



Performance Analysis of Single Cylinder Diesel Engine on Biodiesel Fuel Temperature Variation

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Abstract: The use of biodiesel or bio solar fuel continues to grow in line with the increasing awareness of renewable energy and environmental concerns. However, the relatively high viscosity of bio solar fuel can affect the performance of diesel engines. This study aims to analyze the effects of fuel temperature variation using a heater on the performance of diesel engines. The research method employed was experimental testing on a single cylinder Jiangdong 170F diesel engine with fuel heating set at temperatures 40°C, 50°C, 60°C, and 70°C. The parameters analyzed include power, torque, fuel flow rate, thermal efficiency, and Brake Specific Fuel Consumption. The test results show that at a temperature of 50°C, the engine produced the highest power and torque at a rotational speed of 2600 rpm with a torque of 6.2 Nm and power output of 1.68 kW. At temperatures of 70°C the highest thermal efficiency was observed along with reductions in fuel consumption and BSFC at the same engine speed, yielding a thermal efficiency of 34.04%, a fuel consumption rate of 1.128×10^{-5} kg/s and a BSFC of 6.912×10^{-5} g/kWh. These results suggest that a temperature of 50°C is recommended for achieving high power and torque at high speeds, while temperature 70°C is recommended for attaining high thermal efficiency and lower fuel consumption at high engine speeds.

Keywords: biodiesel; fuel; temperature; diesel; heater



SDGs Problem Solving

The research and problem-solving in the attached study directly support SDGs Chapter #7 by optimizing biodiesel utilization through experimental analysis. This research offers practical solutions for healthier energy systems and sustainable industrial applications by enhancing renewable fuel performance, reducing fuel consumption, and improving engine efficiency.

Conflict of Interest Statement: The author(s) declares that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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1. INTRODUCTION

In the global environment, the diesel engine remains a primary driver across various sectors, including heavy transportation, industry, and agriculture (Maulana *et al.*, 2023). Diesel engines, with their exceptional capacity to generate substantial power and torque along with high fuel combustion efficiency and operational robustness, are irreplaceable for applications demanding superior performance and reliability. However, increasing pressure to reduce carbon emissions and environmental pollutants from diesel fuel continues to mount, fostering innovation in the search for alternative fuels (Kodate *et al.*, 2022). One of the most promising substitutes is biodiesel a renewable fuel derived from vegetable oils and other biomass sources which also contributes to the reduction of greenhouse gas emissions (Kralova and Sjöblom, 2010).

Despite its environmental benefits, the adaptation of biodiesel in conventional diesel engines is not without technical challenges (Zheng, Cho and Xu, 2022). One critical issue is its high viscosity, particularly at low temperatures (Jbril and Mekonen, 2021). This characteristic negatively affects fuel atomization and combustion efficiency, as diesel injection systems are calibrated to operate within spesific viscosity ranges for optimal atomization (Priyanto and Sudarmanta, 2015; Tariq and Saleh, 2024). Proper atomization is essential to ensure the fuel is broken down into fine, evenly distributed droplets in the combustion chamber. When the fuel is too viscous , it leads to poor atomization, incomplete combustion, inefficient fuel air mixing, increased fuel consumption, reduced engine efficiency, and higher exhaust emissions (Prasad, Rao and Raju, 2021).

To overcome this issue, a practical solution is to preheat the biodiesel fuel using a heater (Jbril and Mekonen, 2021). According to thermodynamic principles, increasing the temperature of a fluid reduces its viscosity. Preheating allows the viscosity of biodiesel to be adjusted to the optimal range required for efficient combustion and engine operation (Jbril and Mekonen, 2021). However, the heating process must be carefully controlled, as different temperature levels result in different viscosity values, which in turn influence combustion characteristics (Zheng, Cho and Xu, 2022). At appropriately reduced viscosity levels, improvements can be made in fuel atomization and vaporization, leading to enhanced engine power and torque, better combustion quality, and lower fuel consumption (Jbril and Mekonen, 2021).

The state of the art in this field emphasizes the importance of integrating fuel heating systems to maintain optimal fuel temperature during engine operation. Recent studies have focused on real time viscosity monitoring, adaptive heating control, and their impact on fuel spray dynamics, combustion quality, and emission reduction. These technological advancements represent key progress toward enabling biodiesel to meet or even exceed the performance benchmarks of conventional diesel fuel in internal combustion engines (Srinivasan *et al.*, 2022).

