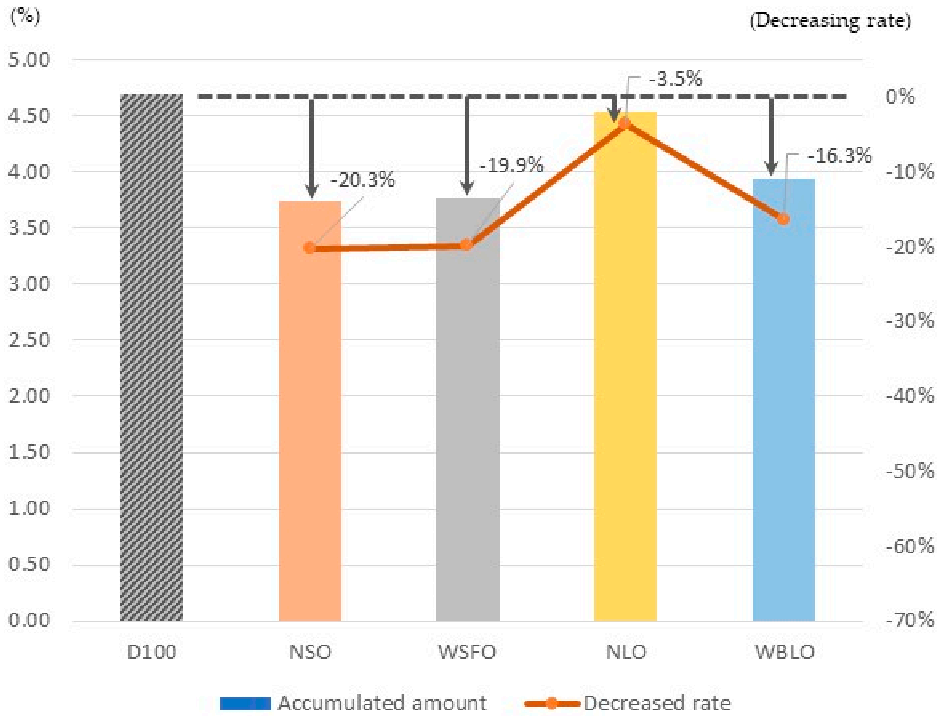

Figure 4. Total amount of PM emissions with various engine speeds.

The lard oil-based biodiesel blends, B20 New Lard and B20 Waste Barbecue Lard Oil, also contributed to a reduction in PM emissions but showed different levels of effectiveness. The B20 New Lard blend decreased PM emissions by a modest 3.5%, indicating that while it did contribute to cleaner emissions than pure diesel, the improvement was marginal. In contrast, the B20 Waste Barbecue Lard Oil showed a more substantial reduction of 16.3%, underscoring the potential environmental benefits of using waste-derived biodiesel. These variations underscore the importance of feedstock selection in biodiesel production for optimal environmental benefits. The results indicate that waste-derived biodiesel, particularly from soybean oil, can be a more effective alternative to traditional diesel in reducing engine PM emissions, reinforcing the role of biodiesel as a viable strategy for reducing air pollution from diesel engines [37].

4.1.2. CO Emission Characteristics

In Figure 5, the evaluation of carbon monoxide (CO) emissions from a diesel engine using different biodiesel blends is depicted, highlighting the environmental impact of various fuel types. The D100 bar sets the baseline for CO emissions, with subsequent bars indicating the CO output when the engine was powered by B20 biodiesel blends composed of 20% biodiesel and 80% diesel. The B20 New Soybean Oil blend showed a reduction in CO emissions by 10.7% and the B20 Waste Soybean Fried Oil blend led with an even greater reduction at 36.6%. These data points suggest that integrating soybean-based biodiesel into diesel fuel can significantly lower CO emissions, which is crucial for mitigating climate change.

