# PROPERTIES IMPACT OF PENTANOL ADDITIVE ON DIESEL ENGINE PERFORMANCE AND EXHAUST EMISSIONS: A REVIEW

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## ABSTRACT

The adoption of alternative fuels on a worldwide scale is primarily driven by concerns about global warming and energy issues. Alcohol fuels are typically derived from many sources and are commonly manufactured locally. Pentanol, a higher carbon alcohol, can serve as a secondary component in fuel blends. It possesses exceptional characteristics such as having a higher calorific value than lower alcohol, while viscosity and cetane number (CN) are more similar to diesel than lower alcohols. The main intentions of this article are to conduct an analysis of the utilisation of pentanol as an additive with diesel and biodiesel as a fuel for diesel engines. The present study examines how the physicochemical characteristics of pentanol affect the engine performance and exhaust emissions of diesel engines. In general, the inclusion of pentanol in both diesel and biodiesel-diesel blends leads to an increase in Brake Specific Fuel Consumption (BSFC) and a decrease in Brake Thermal Efficiency (BTE) compared to diesel fuel. Ternary blends, consisting of a substantial proportion of biodiesel, have reduced emissions of carbon monoxide (CO) and hydrocarbons (HC). These emissions drop as the percentage of pentanol in the blend increases. Pentanol-diesel blends exhibit reduced NOx emissions. Pentanol as an additive to diesel and biodiesel has a substantial impact on the reduction of exhaust emissions.

***Keywords**:* Higher alcohol, diesel fuel, biodiesel, CI engine, Engine Emissions.

## 1.0 INTRODUCTION

The energy demand for the transport sector has increased due to the industry's rapid growth [1]. From year 2010 to 2040, the automotive industry is liable for most (63%) of the global increase in the consumption of crude oil and other liquid fuels. Compression ignition (CI) engines are extensively utilised in the transportation industry, agriculture, and manufacturing due to their higher thermal efficiency compared to spark ignition (SI) engines [2][3][4]. Nevertheless, diesel engines release exhausts that contain numerous dangerous pollutants which have been regulated by legislation in many countries [5][6][7]. It is important to identify alternative fuels for the automotive industry because this business contributes to an exponential increase in the world's oil demand and increases greenhouse gas (GHG) emissions [8][9][10].

Alcohols can be used as alternative fuels and can be blended into diesel or biodiesel to boost its properties. The high oxygen concentration of alcohol makes it a good candidate for renewable fuel that can meet the requirements of diesel engines in order to optimise fuel combustion and reduce exhaust emissions [11] [12]. Alcohol has certain benefits over biodiesel when used as a binary or ternary fuel because of its lower density, kinematic viscosity (KV), and cold flow characteristics [13][14]. Lower carbon alcohols have been utilised as fuel additives in diesel engines. However, a decrease in alcohol level leads to a reduction in both calorific value and energy content, which in turn increases the fuel consumption required to generate an equivalent amount of power [15][16].

Pentanol, a higher carbon alcohol, exhibits superior viscosity and cetane numbers that are more similar to diesel than lower carbon alcohols [17]. It possesses a higher calorific value which can enhance Brake Specific Fuel Consumption (BSFC) [18]. Additionally, higher carbon alcohols burn more efficiently, emit less smoke and hydrocarbons, and produce less carbon soot.

The physicochemical properties of fuels are essential in determining their appropriateness for specific uses. The basic properties of the fuel, such as its calorific value, cetane number, kinematic viscosity and density, have a significant impact on the efficiency of combustion, the quality of fuel atomization, and the performance of the diesel engine's injection system.

## 2.0 PHYSICOCHEMICAL PROPERTIES OF PENTANOL

Pentanols are currently used as fuel additives in diesel blends because of their favourable physical characteristics for liquid transportation fuels [12][19]. Due to their superior blending abilities, hydrophobic characteristics, increased energy density, increased cetane numbers, and increased calorific value, higher alcohols are preferable to lower alcohols [20][21][18]. Table 1 shows the physicochemical properties of pentanol compared with diesel, lower carbon alcohol and higher carbon alcohol. It's proven that higher carbon alcohols have better physicochemical properties than lower carbon alcohol. Furthermore, some of the pentanol's characteristics, like kinematic viscosity, density, latent heat of vaporisation, and calorific value, are resemble diesel more closely. Pentanol exhibits a superior energy density in comparison to butanol, perhaps leading to enhanced fuel efficiency [17]. One appealing benefit of butanol and pentanol is their longer carbon chains compared to ethanol, allowing them to be manufactured using far less energy-consuming techniques [22].