Consequently, this study aims to analyze the impact of varying preheated biodiesel fuel temperatures on diesel engine performance. Through controlled experimental investigation, it will evaluate how temperature variations from low to high affect critical performance parameters such as power, torque, thermal efficiency, and fuel consumption. The results will be used to determine the most effective preheating temperature to optimize biodiesel use in diesel engine applications.

2. METHODOLOGY

The study is conducted experimentally to a single cylinder diesel engine with temperature variations using a heater. The temperature variations start from 40°C, 50°C, 60°C, and 70°C with engine speed variations of 1800, 2000, 2200, 2400, and 2600 RPM (Priyanto and Sudarmanta, 2015; Zheng, Cho and Xu, 2022; Satrio, Sumbogo and Pramanda, 2024). In selecting a temperature of 40°C to a temperature of 70°C, it is based on the characteristics of biodiesel or bio solar which has a higher viscosity than diesel, especially at room temperature and in selecting a range of engine speed variations from 1800 RPM to 2600 RPM (Priyanto and Sudarmanta, 2015; Zheng, Cho and Xu, 2022; Satrio, Sumbogo and Pramanda, 2024). Performance of diesel engine represented by power, torque, and fuel consumption at each engine speed as described by schematic diagram on Figure 1.

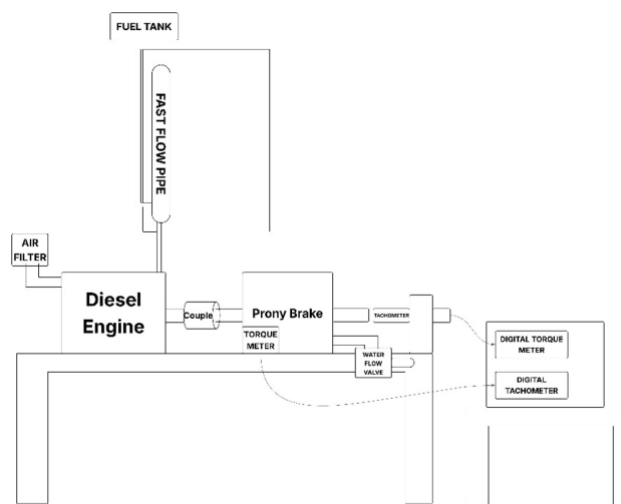


Figure 1. Schematic diagram

The schematic diagram above illustrates the test setup for evaluating engine performance using a prony brake system. The experiment begins with the fuel supply, which is stored in a fuel tank and then delivered to the diesel engine through a fast flow pipe. As the engine shaft rotates the prony brake load, resistance is generated, resulting in torque that is measured using a torque meter. The spesification of diesel engine single cylinder listed in Table 1.

Table 1. Spesification diesel engine

Spesification Jiangdong 170F	
Model	JD170F
Type	Single Cylinder
Bore x Stroke (mm)	70 x 60
Piston Displacement (L)	0.231
Injection Pressure (MPa)	14
Dimension (mm)	395 x 305 x 361

The Techquipment test is employed to evaluate the fuel consumption rate of the Jiangdong 170F diesel engine. It incorporates a digital indicator to read or measure the engine rotational speed and the torque produced by the engine. Additionally, this techquipment includes several other instruments consisting of hydro dynamometer, couple transmission, fuel gauge, and tachometer.

During diesel engine test using an immersion heater to heat the biodiesel. This heater works by submerging a heat-resistant metal element directly into the fuel. As electric current flow, the heating element transfers heat directly to the biodiesel fuel. A thermostat system is used to regulate the temperature during the process.

The fuel to be used in the Jiangdong 170F engine testing is B30 Bio solar Fuel. Because B30 bio solar fuel contains 30% biodiesel and 70% diesel fuel, which is offers better lubrication compared to pure diesel. Additionally, the high viscosity found in B30 bio solar fuel makes it suitable for use in the performance testing of the Jiangdong 170F diesel engine. Table 2 shown the ASTM (American Standard Testing Material) specifications for bio solar fuel composition that can be used as diesel engine fuel (Zheng, Cho and Xu, 2022).

