International Journal of Advanced Technology and Social Sciences (IJATSS)
Vol.4, No.8, 2026: 1003-1012

Comparative Analysis of Biosolar, Dexlite, and Pertamina Dex on the Exhaust Emission Characteristics of a C223 Diesel Engine at Constant Engine Speed

Moch. Ilhan Nurrofiq[1]*, Achmad Rijanto[2], Nuril Ahmad[3]
Universitas Islam Majapahit, Mojokerto, East Java, Indonesia
Corresponding Author: Moch. Ilhan Nurrofiq; ilhanmael098@gmail.com

ARTICLEINFO

Keywords: Diesel Fuel Type, Exhaust Emission, Cetane Number, C223 Diesel Engine, Combustion Efficiency

Received: 5 June
Revised: 23 July
Accepted: 30 August

ABSTRACT

Fuel type is one of the key factors governing combustion quality and exhaust emission behaviour in compression-ignition engines, yet comparative evidence for widely used Indonesian retail diesel fuels on a specific engine platform remains limited. This study experimentally examined the effect of three commercial diesel fuels — Biosolar, Dexlite, and Pertamina Dex — on the exhaust emission characteristics of a C223 diesel engine. A quantitative experimental method was applied, in which the engine was operated at a constant speed of 1,500 rpm and each fuel was tested with three repetitions. A calibrated gas analyzer was used to measure carbon monoxide (CO), hydrocarbon (HC), and carbon dioxide (CO2) concentrations in the exhaust gas, supported by a tachometer and stopwatch to maintain stable operating conditions. The results show that Pertamina Dex produced the lowest average HC emission (25 ppm) and the highest average CO2 emission (2.1%), Dexlite produced 135 ppm HC and 1.70% CO2, while Biosolar produced the highest HC (140.67 ppm) and the lowest CO2 (1.63%). CO emissions were uniformly very low across all fuels, ranging from 0.00% to 0.02%. These findings indicate that fuel cetane number and sulfur content strongly influence HC and CO2 formation but have a negligible practical effect on CO at the tested condition. Pertamina Dex is therefore identified as the most recommended fuel for the C223 engine when the objective is to minimize unburned hydrocarbon emission and maximize combustion completeness. or findings and conclusions. Abstracts are written in only one paragraph

DOI: https://doi.org/10.59890/ijatss.v4i8.297
E-ISSN: 3026-2410
https://aprmultitechpublisher.my.id/index.php/ijatss/index

INTRODUCTION

The growing energy demand in the transportation, industrial, and agricultural sectors continues to sustain the widespread use of internal combustion engines, among which the diesel (compression-ignition) engine remains a preferred choice due to its high thermal efficiency, comparatively economical fuel consumption, and its capacity to deliver large torque at low rotational speed (Saksono, 2023). Despite these advantages, diesel combustion generates exhaust emissions containing carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), carbon dioxide (CO2), and particulate matter, all of which contribute to air pollution and pose risks to human health and environmental quality (Saksono et al., 2025). One of the principal factors governing the completeness of combustion in a diesel engine is the type of fuel used. In Indonesia, three grades of diesel fuel are commonly available to consumers: Biosolar (a B30 biodiesel blend with a minimum cetane number of 48), Dexlite (minimum cetane number 51, maximum sulfur content 1,200 ppm), and Pertamina Dex (minimum cetane number 53, maximum sulfur content 300 ppm). These fuels differ substantially in cetane number, sulfur content, density, and chemical composition (Supriyanto et al., n.d.). A higher cetane number generally shortens the ignition delay period, allowing the premixed combustion phase to be more tightly controlled and, in principle, more complete, whereas biodiesel-blended fuels such as Biosolar contain intrinsic oxygen that can assist oxidation but may also raise local combustion temperature and promote NOx formation under certain conditions (Saksono et al., 2025).

Prior studies have investigated the influence of fuel variation on diesel exhaust emissions from various perspectives. Higher-cetane fuels have been associated with more complete combustion and reduced CO and HC emissions, while biodiesel blends have been reported to lower CO and particulate emissions, sometimes at the expense of increased NOx (Hariyanto et al., 2021). Engine speed and load have likewise been shown to affect emission concentration (Kadhim & Oshchepkov, 2024). However, most existing research has been conducted on vehicular diesel engines or standardized test engines with widely varying specifications, and has more often focused on biodiesel blend ratios than on direct, side-by-side comparison of commercially available diesel grades on a single, well-defined engine platform (Persulesy et al., 2022).