Table 1: Comparison of diesel fuel properties with lower and higher alcohol properties that related to fuel combustion [11][16][15][23][24].

| Property | Diesel | Lower Alcohol | | Higher Alcohol | | |
|---|---|---|---|---|---|---|
| | | Ethanol | Methanol | Propanol | n-Butanol | n-Pentanol |
| Molecular Formula | $C_{12}\sim C_{25}$ | $C_2H_5OH$ | $CH_3OH$ | $C_3H_7OH$ | $C_4H_9OH$ | $C_5H_{11}OH$ |
| Kinematic Viscosity ($mm^2/s$) at $40^0C$ | 3.196 | 1.08 | 0.578 | 1.74 | 2.22 | 2.89 |
| Density (g/ml) at $15^0C$ | 0.825 | 0.789 | 0.791 | 0.803 | 0.810 | 0.815 |
| Cetane Number | 54 | 11 | 2 | 12 | 17 | 20 |
| Calorific Value (MJ/kg) | 42.8 | 26.83 | 20.08 | 30.63 | 33.1 | 34.65 |
| Oxygen Content (wt%) | 0 | 34.7 | 49.9 | 26.62 | 21.59 | 18.15 |
| Latent Heat of Evaporation (kJ/kg) | 250 | 918.42 | 1162.64 | 727.88 | 585.40 | 308 |

Understanding the characteristics of substances, such as their density and viscosity, is crucial for accurately modelling the flow of fluids in various systems [25]. Fuel density is a crucial attribute that directly impacts the performance parameters of the engine. The measurement of density follows the established protocols outlined in ASTM D1298. Increased density typically causes increased fuel flow resistance, resulting in elevated viscosity and perhaps leading to inadequate fuel injection [26]. Density of pentanol is lower than diesel as shown in Table 1.

The determination of kinematic viscosity is conducted according to the standard protocols outlined in ASTM D445 [27]. Kinematic viscosity plays a crucial role in evaluating the fuel injection process and determining the quality of the fuel. Viscosity impacts the size of the fuel droplet, the depth of jet penetration, the quality of atomization, the spray characteristics and the quality of combustion [28]. The Performance of the engine is influenced by the viscosity of the fuel, which can be either too high or excessively low. Injecting a fuel with high density results in the formation of larger droplets, which has a direct impact on the quality of combustion and leads to increased exhaust emissions [29]. The majority of biodiesel does not satisfy the viscosity criteria outlined in the regulations. Introducing pentanol into fuel blend samples is an additional method to enhance the fuel qualities by lowering the viscosity and density [30].

The cetane number quantifies the ignition delay of fuel as it is fed into the combustion chamber of a diesel engine [31]. It is determined according to the ASTM D613; their minimum limit presented in ASTM D6751 is 47, and EN14214 is 51 [16]. The CI engines need a cetane number between 45 and 60 [12][32]. Fuels with lower cetane values have longer ignition delays, allowing for increased vaporisation time prior to combustion. Greater initial combustion rates lead to increased heat generation within a certain volume, hence enhancing the efficiency of the conversion of heat into useful work.

The calorific or heating value of a fuel is a property used to assess its efficiency in terms of emissions and performance during combustion [27]. A researcher measured calorific value according to the ASTM D240. Table 1 demonstrates that the calorific values of pentanol are inferior to diesel compared to other alcohols hence it is noted that energy content of pentanol is more similar to that of diesel fuel.

## 3.0 ENGINE PERFORMANCE

Engine performance can be considered an important indicator of fuel conversion efficiency. Moreover, it is adopted to evaluate the fuel quality and verify its suitability for operating a diesel engine. The performance characteristics of diesel engines are influenced directly by the used fuel properties. Tables 2 provide a summary of the impact of pentanol fuel blends on the performance parameters of diesel engines, as discussed in the literature. Brake Specific Fuel Consumption (BSFC) is a parameter that measures an engine's ability to burn fuel and provides the crankshaft with whirling potential [33].