Table 2. Specification Standard bio solar ASTM D6751 (Zheng, Cho and Xu, 2022)

Property	Method	Limits	Units
Flash point. Closed cup	D93	130 min	°C
Water and sediment	D2709	0,050 max	%volume
Kinematic viscosity 40°C	D445	1,9 – 6,0	Mm ² /s
Sulphated ash	D874	0,020 max	Wt%
Total ash	D5454	0,050 max	Wt%
Copper strip corrosion	D130	No.3 max	
Cetane number	D613	47 min	
Cloud point	D2500	Report	
Carbon residue	D4530	0,050 max	Wt%
Acid number	D664	0,80 max	mgKOH/g
Tree glycerin	D6584	0,020max	Wt%
Total glycerin	D6584	0,240 max	Wt%
Phosphorus	D4951	0,0010	Wt%
Vacuum distillation end point	D1160	360°C max	°C
Oxidative stability	EN14538	at 90%, 5 max	Ppm
Sodium potassium	EN14538	3min	Hours
Calcium, magnesium	EN14538	5 max	ppm

In this experimental method, testing is carried out to collect test data with predetermined research variables. In this research variable it consists of temperature variations in fuel heating and engine speed variation variables. The temperature variations in this test were carried out at temperature of 40°C, 50°C, 60°C, and 70°C (Zheng, Cho and Xu, 2022), as well as at engine speed variations of 1800, 2000, 2200, 2400, and 2600 RPM. In addition to research variables like variations in temperature and engine speed, there are also performance variables that will be calculated using specific equations. The performance variables that will utilize these equations to determine diesel engine performance are torque, BHP (Brake Horse Power), fuel consumption rate, engine thermal efficiency, and BSFC (Brake Specific Fuel Consumption). In this test there are also several steps or methods in collecting data during testing, as follows:

- 1) On the equipment tool, the Jiangdong 170F diesel engine is mounted on a hydro dynamometer system.
- 2) Installation of fuel inlet and outlet pipes between the injection pump and nozzle that have been combined with a container that will be filled with water. After that, the heater is

installed in the container, then filled with water. After filling with water, turn on the heater and use the thermostat to set the desired temperature to heat during the test.

- 3) If the fuel is at a temperature of 40°C, the engine can be turned on.
- 4) At a temperature of 40°C, it will take data such as fuel volume, which is 8 ml, torque produced by the engine, fuel flow time for 8 ml and rotation speed of 1800, 2000, 2200, 2400, and 2600 RPM. After obtaining the data results from the test with a temperature of 40°C, the next steps are to variations of temperature in multiples of 10°C such as 50°C, 60°C, and 70°C.

In this test result is calculated using the following formula equation (Das *et al.*, 2024):

$$T = F \times r \quad (1)$$

where T is torque (Nm); F is applied Force (N); and r is distance from the pivot point (m).

$$BHP = \frac{2\pi nT}{60 \times 1000} \quad (2)$$

where BHP is brake horse power (kW); n is rotational Speed (RPM); and T is torque (Nm).

$$mf = \frac{\rho \times V}{t} \quad (3)$$

where mf is fuel consumption (kg/s); ρ is density (kg/m³); V is fuel volume (L); and t = time (s).

$$\eta_{ther} = \frac{BHP}{LHV \times mf} \times 100\% \quad (4)$$

where η_{ther} is thermal efficiency (%) and LHV is lower heat value (kJ/kg).

$$BSFC = \frac{mf}{BHP} \quad (5)$$

where mf is fuel consumption (kg/s) and BHP is brake horse power (kW).

3. RESULTS AND DISCUSSION

The performance test results for the Jiangdong 170 F diesel engine yielded test data from bio solar testing without preheating, which serves as a reference for comparison with the test data from various temperature conditions listed in [Table 3](#).

Table 3. Results bio solar test data

Engine Rotational Speed (RPM)	Indicator Torque (Nm)	m _f (kg/s)
1800	22	9.207 × 10 ⁻⁵
2000	24	1.014 × 10 ⁻⁴
2200	25	1.093 × 10 ⁻⁴
2400	27	1.186 × 10 ⁻⁴
2600	28	1.320 × 10 ⁻⁴

Based on the data provided on [Table 3](#), it can be observed that in the testing of bio solar fuel, as the engine speed increases, the torque also increases. The higher the torque, the greater the fuel flow rate consumption becomes. At 1800 RPM, the engine produces a torque of 22 Nm, with a fuel consumption time measured using a stopwatch of 9.207 x 10⁻⁵ kg/s. This indicates that at lower RPM,

the fuel flow rate is lower. At 2600 RPM, the torque increases to 28 Nm with a fuel consumption time of 1.320×10^{-4} kg/s, meaning that the fuel consumption increases significantly. This demonstrates that as the engine speed increases, the resulting torque and fuel flow rate both increases, thereby producing a higher engine power output (Krishna et al., 2014).

