



# Performance Enhancement and Emissions Analysis of Diesel Engine with Biodiesel, N-Propanol and 1-Butanol Blend

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## ABSTRACT

An experimental investigation is conducted to evaluate the effects of using blends of 1-Butanol, n-Propanol and biodiesel with base diesel fuel, with 5% and 10% (by vol.) each alcohol fuel (1-Butanol and n-Propanol), on the diesel engine performance and exhaust gas emissions. The experimental investigation of the above fuel blends, with the engine working at different loads. Engine performance and exhaust gas emissions such as nitrogen oxides, carbon monoxide, carbon dioxide, unburned hydrocarbons and smokiness are measured. The measured results of alcohol fuel blends with different concentration compared with base diesel fuel results. It is revealed that this fuel, which can be produced from alcohol fuel blend with biodiesel and base diesel blends, is very promising biodiesel performance enhancement of diesel engine operations. The present work proved that the 5% of alcohol fuel blend with 25% of biodiesel and diesel produced maximum efficiency and minimize the exhaust emission level compare with 10% of alcohol blend and base diesel.

**Keywords:** Diesel engine; 1-Butanol; N-Propanol; Emission; Performance.

## NOMENCLATURE

BTE	brake thermal efficiency	HC	hydro carbon
SFC	specific fuel consumption	NOx	nitrous oxide
BP	brake power	CO <sub>2</sub>	carbon di oxide
CO	carbon monoxide		

## 1. INTRODUCTION

Diesel engine plays a very important role for road transport. The diesel engine powered by petroleum diesel fuel. The demand of diesel fuel engorges the research on alternative fuel. The researchers found, vegetable oil and animal fat is a major source for alternative fuel extraction. Demirbas (2008a) compared these two source transesterification and its components effects. Lapuerta *et al.* (2008) reviewed that the effect of alternative fuel on diesel engine performance and emissions. They mentioned important factors which mainly affect the engine performance and emissions, such as lower heating values, viscosity, chemical bonding and density. Palash *et al.* (2013), Hoekman *et al.* (2012), Fernando

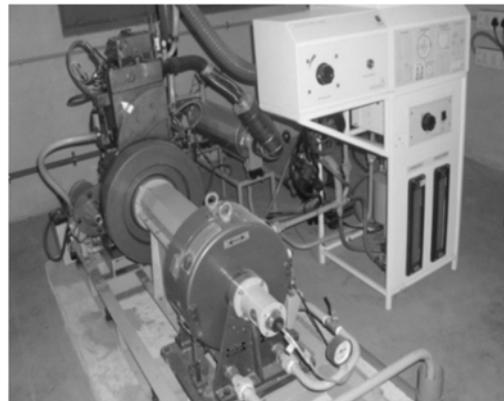
(2006) mentioned that the major emissions from alternative fuels. NOx and soot consider as a major pollutant in CI engine exhaust, unfortunately alternative fuels also increase these types of pollutants due to high combustion temperature and fuel NOx. Demirbas (2008b) studied on Cotton seed biodiesel preparation and its properties. The cotton seed oil has a higher viscosity, lower certain number and heating values. Nabi *et al.* (2009) investigated performance and exhaust emission on diesel engine powered by cotton seed biodiesel. The biodiesel concentration results shown less CO, PM and smoke emission than neat diesel fuel. NOx emission with biodiesel concentration shows higher values when compared with neat diesel fuel. The higher oxygen molecules present in the biodiesel were the main

reason for results. The brake thermal efficiency of biodiesel concentration was lower than the neat diesel fuel due to lower heating values of the mixtures, volatility, higher viscosity and higher density. [Oguzhan Dogan \(2011\)](#) studied the performance development and emissions reduction of a single cylinder diesel engine at a constant engine speed and different loads by using n-butane blended diesel fuel. Butane can blend with diesel fuel easily. The brake thermal efficiency and brake specific fuel consumption were increased little with increasing butane content in the fuel. The exhaust emissions were NOx, CO, smoke was reduced with increasing butane content in the fuel, but HC pollutant was reduced significantly with increasing butane content in the fuel. [Xiaolei \(2012\)](#) reported ignition delay period for iso butanol-diesel blend and n-butanol-diesel blend. A result shows that n butanol- diesel blend took some longer ignition delay compare with Iso butanol – diesel blend. Iso butane produced higher cylinder peak pressure and higher pre mixed combustion heat release rate compare with n-butanol. Lower Soot emissions produced by n-butanol compare with isobutene. [Ibrahim \(2006\)](#) found that the effect of diesel, biodiesel and diesel-biodiesel-butanol mixtures on diesel engine performance and emissions. [Zhang \(2016\)](#) investigated that the effect of butanol and pentanol on diesel engine performance and emissions. It observed significant change in particulate mass and elemental carbon emission with no significant change in the performance. [Balamurugan et al. \(2014\)](#) investigated performance and emission analysis of the diesel engine with the blend of n-propanol at different proportions. The blending of n-propanol with diesel shows augments the brake thermal efficiency at the maximum load condition and reduces the brake specific fuel consumption at medium and maximum load . However, the n-propanol blend reduces engine operating temperature which is cause to generate NOx emissions, so notable NOx reduction was achieved. The maximum HC produced with n-propanol blended fuel at maximum load and lower CO noted at medium and higher load ranges. This present experimental study discussed about the impact of diesel engine performance and emission when the engine powered diesel and mixture of different proportionate diesel-butanol-propanol with 25% of biodiesel blend. The diesel engine powered by two different combinations of fuel (D55 and D65) and five different loads (20%, 40%, 60%, 80% and 100%).