The C223 diesel engine — a four-cylinder, indirect-injection unit of approximately 2,300 cc — is widely used in Indonesia, including in the Isuzu Panther and various agricultural and light transportation applications, and is also commonly used as a laboratory and teaching platform (Pratiwi et al., 2025). Because its combustion-chamber design and fuel-injection characteristics differ from those of common-rail or vehicular test engines used in earlier studies, its emission response to fuel-type variation has not been extensively documented. Indonesian regulation (Presidential Regulation No. 55/2019) further mandates periodic emission testing for diesel vehicles, with opacity limits of 40–70% depending on vehicle age, underscoring the practical relevance of identifying fuel choices that minimize exhaust pollutant levels (Saputro & Abdurrahman, 2022). This study therefore aims to analyze and compare the effect of three commercial diesel fuels — Biosolar, Dexlite, and Pertamina Dex — on the CO, HC, and CO2 exhaust emission characteristics of the C223 diesel engine under a fixed operating condition. The findings are expected to provide empirical guidance on which commercial diesel fuel yields the lowest exhaust emission for this specific and widely used engine type.

LITERATURE REVIEW

Diesel fuel is a petroleum-derived hydrocarbon mixture whose ignition performance is characterized by its cetane number (CN), a measure of ignition quality: a higher CN shortens the ignition delay and promotes earlier, more controlled combustion (Dwinanto et al., 2022). Biosolar is a B30 biodiesel blend (30% biodiesel, 70% diesel) with CN ≥ 48 and sulfur content up to 3,500 ppm, formulated in accordance with Ministry of Energy and Mineral Resources (ESDM) Regulation No. 12/2015. Dexlite carries CN ≥ 51 with a maximum sulfur content of 1,200 ppm, while Pertamina Dex, the premium grade designed for common-rail and turbocharged engines, carries CN ≥ 53 and a maximum sulfur content of only 300 ppm (Wahyudi et al., 2019). Exhaust CO is formed when the fuel–air mixture is locally rich or when combustion temperature is insufficient to complete oxidation of carbon to CO2; HC in the exhaust represents fuel that escaped combustion entirely, commonly linked to poor atomization or an excessively short combustion duration; CO2, while itself a greenhouse gas, is generally regarded in combustion diagnostics as an indicator of oxidation completeness, since more thorough combustion converts a larger fraction of fuel carbon into CO2 rather than CO or HC (Prahmana et al., 2020). A broad body of international literature corroborates the general relationship between cetane number and regulated emissions: cetane improvers have repeatedly been shown to reduce HC and CO while their effect on NOx and CO2 depends on operating load and injection strategy (Majewski, 2023; Kuszewski & Jaworski, 2024). Diesel fuel-injection systems are further classified into conventional mechanical systems and electronically controlled common-rail systems, the latter offering improved combustion efficiency, reduced vibration, and lower noise at higher cost (Maulana et al., n.d.).

METHODOLOGY

This research employed a quantitative experimental design to evaluate the effect of diesel fuel type on exhaust emission characteristics. The independent variable was fuel type (Biosolar, Dexlite, Pertamina Dex); the dependent variables were the concentrations of CO (%), HC (ppm), and CO2 (%) in the exhaust gas; and the controlled variables were engine speed (held constant at 1,500 rpm) and engine operating condition (standard, unmodified C223 diesel engine).

Research Object and Instrumentation

The test object was a standard, unmodified four-stroke C223 diesel engine. Before data collection, the fuel, lubrication, and cooling systems were inspected to confirm the engine was fit for testing. The primary measurement instrument was a calibrated gas analyzer, used to measure CO, HC, and CO2 concentrations by inserting its probe into the exhaust pipe once the engine reached a stable reading. A tachometer was used to monitor and maintain crankshaft speed at 1,500 rpm, and a stopwatch was used to standardize warm-up duration and measurement intervals across all trials. Each fuel type was stored in a separate, clearly labelled container, and the fuel line was purged between fuel changes to prevent cross-contamination.