Table 4. Results bio solar test data with temperature variations

Temperature (°C)	Engine Rotational Speed (RPM)	Indicator Torque (Nm)	m_f (kg/s)
40 °C	1800	21	8.330×10^{-5}
	2000	23	8.857×10^{-5}
	2200	25	9.855×10^{-5}
	2400	28	1.093×10^{-4}
	2600	31	1.206×10^{-4}
50 °C	1800	21	7.775×10^{-5}
	2000	24	8.971×10^{-5}
	2200	26	9.585×10^{-4}
	2400	28	1.044×10^{-4}
	2600	31	1.186×10^{-4}
60 °C	1800	22	8.136×10^{-5}
	2000	24	8.747×10^{-5}
	2200	27	9.855×10^{-4}
	2400	28	1.060×10^{-4}
	2600	29	1.186×10^{-4}
70 °C	1800	22	7.524×10^{-5}
	2000	25	8.330×10^{-5}
	2200	27	9.718×10^{-5}
	2400	29	1.060×10^{-5}
	2600	30	1.128×10^{-5}

Based on the data provided on Table 4, it is found that increasing the temperature from 40°C to 70°C affects the increase in torque and efficient fuel consumption rate. This explains that with the increase in temperature, the viscosity of the fuel will decrease resulting in a combustion process in the combustion chamber. From Table 3 and Table 4, we have obtained results regarding the time and torque produced. Therefore, to determine the fuel flow rate, efficiency, and BSFC (Brake Specific Fuel Consumption) based on the calculation results of the data provided on Table 5 and Table 6, it's evident that using biodiesel with increasing engine speed enhances performance. At a low engine speed of 1800 rpm, the engine produced a torque value of 4.4 Nm and a BHP of 0.82 kW, resulting in a thermal efficiency of 21.18%. This performance significantly improved at a high engine speed of 2600 rpm, where a torque value increased to 5.6 Nm and BHP to 1.52 kW, yielding a thermal efficiency of 27.16%. This indicates that higher engine speeds lead to more efficient combustion, which in turn generates greater torque and power. Furthermore, the decrease in BSFC from 1.110×10^{-4} g/kWh to 8.663×10^{-5} g/kWh at a higher engine speed also demonstrates that the engine operates by consuming or requiring less fuel to produce its power output. This overall positively impacts the engine's performance.

Table 5. Results of torque and BHP in bio solar test

Torque (Nm)	BHP (kW)
4.4	0.82
4.8	1.00
5	1.15
5.4	1.35
5.6	1.52

Table 6. Results of performance in bio solar test

m_f (kg/s)	Efficiency (%)	BSFC (g/kWh)
9.207×10^{-5}	21.18%	1.110×10^{-4}
1.014×10^{-4}	23.31%	1.009×10^{-4}
1.093×10^{-4}	24.78%	9.496×10^{-5}
1.186×10^{-4}	26.91%	8.743×10^{-5}
1.320×10^{-4}	27.16%	8.663×10^{-5}

Based on the data provided in [Table 7](#) and [Table 8](#), it was found that increasing the fuel temperature from 40°C to 70°C increased the power, torque, fuel consumption, efficiency, and decreased BSFC values. At a temperature of 40°C, the efficiency increased from 22.35% to 32.91% and the BSFC value decreased. At a temperature of 50°C, it showed a high efficiency of 33.47% with a low BSFC value, which indicates good combustion. At temperature of 60°C, it produced increased efficiency and power values. At temperature of 70°C, it reached the highest efficiency of 34.04%. This shows that fuel heating improves diesel engine performance due to lower viscosity and increased fuel evaporation and produces finer atomization resulting in perfect combustion.