Atmanli et al. [23] examined the blends of waste oil methyl ester and higher alcohols of C3, C4 and C5. Based on engine performance results, BSFC increased because higher alcohols have a lower energy content. The increased oxygen content in pentanol leads to a reduction in its calorific value, leading to increased fuel consumption for an equivalent power output. Other studies have also found similar results, indicating that the values of BSFC rose when higher alcohols were used [34] [11]. However, when compared to C3 and C4, it was observed that C5 (pentanol) exhibited the lowest fuel consumption.

In another work, the fuel properties of diesel, waste oil methyl ester, and propanol, n-butanol, and 1-pentanol ternary blends were compared by Atmanli et al. [20] and investigated their effect on engine performance. The physicochemical properties of ternary blends indicate that higher alcohols- diesel-biodiesel blends decrease in heating value, density, flash point, cetane number and kinematic viscosity. BSFC performance for pentanol ternary blends was a sequence with other results [23] as the calorific value diminishes as the fuel oxygen concentration increases, resulting in a higher BSFC and necessitating a greater amount of fuel to maintain the same engine performance. However, quaternary blends of pentanol (10%-40%)-oil (5%)-diesel (50%)-biodiesel BSFC decreased as the pentanol content increased [13]. The decreased in BSFC observed in quaternary blends can be due to the elevated oxygen level in the fuel sample, which leads to enhanced combustion efficiency. 10% pentanol produced the greatest BSFC among the quaternary blends, whereas 40% pentanol addition produced the lowest BSFC [13].

M. Yesilyurt et al. [34] conducted a study on biodiesel/diesel/ n-pentanol fuel blends with 5 and 10 vol% pentanol concentrations. Engine test results indicated that BSFC increased between 0.77% and 8.07%, with a 5% and 10% addition ratio. The BSFC values in the blends exhibited an increase as the alcohol content was raised because pentanol has a lower heating value than diesel and biodiesel fuels. When the data were analysed, it was shown that the BTEs frequently reduced with the addition of pentanol.

Atmanli [20] and H. Imdadul et al. [35] study reveal that adding pentanol to the diesel-biodiesel blend positively impacts BTE. Currently, Ashok et al. [36] investigated a blend of biodiesel and pentanol (10%, 20%, and 30% vol). At full load conditions, BTE of the jatropha oil/1-pentanol blends is greater than that of diesel fuel by 20% and 30% for the respective pentanol fractions due to the increased oxygen content in pentanol, which causes an increase in temperature and improved combustion. The lower boiling point of higher alcohols, in comparison to diesel fuel, can enhance combustion and minimise heat losses.

Chaitanya et al. [33] observed that biodiesel-pentanol blends with 30% pentanol show slightly decreased BTE compared to diesel fuel. The high volume of pentanol in the biodiesel-pentanol blends results in higher oxygen content. Consequently, throughout the combustion process, the fuel is properly atomized and vaporised

Table 2: Summary of the relationship between the properties of pentanol fuel blends and engine performance of diesel engine

| Pentanol Blends | Engine Type | Operating Condition | Engine performance in comparison with Diesel | | Investigator |
|---|---|---|---|---|---|
| | | | BSFC | BTE | |
| P10WPO90<br>P20WPO80<br>P30WPO70 | Four cylinder | N=2000<br>Load=20-80%<br>EGR | Increased:<br>P10WPO90>P20WP080>P30WPO70>Diesel<br>• Lower cetane number | Decreased:<br>Diesel>P30WPO70>P20WPO80>P10WPO90<br>• Higher viscosity and lower heating value of WPO and Pentanol blends. | A.V.K Chaitanya et al.[33] |
| BD90P10<br>BD80P20<br>BD70P30 | Single cylinder | N = 2000 rpm<br>Load = 50%, 100% Fuel Injection Pressure (FIP) =400, 500, and 600 bar | - | Increased<br>BD70P30>BD80P20>D100> BD90P10<br>• Availability of extra oxygen at full load | A. Ashok et al.[36] |
| D70P30 | Single cylinder, | N = 1500 rpm<br>Load = 25%-100%<br>Injection timing = 90,120and 150bTDC | - | Decreased<br>• Higher latent heat of evaporation<br>• Higher viscosity<br>• Lower CN | N. Seelam [37] |
| DBOP10<br>DBOP20<br>DBOP30<br>DBOP40 | Single cylinder | N = 1500 rpm<br>Load = 25%, 50%, 75%, 100% | Increased: DBOP10 > DBOPO20 > DBOPO30 > DBOP40>Diesel<br>• Lower Calorific Value<br>*DBOP40: Lowest BSFC<br>• Higher oxygen content<br>• Lowered CN of alcohols | Decreased: Diesel > DBOB40 > DBO30 > DBOP20 > DBOP10<br>• Lower Calorific value of pentanol blends<br>*DBOP40: Maximum BTE<br>• Increased oxygen levels enhanced the heating efficiency.<br>• Lower CN | P. Appavu et al. [13] |