Testing Procedure

The engine was first warmed up until it reached normal operating temperature. One fuel type was then loaded into the system, engine speed was set and confirmed at 1,500 rpm using the tachometer, and the gas analyzer probe was installed in the exhaust line. HC (ppm), CO2 (%), and CO (%) readings were recorded once the display stabilized. This measurement was repeated three times for each fuel to obtain a representative data set. After completing all repetitions for one fuel, the engine was stopped, the fuel system was drained and purged, and the procedure was repeated for the next fuel (Dexlite, then Pertamina Dex).

Data Analysis

Data from the three repetitions of each fuel were tabulated, and the arithmetic mean of each emission parameter was calculated using the standard mean formula $\bar{x} = (\Sigma x_i) / n$, where xi is the i-th measured value and n is the number of repetitions. The resulting mean values were presented in tabular and graphical form and compared across the three fuels to identify the fuel type associated with the lowest HC, the highest CO2 (indicating more complete oxidation), and the lowest CO, and to interpret the observed differences in relation to each fuel's cetane number and sulfur content.

RESULTS

Testing was conducted at a constant engine speed of 1,500 rpm, with three repetitions for each of the three fuel types. The results are summarized in Tables 1–3 and Figures 1–4.

Table 1. Exhaust Emission Test Results – Pertamina Dex

Trial	CO (%)	HC (ppm)	CO2 (%)
1	0.02	30	1.8
2	0.00	30	2.2
3	0.04	15	2.3
Mean	**0.02**	**25**	**2.1**

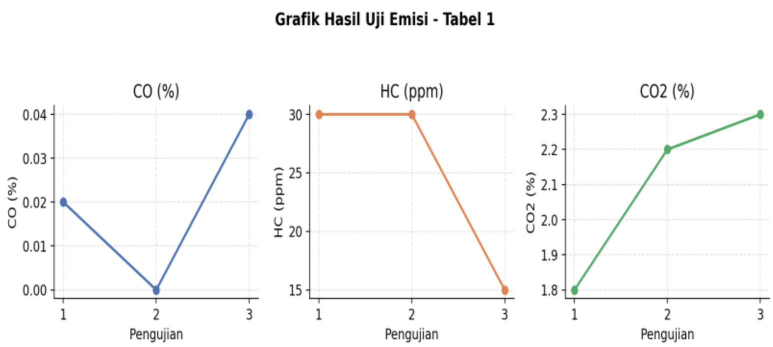

Figure 1. Exhaust Emission Test Results for Pertamina Dex

Pertamina Dex produced the lowest mean CO of the tested condition trend (0.02%), with one trial recording 0.00%, indicating a near-stoichiometric air–fuel ratio and near-complete carbon oxidation; the third-trial rise to 0.04% remained well within typical regulatory limits and is attributable to minor operational fluctuation (e.g., chamber temperature or injection pressure). Mean HC was the lowest among all three fuels (25 ppm), consistent with Pertamina Dex's high cetane number and low sulfur content, which shorten ignition delay and promote more uniform fuel–air mixing. Mean CO2 was the highest recorded (2.1%), reinforcing the interpretation that a larger share of fuel carbon was fully oxidized rather than emitted as CO or HC.

Table 2. Exhaust Emission Test Results – Dexlite

Trial	CO (%)	HC (ppm)	CO2 (%)
1	0.00	135	1.7
2	0.00	135	1.7
3	0.00	135	1.7
Mean	**0.00**	**135**	**1.70**