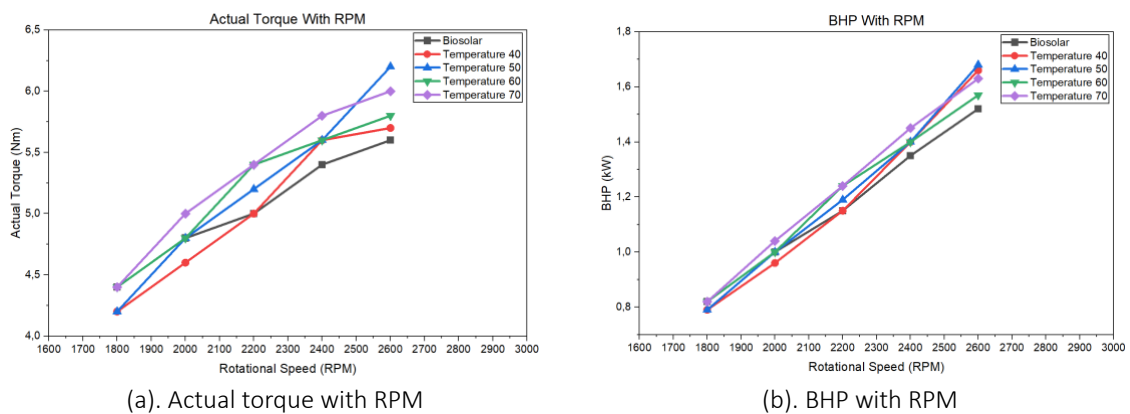
Table 7. Results of measured torque and BHP in bio solar temperature variations

Temperature (°C)	Torque (Nm)	BHP (kW)
40	4.2	0.79
	4.6	0.96
	5	1.15
	5.6	1.40
	6.2	1.66
50	4.2	0.79
	4.8	1.00
	5.2	1.19
	5.6	1.40
	6.2	1.68
60	4.4	0.82
	4.8	1.00
	5.4	1.24
	5.6	1.40
	5.8	1.57
70	4.4	0.82
	5	1.04
	5.4	1.24
	5.8	1.45
	6	1.63

Table 8. Results of performance in bio solar temperature variations

Temperature (°C)	m_f (kg/s)	Efficiency (%)	BSFC (g/kWh)
40	8.330×10^{-5}	22.35	1.052×10^{-4}
	8.857×10^{-5}	25.58	9.198×10^{-5}
	9.855×10^{-5}	27.49	8.560×10^{-5}
	1.093×10^{-4}	30.27	7.772×10^{-5}
	1.206×10^{-4}	32.91	7.150×10^{-5}
50	7.775×10^{-5}	23.95	9.825×10^{-5}
	8.971×10^{-5}	26.35	8.928×10^{-5}
	9.585×10^{-4}	29.39	8.005×10^{-5}
	1.044×10^{-4}	31.69	7.424×10^{-5}
	1.186×10^{-4}	33.47	7.029×10^{-5}
60	8.136×10^{-5}	23.97	9.815×10^{-5}
	8.747×10^{-5}	27.03	8.705×10^{-5}
	9.855×10^{-4}	29.69	7.926×10^{-5}
	1.060×10^{-4}	31.22	7.536×10^{-5}
	1.186×10^{-4}	31.31	7.514×10^{-5}
70	7.524×10^{-5}	25.92	9.076×10^{-5}
	8.330×10^{-5}	29.56	7.959×10^{-5}
	9.718×10^{-5}	30.10	7.816×10^{-5}
	1.060×10^{-5}	32.33	7.277×10^{-5}
	1.128×10^{-5}	34.04	6.912×10^{-5}

Based on the results of the graph provided on [Figure 2a](#), it was found that with the increase in fuel temperature has a significant effect on the increase in torque with the increase in engine speed. With the heating of the fuel reduces the viscosity of the fuel, resulting in a good combustion process. At a temperature of 70°C shows high torque at low to medium rotation speeds, while a temperature of 50°C produces the highest torque value at a rotation speed of 2600 rpm, so this explains that at a temperature of 50°C produces the highest torque value at high rotation speeds, although fuel consumption increases. When compared to biodiesel without heating show a low torque value and increased fuel consumption, because the high viscosity of biodiesel without heating inhibits the combustion process ([Tiwari and Singh, 2023](#); [Jaichandar, 2024](#)).

**Figure 2.** Graph actual torque and BHP vs RPM

[Figure 2b](#), it shows that fuel heating increases the BHP value along with increasing engine rotation speed. At a temperature of 50°C it produces the highest BHP value a rotation speed of 2600 rpm than other temperatures. At a temperature of 70°C it does not produce a high-power value, so this explains that a temperature of 50°C with increasing rotation speed requires an increase in fuel

consumption so that the power value will also increase than at a temperature of 70°C.