## 2. EXPERIMENTAL SETUP

A sequence of test was carried out to investigate the power of 1-butanol, n-propanol, biodiesel and diesel fuel blends in a single cylinder, four stroke, unmodified, air cooled, naturally aspirated engine and five engine loads by using 1-butanol, n-propanol, biodiesel and diesel fuel blends. The experimental set up (Fig.1) consisted of a diesel test engine, SAJ test plant made AG10 eddy current DC dynamometer with APEX made AX-155 model constant speed 230V loading unit, fuel flow meter,

and exhaust gas analysis systems. The engine specification details used in the experiments are given in the Table 1. Dynamometer used to take engine torque and speed. The amount of fuel consumption was calculated by using fuel meter, which included a mass burette and a chronometer. K-type thermocouple connected to the digital display unit was in the measurement of exhaust gas temperature. Emissions (HC and NO in ppm, CO, CO2 and O2 in percentage volume) were measured by an AVL 473C exhaust gas analyzer and smoke opacity (in percent) was measured by the AVL smoke meter. The specification of the exhaust gas analyzer and smoke meter are given in Table 2. Exhaust gas measuring device AVL 473C determines the emissions of CO, HC with means of infrared measurement (Non-dispersive infra-red) and NO with a means of electrochemical sensors. The test engine was not modified in any way for use with fuel blends. Data were collected for the engine torque, engine power, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), exhaust gas temperature, smoke opacity, CO, HC and NOx emissions. The nomenclature and accuracy of the measurements and the uncertainty of the computed results of the parameters are given in Table 2.



**Fig. 1. Experimental Setup.**

**Table 1 Test engine specifications**

Particulars	Specifications
Manufacturer	Kirloskar
Type	Four stroke, single cylinder, Direct injection, VCR engine
Bore	87 mm
Stroke	110 mm
Compression ratio	17:1
Engine speed	1750 – 1690 RPM
Fuel injection pressure	210 bar
Injection timing	23° BTDC
Cooling system	Water cooled engine

**Table 2 Uncertainty and measuring range of gas analyzer and smoke meter**

S.No	Pollutant	Range	Accuracy
1	CO % Vol	0 -10	±0.03
2	CO <sub>2</sub> % Vol	0 -20	±0.5
3	HC ppm Vol	0 -20000	±10
4	O <sub>2</sub> % Vol	0 -22	±5
5	NO ppm Vol	0 - 5000	±10
6	SMOKE %	0-100	±1

In this study, experiments were performed at the engine speed of 1750 – 1690 RPM and varying engine loads of 20%, 40%, 60%, 80% and 100%. Tests were carried out initially using diesel fuel to generate the reference line data, and it was called on figures as “D100”. Then, biodiesel, n-Propanol and 1-butanol blend with diesel (D55 and D65) were prepared and test under the same conditions for comparison.

**Table 3 Fuel properties**

Properties	Diesel	Cotton Seed	1-Butanol	n-Propanol
Viscosity at 40°C mm <sup>2</sup> /s	3.9	6	3.64	2.8
Density kg/m <sup>3</sup> at 15°C	835	850	811	803
Cetane Number	50	52	Max 25	15
Flash Point	>52°C	162 °C	35°C	22°C
Auto Ignition Temperature °C	>250°C	-	385	371
Heating Value MJ/kg	43.92	41.68	33.1	30.68

The purity of the reference diesel fuel is 99.5%, 1-butanol is 99%, and n-propanol is 99% were purchased from a commercial supplier. The 1-butanol and n-propanol contain with 0.2% of water content. The properties of the fuels used in this study are presented in Table 3. It was observed that biodiesel, 1-butanol and n-propanol blended easily with reference diesel fuel and no homogeneity problem were seen with the fuel blends.