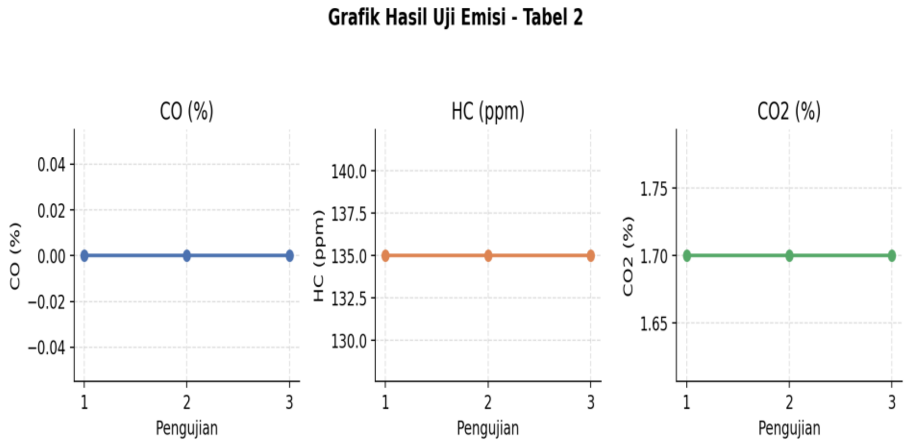

Figure 2. Exhaust Emission Test Results for Dexlite

Dexlite showed perfectly consistent readings across all three repetitions (CO 0.00%, HC 135 ppm, CO2 1.70%), suggesting stable operating conditions during testing. The zero CO reading indicates that carbon oxidation to CO was not a limiting issue for this fuel; however, the substantially higher HC (135 ppm, roughly 5.4 times that of Pertamina Dex) and lower CO2 relative to Pertamina Dex indicate a comparatively less complete combustion process, consistent with Dexlite's intermediate cetane number and sulfur specification.

Table 3. Exhaust Emission Test Results – Biosolar

Trial	CO (%)	HC (ppm)	CO2 (%)
1	0.00	155	1.9
2	0.00	144	1.4
3	0.00	123	1.6
Mean	**0.00**	**140.67**	**1.63**

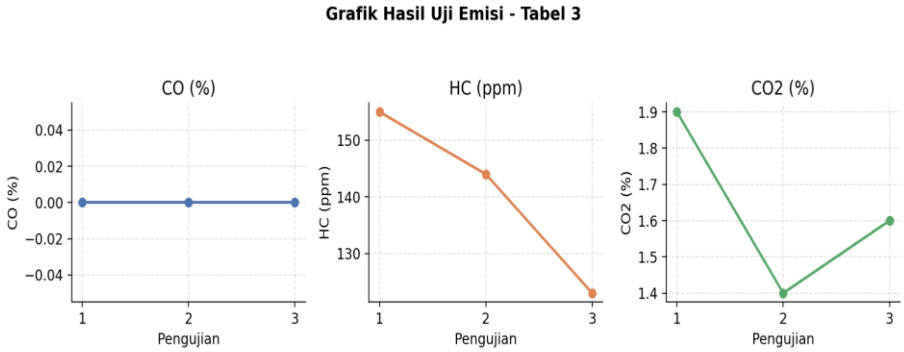

Figure 3. Exhaust Emission Test Results for Biosolar

Biosolar likewise produced consistently negligible CO (0.00%) across all trials, benefiting from the intrinsic oxygen content of its biodiesel fraction. HC declined steadily across the three repetitions (155 → 144 → 123 ppm), the clearest trend among the three fuels and suggestive of a warm-up-related improvement in combustion quality; nonetheless, its mean HC (140.67 ppm) was the highest of the three fuels tested, and its mean CO_2 (1.63%) was the lowest, forming a non-monotonic (V-shaped) pattern across repetitions that points to additional operational factors beyond combustion completeness alone.

Table 4. Comparison of Mean Exhaust Emission Values

Fuel	CO (%)	HC (ppm)	CO2 (%)
Pertamina Dex	0.02	25	2.1
Dexlite	0.00	135	1.70
Biosolar	0.00	140.67	1.63

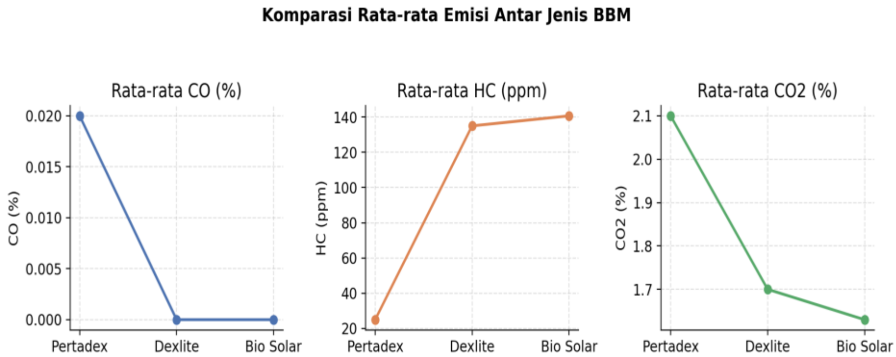

Figure 4. Comparison of Mean CO, HC, and CO2 Emissions Among Pertamina Dex, Dexlite, and Biosolar

Averaged across repetitions, HC rose sharply from Pertamina Dex (25 ppm) to Dexlite (135 ppm) and further to Biosolar (140.67 ppm), while CO_2 fell in the opposite order (2.1% → 1.70% → 1.63%) — a consistent inverse relationship, since carbon not fully oxidized to CO_2 is instead emitted as unburned HC. Mean CO differed only marginally (0.02% for Pertamina Dex versus 0.00% for the other two fuels), a difference that is statistically visible on the chart but practically negligible, as all three values lie far below regulatory exhaust-emission thresholds. Overall, the ranking from best to weakest combustion completeness was Pertamina Dex, Dexlite, and Biosolar — a hierarchy that mirrors the ascending cetane number and descending sulfur content of the three fuel grades.