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|---|---|---|---|---|---|
| D75B20Pen5<br>D70B20Pen10<br>D60P20Pen20 | Ssingle cylinder | N = 2000 rpm<br>Load = 0 kW, 1.5 kW, 3kW | Increased:<br>• Lower heat of combustion of pentanol<br>• High LHV | Decreased: D100 > D70B20Pen10 > D75B20Pen5 >D60P20P20<br>• Inversely proportional to the lower heating value and BSFC | N. Yilmaz et al. [11] |
| D90P10,<br>D80P20 | Four-cylinder | N = 1800 rpm<br>Load = 0, 3, 6, 9kW | Increased<br>• High **latent heat of evaporation** | Decreased<br>• Lower heating value | N. Yilmaz et al [38] |
| D40B40Pn20 | Four-cylinder | N = 1800 rpm<br>Load = 1, 3, 6, 9 kW | Increased: D40B40Pn20 > D100<br>• Calorific value decreases<br>• Oxygen content of the fuel increases | Increased:<br>• Higher oxygen creates a better combustion.<br>• Lower boiling point of higher alcohols compared to diesel fuel | A. Atmanli [20] |
| C10P10<br>C15P15<br>C20P20 | Single cylinder, | N = 1200 rpm-2400 rpm | Increased<br>• Lower calorific value | Increased<br>• Higher oxygen and better atomization | H. Imdadul et al. [35] |
| 80%WB-20%C5 | Four-cylinder | N = 1800 rpm)<br>Engine loads = 0, 3, 6, 9 kW | Increased<br>• The higher oxygen content reduce the calorific value.<br>• High latent heat of evaporation | Decreased<br>• A lower cetane number causes longer ignition delay | A. Atmanli et al. [23] |
| C90P10<br>C80P20 | Single cylinder | N = 1800rpm<br>Load = 0 to 100% (25% increment) | Increased<br>• Lower calorific value<br>• Lower viscosity<br>• Increased of energy density as pentanol volume increases. | Decreased<br>• Lower calorific value of biodiesel-pentanol blends<br>• However, BTE increased as pentanol volume increased due to high energy density of pentanol which improves combustion rate.<br>• Enhanced atomization and vaporization of fuel due to lower viscosity | Y. Devarajan et al. [39] |

## 4.0 EXHAUST EMISSIONS

Exhaust gas emissions have adverse effects on human health. Moreover, the ozone layer's formation and the greenhouse effect may be facilitated by HC and NOx emissions [40]. The primary cause of CO is the inadequate oxygen present during the process of combustion [41]. HC emissions result from the inadequate combustion of fuels caused by oxygen deficiency[41]. The generation of NOx is varying in direct proportion to the temperature. Combustion temperature reduction can effectively lower NOx emissions [41]. The effects of pentanol exhaust emissions listed in the literature are summarised in Table 3, which includes different engine types, operation conditions and the effects of pentanol blends on the emission.

Q. Ma et al.[42] investigated emissions characteristics of diesel-biodiesel-pentanol blends on the diesel engine. Pentanol blends with a 10% concentration have minimal effect on NOx emissions. However, the high latent heat of vaporisation of pentanol causes the decline of exhaust gas temperatures for pentanol-diesel-biodiesel blends at low speed. The pentanol's higher latent heat of vaporisation results in a decrease in combustion temperature, hence contributing to the reduction of NOx generation. However, J. Liang et al. [43] experimented with investigating the biodiesel-pentanol blends on exhaust gas recirculation (EGR) at different rate, showing different NOx results. The NOx emissions exhibited a positive correlation with the amount of pentanol, with marginal variations seen among different fuels. Pentanol blends containing 20% and 30% pentanol concentrations exhibit increased ignition delay and decreased viscosity. These blends enhance atomisation mixing time and improve the proportion of the fuel-air ratio. Consequently, they result in higher peak temperatures within the cylinder and longer durations at elevated temperatures. Similarly, P. Appavu et al. [13] found NOx emissions increase as pentanol concentration increases for diesel-biodiesel-oil-pentanol blends (10%-40% pentanol concentration).