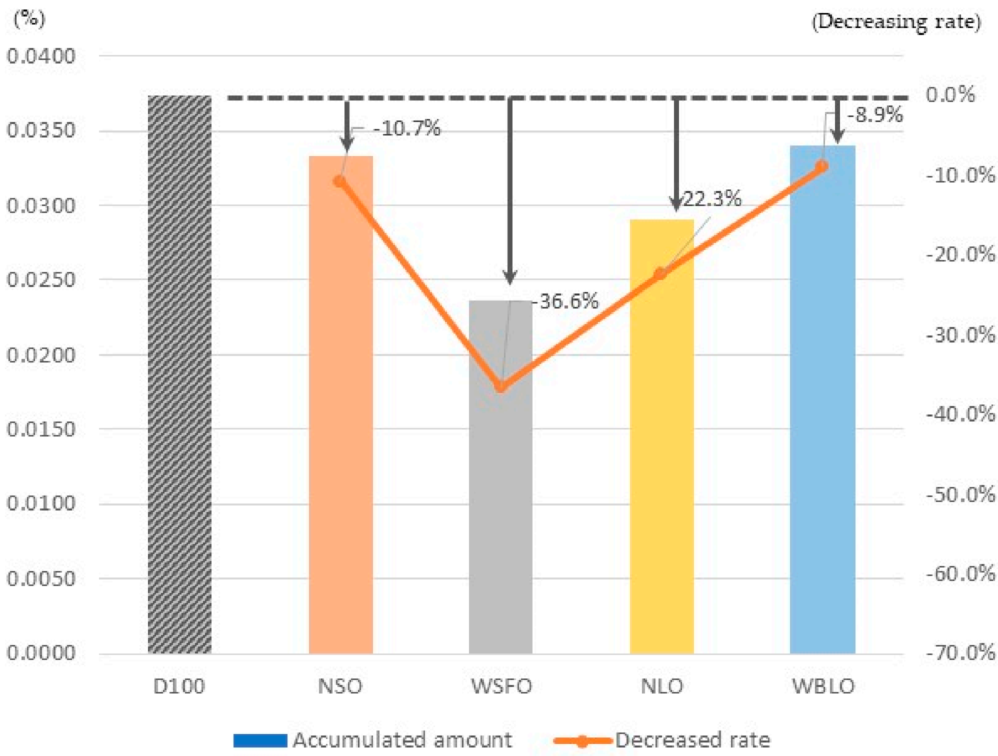

Figure 5. Total amount of CO emissions with various engine speeds.

B20 New Lard and B20 Waste Barbecue Lard biodiesel blends also reduced CO emissions by 22.3% and 8.9%, respectively. Although all biodiesel blends showed a reduction in CO emissions compared to pure diesel, the results indicate that the type of feedstock and its disposal (fresh vs. waste) play a pivotal role in the extent of reduction. Normally, CO has a reduction effect when the air–fuel ratio is high, and it has the characteristic of being emitted in large quantities when an engine is idling rather than driving on the road [38]. In this experiment, biodiesel extracted from waste soybean fried oil is known to be the most effective in reducing CO emissions, reinforcing the environmental value of waste utilization in biofuel production. The results presented support the use of biodiesel as a sustainable alternative to diesel, with the potential to significantly contribute to reductions in air pollutant emissions from diesel engines.

4.1.3. HC Emission Characteristics

Figure 6 illustrates the impact of biodiesel blends on hydrocarbon (HC) emissions from a diesel engine compared to the baseline emissions from standard diesel fuel (D100). The baseline established by D100 is visibly higher than the subsequent bars, which represent the accumulated HC emissions when the engine operated on B20 biodiesel blends. Notably, the B20 New Soybean blend showed a modest decrease in HC emissions of 4.7%, suggesting some improvement over traditional diesel. However, the B20 Waste Soybean Fried Oil blend exhibited a more substantial reduction, decreasing HC emissions by 19.3%. This significant reduction highlights the effectiveness of Waste Soybean Fried Oil as a biodiesel feedstock in lowering HC emissions, which is beneficial for improving air quality and reducing an engine's overall environmental impact.