DISCUSSION

The experimental results confirm that fuel type exerts a measurable effect on the exhaust emission characteristics of the C223 diesel engine, with the effect most pronounced for HC and CO2 and comparatively minor for CO. This pattern is consistent with the well-established relationship between cetane number and ignition delay: fuels with higher cetane number, such as Pertamina Dex (CN ≥ 53), ignite sooner after injection, shortening the premixed combustion phase and reducing the amount of fuel that escapes oxidation as HC (Dwinanto et al., 2022). The same mechanism is reported by Kadhim and Oshchepkov (2024), who found that diesel fuel grade significantly altered engine-out HC and CO2 while producing only marginal differences in CO across comparable diesel fuel types — a finding that closely parallels the present results. The inverse HC–CO2 relationship observed here is also supported by heavy-duty engine studies summarized by Majewski (2023), who reported that increasing cetane number lowers HC, CO, and NOx in heavy-duty diesel engines, while Kuszewski and Jaworski (2024) demonstrated that a cetane improver additive reduced ignition delay and produced measurable gains in combustion completeness in a butanol–diesel blend. Although the present study used unmodified commercial fuels rather than additised blends, the underlying combustion mechanism — shortened ignition delay leading to more complete oxidation — is directly analogous.

The comparatively high HC and low CO2 of Biosolar align with findings on biodiesel-blended fuels reported by Sa'diyah et al. (2024) and Hariyanto et al. (2021), both of whom noted that the intrinsic oxygen content of biodiesel supports CO oxidation but that its higher viscosity can impair fuel atomization, particularly during early operating stages, leaving a larger residual HC fraction. This is consistent with the declining-then-partially-recovering HC and V-shaped CO2 trend recorded for Biosolar in the present study (Table 3), which suggests that atomization quality improved somewhat as the engine continued running but did not fully close the gap with the higher-cetane fuels. The intermediate position of Dexlite across all three parameters mirrors its position between Biosolar and Pertamina Dex in cetane number (≥ 51) and sulfur content (≤ 1,200 ppm), and is broadly consistent with the emission trends reported for Dexlite-based studies on other diesel platforms, including R175A engines (Lesmana et al., 2022) and Dexlite–waste cooking oil blends (Saputro & Abdurrahman, 2022), both of which similarly positioned Dexlite as a mid-tier performer between subsidized biodiesel blends and premium diesel grades.

The negligible variation in CO across all three fuels (0.00–0.02%) contrasts somewhat with reviews suggesting that cetane number is the key determinant of CO formation in heavy-duty diesel engines (Majewski, 2023); however, this discrepancy is plausibly explained by the fact that the C223 is a comparatively low-duty, indirect-injection engine operating at a single, moderate speed, where sufficient excess air is available across all three fuels to keep the air–fuel ratio away from CO-forming rich conditions, regardless of cetane number. This observation is consistent with Persulesy et al. (2022) and Marhaini et al. (2022), who likewise reported that CO differences between diesel fuel variants become more pronounced only at higher engine loads or richer mixture conditions, both of which were outside the scope of the present constant-speed, unloaded test. From a practical standpoint, these findings support Saksono (2023) and Saksono et al. (2025) in recommending higher-cetane, lower-sulfur diesel grades where minimizing HC and maximizing combustion completeness is the priority — for example, in urban fleets subject to strict opacity limits under Presidential Regulation No. 55/2019 (Saputro & Abdurrahman, 2022). At the same time, the results reaffirm that fuel choice alone cannot be assessed on a single emission parameter: Pertamina Dex, despite its superior HC and CO2 performance, exhibited a marginally higher mean CO than the other two fuels, illustrating the trade-off dynamics that have also been reported in multi-parameter emission studies of alternative diesel and biodiesel blends (Norhafana et al., 2024; Pratiwi et al., 2025).