An experiment conducted by H.Imdadul et al.[44] demonstrated that the inclusion of pentanol in diesel-biodiesel blends. The result shows a significant decrease in HC emissions. Specifically, the 20%vol pentanol blend showed a reduction of 67.7% compared to the diesel-biodiesel blend, while the 15%vol pentanol blend showed a reduction of 56.25%. The anticipated outcome is a direct consequence of the augmented quantity of oxygen molecules engaged in the combustion process of the blends, leading to reduced HC emissions [42][17]. According to a study conducted by J. Liang et al.[43] the use of diesel-biodiesel-pentanol blend enhances the spray properties and decreases the latent heat of vaporisation of the fuel mixture.

N.Yilmaz et al.[38] examined the effect of 1-pentanol (10% and 20% by volume) in waste oil methyl ester and diesel fuel on diesel engine exhaust emissions. Diesel-pentanol blends and biodiesel-pentanol blends exhibit different behaviours. Diesel-pentanol blends raised CO and HC emissions while decreasing NOx generation. When employing biodiesel-pentanol blends, the generation of CO, HC, and NOx emissions decreased at 0 and 3kW loads but increased at 6 and 9kW loads. Pentanol-diesel blends resulted in a reduction in the overall cetane number of the blended fuel, which in turn extended the duration of the premixed combustion phase. This causes timing problems in relation to the combustion and expansion stages, leading to higher levels of HC emissions.

Table 3: Summary of the relationship between the properties of pentanol fuel blends and exhaust emissions of diesel engine

| Pentanol Blends | Engine Type | Operating Condition | Exhaust Emissions in comparison with D100 | | | Investigator |
|---|---|---|---|---|---|---|
| | | | CO | HC | NOx | |
| BD90P10<br>BD80P20<br>BD70P30 | Single cylinder | N = 2000 rpm<br>Load = 50%, 100% Fuel Injection Pressure (FIP) | Increased<br>BD70P30> BD80P20> BD90P10> Diesel<br>• Higher latent heats of vaporisation | Increased<br>BD70P30> BD80P20> BD90P10> Diesel<br>• Lower Cetane Number | Decreased<br>• Higher latent heats of vaporisation<br>• Low calorific value | A. Ashok et al [36] |
| D80P20 | Four-cylinder | N = 1500 rpm<br>EGR rate = 0-25% | Decreased:<br>• Higher local oxygen content | Increased<br>• Lower Cetane Number<br>• High latent heat of evaporation | Increased<br>• Lower Cetane Number<br>• High Oxygen content | N. Seelam [45] |
| B10P10 | Single cylinder | n = 1000-1800 rpm | Decreased: D100 > B10P10<br>• High Cetane Number | Decreased: D100 > B10P10 | Decreased: D100 > B10P10<br>Higher latent heats of vaporisation | Q. Ma et al. [42] |
| B10P20<br>P30<br>B20P10 | Single cylinder | N = 1500 rpm<br>Pi = 0.15 MPa<br>EGR | Decreased:<br>D100 > B20P10 > B10P20 ><br>P30<br>• High oxygen content | Decreased:<br>• High oxygen-containing properties. | Decreased: D100 > B20P10<br>• Higher latent heats of vaporisation<br>Increased: P30 > B10P20 > D100<br>• Lower Cetane Number<br>• Lower viscosity | J. Liang et al. [43] |
| D80NP20<br>D80IP20 | Four cylinder | N = 1800rpm, 2200 rpm | - | - | Increased: D80NP20 > D80IP20 > D100 | H. Chen et al. [46] |
| DBOP10<br>DBOP20<br>DBOP30<br>DBOP40 | Single cylinder | N = 1500 rpm<br>Load = 25%, 50%, 75%, 100% | Decreased:<br>D100 > DB0P10 > DBOP20 > DBOP30 > DBOP40<br>• Increases the oxygen concentration<br>• Higher calorific value | Decreased:<br>D100 > DB0P10 > DBOP20 > DBOP30 > DBOP40 | Increased:<br>DBOP40 > DBOP30 > DBOP20 > DBOP10 > D100<br><br>However, it reduces as the engine load increases: | P. Appavu [13] |