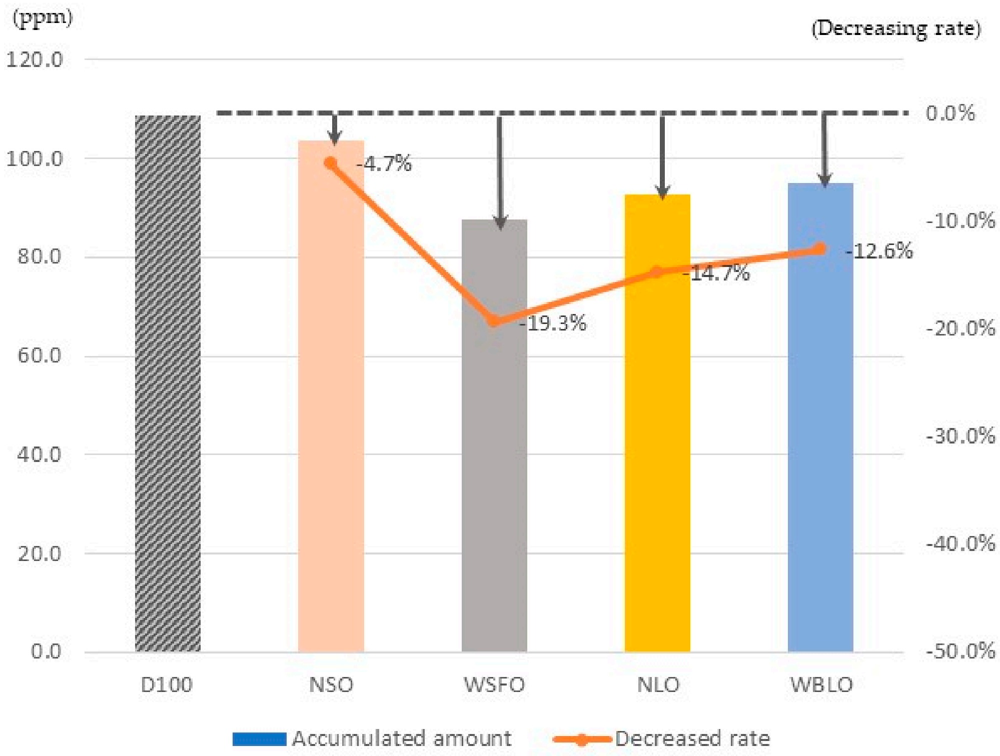

Figure 6. Total amount of HC emissions with various engine speeds.

In the case of lard-based biodiesel blends, the B20 New Lard showed a decrease in HC emissions of 14.7%, while the B20 Waste Barbecue Lard Oil blend presented a decrease of 12.6%. These reductions indicate that both new and waste barbecue lard oil biodiesels contribute to lowering HC emissions, albeit to a lesser degree than the Waste Soybean Fried Oil blend. The data from Figure 6 reveal that biodiesel blends, particularly those derived from waste oils, can effectively reduce HC emissions from diesel engines. The varying degrees of emission reductions across the different biodiesel blends underscore the importance of biodiesel feedstock selection for achieving optimal environmental performance [39].

4.1.4. NOx Emission Characteristics

Figure 7 presents data on the total nitrogen oxide (NOx) emissions produced by a diesel engine utilizing different fuel blends, depicted by a bar and line graph. The foundational metric is established by D100, which is assumed to be pure diesel fuel, serving as the baseline for NOx emissions. The subsequent bars represent the accumulated amount of NOx emissions when the engine operated on B20 biodiesel blends, which consisted of 20% biodiesel mixed with 80% diesel. The B20 New Soybean biodiesel blend showed a notable increase in NOx emissions of 42.4%, whereas the B20 Waste Soybean Fried Oil blend demonstrated a smaller increase of 8.8%. This considerable discrepancy suggests that the source of the biodiesel—new versus waste—has a significant impact on NOx emission levels, with Waste Soybean Fried Oil being the more environmentally favorable option.

The line graph, which depicts the increased rate of NOx emissions relative to D100, illustrates that the B20 New Lard biodiesel blend resulted in a 36.3% increase in NOx emissions, while the B20 Waste Barbecue Lard Oil blend showed a lesser increase of 25.4%. These data indicate that while all tested biodiesel blends led to higher NOx emissions compared to pure diesel, the extent of the increase was contingent upon the type of oil used in biodiesel production. Biodiesel produced from waste oils (soybean and lard) tended to have a lower impact on NOx emissions than those produced from new oils. NOx is created by combining nitrogen and oxygen under high temperature and pressure conditions during engine combustion. In particular, biodiesel has the disadvantage of emitting a large amount of oxygen during combustion because it contains about 10% of the oxygen content of the fuel compared to pure diesel [40]. Although biodiesel is associated with reduced PM and CO emissions, it poses challenges in terms of increased NOx emissions, which must be addressed to improve the overall environmental performance of biodiesel fuel.