CONCLUSIONS AND RECOMMENDATIONS

Fuel type was shown to significantly affect the exhaust emission characteristics of the C223 diesel engine at a constant speed of 1,500 rpm, with the clearest effect observed on hydrocarbon (HC) and carbon dioxide (CO2) concentrations, and a comparatively minor, practically negligible effect on carbon monoxide (CO). Fuels with higher cetane number and lower sulfur content — represented here by Pertamina Dex — exhibited a shorter ignition delay, more complete combustion, and correspondingly lower HC and higher CO2 than Dexlite and Biosolar. Pertamina Dex was identified as the best-performing fuel overall, producing the lowest mean HC (25 ppm, compared with 135 ppm for Dexlite and 140.67 ppm for Biosolar) and the highest mean CO2 (2.1%, compared with 1.70% for Dexlite and 1.63% for Biosolar). Dexlite consistently occupied an intermediate position across all three parameters, while Biosolar recorded the highest HC and the lowest CO2, despite maintaining a CO level as low as Dexlite's. Mean CO across all three fuels remained within a narrow and very low range (0.00–0.02%), indicating that this parameter is less discriminating than HC or CO2 for distinguishing combustion quality among the fuels tested. On this basis, Pertamina Dex is recommended as the preferred fuel for the C223 diesel engine where the primary objective is to minimize exhaust emissions and support cleaner combustion.

FURTHER STUDY

This study was limited to a single engine speed (1,500 rpm) under no-load conditions and to three emission parameters (CO, HC, CO2); consequently, the findings should be interpreted within this operating envelope. Future work is recommended to (1) extend testing across a range of engine speeds and mechanical loads to better represent field operating conditions; (2) include additional emission parameters, such as NOx and smoke opacity, together with higher-resolution gas analyzers to reduce measurement bias at low concentrations; (3) apply statistical significance testing (e.g., ANOVA) with a larger number of repetitions to confirm that the observed differences between fuels are not due to random measurement variation; (4) examine specific fuel consumption alongside emissions to identify the most efficient operating point for each fuel; and (5) replicate the testing protocol on diesel engines of different specifications (e.g., conventional versus common-rail injection, or differing displacement and service age) to assess whether the observed fuel-emission relationships generalize beyond the C223 platform.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Rector of Universitas Islam Majapahit, the Dean of the Faculty of Engineering, and the Mechanical Engineering Study Program for their institutional support and provision of laboratory facilities used in this research.

REFERENCES

Dwinanto, M. M., Pell, Y. M., & Wadu, A. B. J. (2022). Studi pengaruh rasio tekanan kompresor turbocharger terhadap kinerja mesin diesel. Lontar Jurnal Teknik Mesin Undana, 9(01), 21–27.https://doi.org/10.35508/ljtmu.v9i01.7270

Harindah, G. (2024). Implementasi pemeliharaan prediktif berbasis analisis getaran menggunakan standar ISO 10816 pada mesin diesel di PLTD Tobelo. Jurnal Sosial Teknologi, 4(7), 501–515. https://doi.org/10.59188/jurnalsostech.v4i7.1326

Hariyanto, H., Gamayel, A. K., & Mulyana, F. (2021). Pengaruh campuran biodiesel-minyak nabati-minyak atsiri terhadap emisi gas buang mesin diesel. Jurnal Mekanik Terapan, 2(1), 41–47. https://doi.org/10.32722/jmt.v2i1.3819

Kadhim, M. Q., & Oshchepkov, P. P. (2024). Comparative analysis of diesel fuel types on engine performance and emissions. International Journal of Low-Carbon Technologies, 19, 2702–2708. https://doi.org/10.1093/ijlct/ctae198

Kuszewski, H., & Jaworski, A. (2024). Investigating the effect of 2-ethylhexyl nitrate cetane improver (2-EHN) on the autoignition characteristics of a 1-butanol–diesel blend. Energies, 17(16), 4085. https://doi.org/10.3390/en17164085

Lesmana, I. G. E., Hartantrie, R. C., & Sunjaya, E. (2022). Analisis perbandingan emisi gas buang bahan bakar biodiesel B30 dan solar Dexlite pada mesin diesel R175A. Almikanika, 4(1), 22–27. https://doi.org/10.32832/almikanika.v4i1.7170