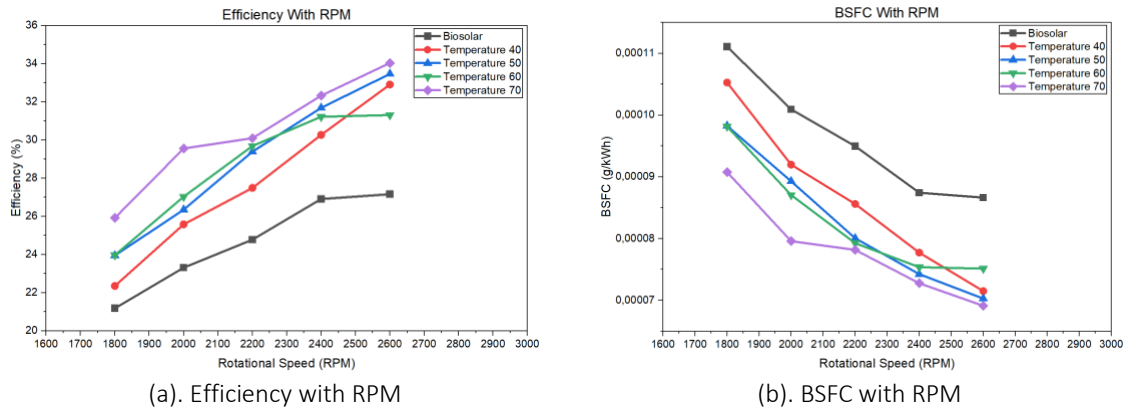


Figure 3. Graph efficiency and BSFC vs RPM

Based on the results of the graph provided on Figure 3a, it shows that with the heating of the fuel significantly increases the thermal efficiency of the engine, especially with the increasing engine speed. At a temperature of 70°C, it shows the highest thermal efficiency value of 34.04 % at an engine speed of 2600 rpm, because with the increase in fuel temperature, it accelerates fuel evaporation and produces finer atomization and produces faster and more homogenous combustion which produces high effective pressure, resulting in high engine thermal efficiency (Jaiswal *et al.*, 2015; Jbril and Mekonen, 2021). At temperatures of 40°C, 50°C, and 60°C also produce high efficiency, at a temperature of 40°C of 32.91%, a temperature of 50°C of 33.47%, and a temperature of 60°C of 31.31% than biodiesel without heating of 27.16%. This shows that heating the fuel increases efficiency by reducing fuel viscosity and producing fine atomizations (Ibrahim *et al.*, 2024).

Provided on Figure 3b, it shows that the value of the BSFC decrease with the increasing engine speed. At a temperature of 70°C shows the lowest BSFC value of 6.912×10^{-5} g/kWh at an engine speed of 2600 rpm. This shows that at a temperature of 70°C there is perfect combustion so that it requires little fuel to produce power (Jaichandar, 2024). Therefore, by heating the fuel, the decrease in fuel viscosity causes the nozzle mist to be smoother when injected (Srinivasan *et al.*, 2022; Das *et al.*, 2024). At temperatures of 50°C and temperature 60°C shows a low BSFC value where at a temperature of 50°C of 7.029×10^{-5} g/kWh and a temperature of 60°C of 7.514×10^{-5} g/kWh than bio solar without heating has the highest BSFC value of 8.663×10^{-5} g/kWh because it has a high viscosity so that it inhibits the fuel atomization process.

4. CONCLUSION

Based on experimental results, an elevation in fuel temperature diminishes fuel viscosity, therefore augmenting atomization and evaporation during the combustion process in a diesel engine, leading to more uniform combustion and enhanced overall engine performance. Reduced gasoline viscosity immediately enhances torque, power output, thermal efficiency, and fuel consumption optimization. Experimental findings indicate that the optimal torque and power were attained at a fuel temperature of 50°C, yielding 6.2 Nm and 1.68 kW at 2600 rpm; yet this condition was associated with heightened fuel consumption. In contrast, the best thermal efficiency and lowest

brake specific fuel consumption (BSFC) were obtained at a fuel temperature of 70°C, reaching 34.04% and 6.912×10^{-5} g/kWh, with a fuel consumption rate of 1.128×10^{-5} kg/s, indicating superior fuel economy despite a slight reduction in power output. The results indicate that fuel heating influences engine performance variably at different temperatures, with 50°C being best for power maximization, whilst 70°C is preferable for enhanced efficiency and fuel economy.

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