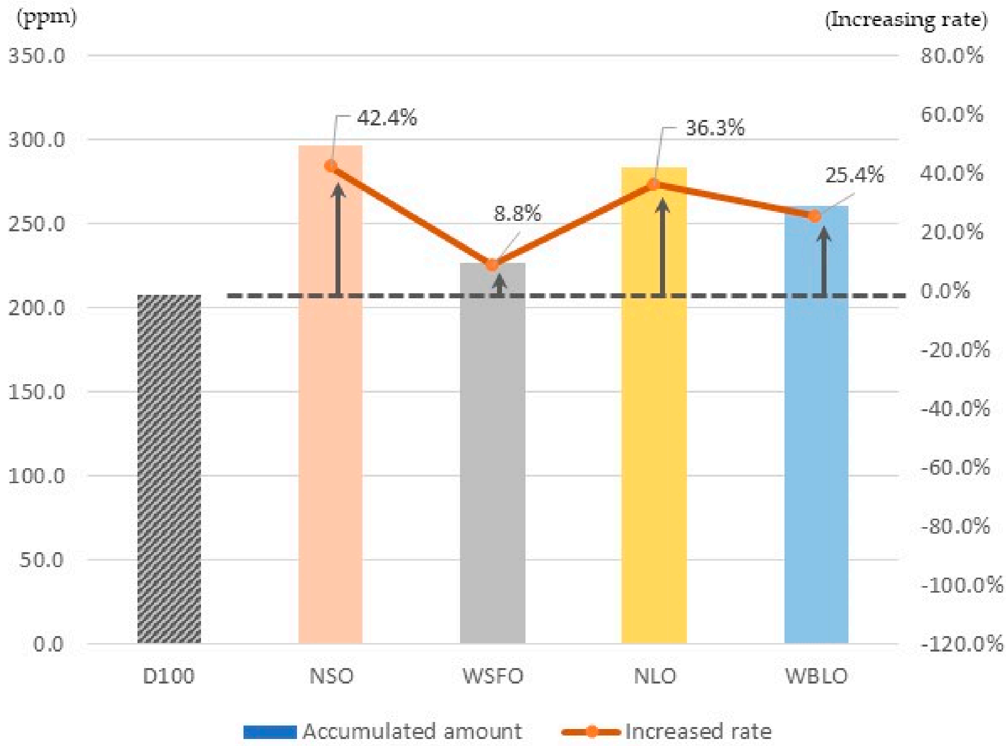

Figure 7. Total amount of NOx emissions with various engine speeds.

4.2. Fuel Consumption Characteristics

Figure 8 shows the influence of various biodiesel formulations on fuel consumption in comparison to standard diesel fuel, labeled as D100. The graph illustrates that when the diesel engine operated on a B20 New Soybean biodiesel blend, there was a 7.6% reduction in fuel consumption relative to D100, indicating an improvement in fuel efficiency with this type of biodiesel. However, the graph also shows that the B20 Waste Soybean Fried Oil blend resulted in a 9.2% increase in fuel consumption, suggesting that despite potential benefits in reducing emissions, this blend may be less efficient in terms of fuel usage than pure diesel.

For the biodiesel blends derived from lard, the B20 New Lard demonstrated an 8.0% rise in fuel consumption, while the B20 Waste Barbecue Lard Oil recorded a more modest increase of 3.8%. These figures reveal that the environmental advantages of using lard-based biodiesel, potentially reflected in lower emissions, might be offset by higher fuel consumption. This pattern across the different biodiesel blends accentuates the importance of selecting the appropriate feedstock for biodiesel production, not only to achieve environmental goals but also to ensure the economic viability of biodiesel through fuel efficiency. The insights from Figure 4 highlight the multifaceted effects of biodiesel on engine performance and emphasize the need for a holistic approach to evaluating the suitability of biodiesel as an alternative fuel.