Majewski, W. A. (2023). Fuel properties and emissions. DieselNet Technology Guide. https://dieselnet.com/tech/fuel_diesel_emissions.php

Marhaini, M., Mardwita, M., & Suranda, A. (2022). Analisa efisiensi bahan bakar dan dampak lingkungan emisi gas buang pembangkit listrik tenaga diesel (PLTD) terhadap pembangkit listrik mesin gas (PLTMG). Jurnal Surya Energy, 6(2), 57. https://doi.org/10.32502/jse.v6i2.4215

Norhafana, M., Ihsan, C. K., Noor, M. M., Hairuddin, A. A., Kadirgama, K., & Ramasamy, D. (2024). Enhancement of efficiency and mitigation of pollutant emissions in a compression ignition engine by the utilization of rice bran oil as green fuel. Journal of Physics: Conference Series, 2688(1), 012024. https://doi.org/10.1088/1742-6596/2688/1/012024

Persulesy, P. Y., K, B., & Suprapto, E. (2022). Pengaruh penggunaan bahan bakar biodiesel berbasis biji buah nyamplung (Calophyllum inophyllum) terhadap emisi gas buang mesin diesel. Lontar Jurnal Teknik Mesin Undana, 9(01), 48–56. https://doi.org/10.35508/ljtmu.v9i01.6295

Prahmana, R. A., Alfian, D. G. C., Supriyadi, D., Silitonga, D. J., & Muhyi, A. (2020). Pengaruh komposisi campuran minyak sereh wangi dan minyak cengkeh terhadap unjuk kerja mesin diesel. Journal of Science and Applicative Technology, 4(2), 82–89. https://doi.org/10.35472/jsat.v4i2.244

Pratiwi, I. A. P., Krisnaputra, R., Bahiuddin, I., Djati, I., & Nugraha, S. A. (2025). Analisis pengaruh campuran biodiesel terhadap performa dan emisi gas buang mesin diesel common-rail. Jurnal Mekanik Terapan, 6(3), 181–190. https://doi.org/10.32722/jmt.v6i3.8042

Sa'diyah, A., Aulatama, A. A., Shah, M., Anis Mustaghfirin, M., Nidhor Fairuza, M., & Haryono, E. (2024). Pengaruh rasio bahan bakar multi-feedstock biodiesel terhadap nilai emisi gas buang pada mesin diesel 4 langkah. Jurnal Teknologi Maritim, 8(1), 30–41. https://doi.org/10.35991/jtm.v8i1.48

Saksono, P. (2023). Analisis pengaruh jenis bahan bakar terhadap nilai emisi gas buang pada diesel engine common rail system. Al Jazari: Jurnal Ilmiah Teknik Mesin, 8(2). https://doi.org/10.31602/al-jazari.v8i2.12730

Saksono, P., Aji Sudikna, B., Ferdnian, M., & N. S. Sidabutar, S. (2025). Pengaruh jenis bahan bakar terhadap emisi gas buang injection Otto engine system. Journal of Applied Mechanical Engineering and Renewable Energy, 5(1), 43–50. https://doi.org/10.52158/jamere.v5i1.1088

Saputro, B. A., & Abdurrahman, A. (2022). Karakteristik biodiesel dari campuran bahan bakar Dexlite dan minyak jelantah tanpa perlakuan pada mesin diesel. Jurnal Teknik Kimia, 28(2), 51–59. https://doi.org/10.36706/jtk.v28i2.1003

Sukarno, S., Mariki, I. W. W., & Syam, M. Y. (2025). Perbandingan efisiensi bahan bakar dan putaran mesin diesel menggunakan solar dan Dexlite. JTAM Rotary, 7(2), 169–178. https://doi.org/10.20527/jtam_rotary.v7i2.16216

Sumardiyanto, D., & Susilowati, S. E. (2017). Pengaruh kondisi udara bilas terhadap kinerja mesin diesel. Jurnal Konversi Energi dan Manufaktur, 4(2), 81–88. https://doi.org/10.21009/jkem.4.2.5

Wahyudi, W., Sarip, S., Sudarja, S., & Suhatno, H. (2019). Unjuk kerja mesin diesel berbahan bakar campuran biodiesel jarak dan biodiesel jelantah. JMPM (Jurnal Material dan Proses Manufaktur), 3(1), 1–8. https://doi.org/10.18196/jmpm.3135