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|---|---|---|---|---|---|---|
| | | | | | • Higher latent heats of vaporisation | |
| CNSME90P10<br>CNSME80P20 | Single cylinder | Load = 0 to 100% (25% increment) | Decreased<br>• High oxygen content<br>• Low viscosity | Decreased<br>• Higher oxygen content<br>• High Cetane Number<br>• Lower viscosity | Increased<br>• Higher oxygen | Y. Devarajan et al [41] |

| Pentanol Blends | Engine Type | Operating Condition | Exhaust Emissions in comparison with D100 | | | Investigator |
|---|---|---|---|---|---|---|
| | | | CO | HC | NOx | |
| CNSBD90P10<br>CNSBD80P20 | Single cylinder | N = 1300rpm<br>Pi = 200 bar<br>Load = 25, 50, 75, 100% | Decreased<br>• High oxygen content<br>• Lower viscosity | Decreased<br>• Lower viscosity<br>• Higher latent heats of vaporisation<br>• High Cetane Number | Decreased<br>• Lower calorific value<br>• Higher latent heats of vaporisation | Y. Devarajan et al. [47] |
| D90P10,<br>D80P20 | Single cylinder | N = 1800 rpm<br>Load = 0, 3, 6, 9kW | Increased:<br>• Higher latent heat of evaporation<br>• Lower cetane numbers. | Increased:<br>• High latent heat of evaporation | Decreased<br>• High latent heat of evaporation | N. Yilmaz et al [38] |
| B90D5P5<br>B85D5P10 | Direct injection diesel engine | N= 1500 rpm | Decreased<br>Diesel >B90D5P5> B85D5P10<br>• Higher oxygen content | Decreased<br>Diesel >B90D5P5> B85D5P10<br>• Higher oxygen content | - | D. Babu [48] |
| D40B40Pn20 | Four cylinder | N = 1800 rpm<br>Load = 1, 3, 6, 9 kW | Increased: D40B40Pn20 > D100<br>• Lower cetane numbers. | - | Decreased: D100 > D40B40Pn20<br>• Higher latent heats of vaporisation | A. Atmanli [20] |
| D70P30<br>D40B30P30 | Single cylinder | N = 1600 rpm | Decreased: | Decreased: D100 > D40B30P30 | Decreased at low load: | L. Li et al. [49] |

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|---|---|---|---|---|---|---|
| | | Six steady loads<br>IMEP = 0.5-1.0 MPa<br>No EGR | D100 > D70P30 > D40B30P30<br>• Higher local oxygen content | • High oxygen content<br>• High Cetane Number<br>• Due to the addition of biodiesel<br>Increased: D70P30 > D100<br>• Lower Cetane Number | D100 > D70P30 > D40B30P30<br>• Higher latent heats of vaporisation<br>Increased at high load:<br>• Lower Cetane Number<br>• High Oxygen content | |

## 5.0 CONCLUSION

Alcohols, as an alternative fuel, are becoming increasingly important in fulfilling the energy demands of the automotive industry. This paper focuses on how pentanol affects the properties of diesel and biodiesel fuels, with the potential to replace petroleum-based fuels or enhance fuel properties. The following findings can be addressed from the analysing of the surveyed literature as follows:

- Pentanol fuel blends exhibit higher BSFC compared to diesel fuel. The reduced calorific value of the blends leads to inefficient combustion, necessitating a greater quantity of fuel to be consumed in order to achieve the equivalent power output of diesel fuel. The increased BSFC of pentanol fuel blends can be attributed to the lower cetane number and higher oxygen content.

- Pentanol fuel blends resulted in a drop in BTE when compared to diesel fuel due to the LHV of pentanol and its lower cetane number. Some studies show high BTE of pentanol-blended biodiesel due to the high oxygen content in the blended fuel.

- Most studies show that pentanol as an additive in diesel/biodiesel positively impacts reducing CO and HC emissions. Higher concentrations of oxygen molecules of the pentanol fuel blends reduce emissions of CO and HC.

- Higher LHV of pentanol and lower cetane number of pentanol blends lowers the in-cylinder temperature, thus reducing NOx production, especially at low engine load and decreasing with increasing pentanol fraction.

Overall, pentanol can be regarded as a viable oxygenated additive for diesel/biodiesel due to its enhanced properties. In addition, the inclusion of pentanol in diesel and biodiesel has a substantial impact on the environment, greenhouse gas emissions, and overall human health.

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