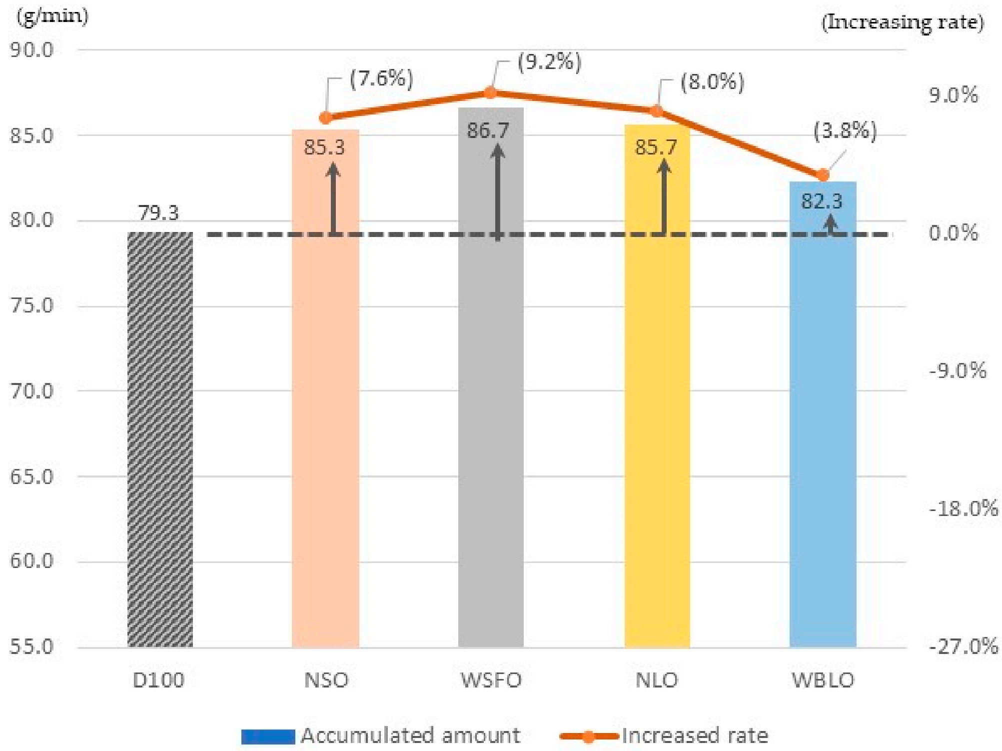

Figure 8. Total amount of fuel consumption with various engine speeds.

5. Conclusions

This experiment, conducted under no-load conditions with a common-rail diesel engine using biodiesel (B20) fuel, measured the exhaust gas components emitted and compared them with those from pure diesel fuel, leading to the following conclusions. The use of biodiesel blends, particularly those based on soybean oil, significantly reduced particulate matter (PM) emissions, implying a meaningful impact on air quality improvement and public health. The B20 New Soybean blend cut PM emissions by 20.3%, while the B20 Waste Soybean Fried Oil showed a slightly lower reduction of 19.9%. Moreover, these biodiesel blends demonstrated a substantial capability to lower carbon monoxide (CO) emissions, with the B20 Waste Soybean Fried Oil leading with a 36.6% reduction, indicating its potential contribution to climate change mitigation efforts.

However, an increase in nitrogen oxide (NOx) emissions across all biodiesel blends tested remains a significant challenge in realizing the environmental benefits of biodiesel. This is a considerable concern given the negative impact of NOx on both the environment and human health. This study also found that the choice of biodiesel feedstock plays an important role in the level of hydrocarbon (HC) emissions reduction, with Waste Soybean Fried Oil biodiesel proving to be the most effective in decreasing HC emissions. Regarding fuel consumption, while some biodiesel blends improved fuel efficiency, others increased fuel consumption, potentially compromising the economic benefits.

This research supports the integration of biodiesel as a viable alternative to diesel that is capable of delivering notable environmental benefits. Yet, it underscores the need for more extensive research and development to address the issue of increased NOx emissions and refine the production process to bolster both the environmental and economic viability of biodiesel.

The potential of biodiesel to act as a sustainable fuel source is clear, but realizing this potential requires addressing the increased NOx emissions in idle conditions. This solution will require a variety of applications by mixing new types of raw materials with biodiesel and conducting subsequent combustion experiments.

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Data Availability Statement: The data presented in this study were collected from the experimental investigation by the first author.

Conflicts of Interest: The authors declare no conflicts of interest.

Nomenclature

B20	Biodiesel 20%
RPM	Revolutions Per Minute
CRDI	Common Rail Direct Injection
WSFO	Waste Soybean Fried Oil
WBLO	Waste Barbecue Lard Oil
KOH	Potassium Hydroxide
NaOH	Sodium Hydroxide
CO	Carbon Monoxide
CO_2	Carbon Dioxide
HC	Hydrocarbon
NO_X	Nitrogen Oxide

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