### 3. RESULTS

The 25% of biodiesel and different ratios of alcohol fuels mixed with diesel. The different alcohol fuels (Butanol and propanol) mixed with different ratios (each 5% and 10%). The 25% of biodiesel mixed with two different alcohol fuels like 5% of Butanol and 5% of propanol and 10% of butanol and 10% propanol. The above blend ratio made some difference with diesel concentration. The detailed blend ratio mentioned in Table 4.

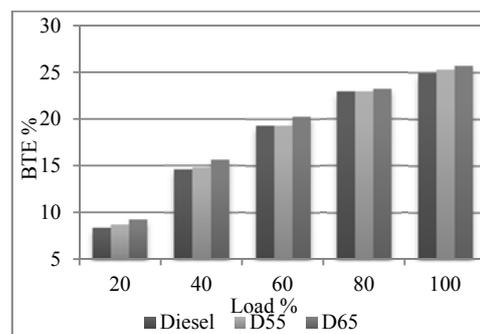
**Table 4 The volume ratio of blending.**

Chemical Content	Diesel	D55	D65
Diesel % Vol	100	55	65
Bio diesel % Vol	-	25	25
n-Propanol % Vol	-	10	5
1-Butanol % Vol	-	10	5

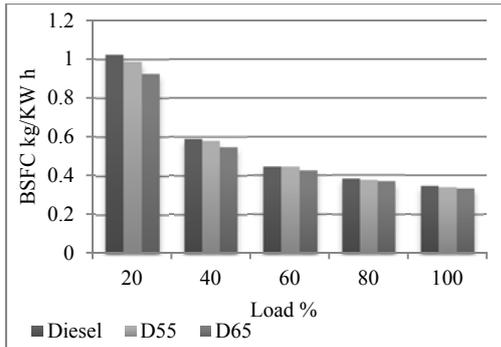
### 3.1 Engine Performance

The discussion of the results and their justification of biodiesel/alcohol fuel blend (1-butanol and n-propanol) with diesel fuel on diesel engine performance and emissions. The test engine maximum load calculated and it was applied like 20%, 40%, 60%, 80% and full load conditions with different fuel combinations like base diesel, D55, D65.

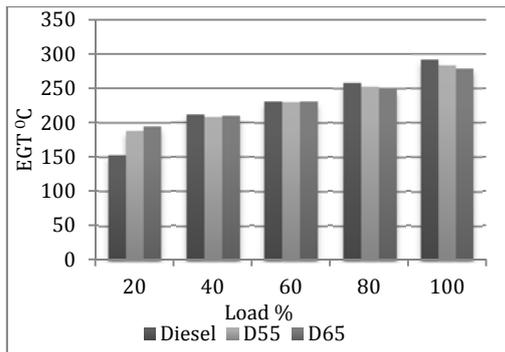
Figure 2 shows that the brake thermal efficiency of different ratios of alcohol fuels mixed with 25% of biodiesel and diesel fuel. The significant impact observed from 1-Butanol and n-Propanol combinations. Alcohol fuel/biodiesel/diesel blend produced maximum efficiency compare with base diesel fuel. Especially D65 produced maximum brake thermal efficiency at entire load conditions, that is 5% of each 1-Butanol and n-Propanol blend produced maximum efficiency compared with 10% of each 1-Butanol and n-Propanol blend. The effect of alcohol fuels combination (1-Butanol and n-Propanol) and biodiesel blend with diesel fuel reduces the fuel viscosity, it's improved the spray characteristics and resulted high brake thermal efficiency. Higher chain alcohol with a four carbon structure and it is known that larger chain alcohol fuel has higher burning velocities. Higher laminar flame speed obtained from alcohol/biodiesel/diesel combustion owing to improved engine brake thermal efficiency. Fig. 3 shows that the brake specific fuel consumption of base diesel, D55 and D65 fuels. The fuel D65 consumed minimum level of producing same output power which is producing other blends. Two alcohol fuel concentration with biodiesel and diesel mixture consumed minimum fuel compare with base diesel results. The 5% of alcohol blends produced more power with a minimum amount of fuel supply compared with 10% of alcohol fuel supply. In this observation clearly mentioned 5 % of alcohol fuel produced good results with biodiesel combustion and in this



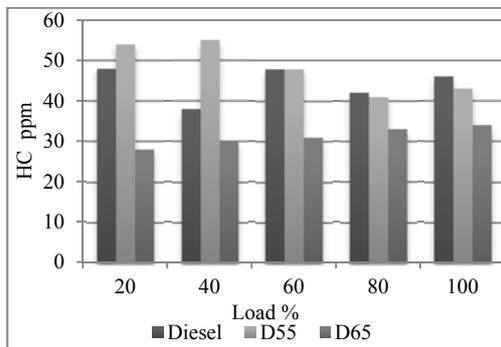
**Fig. 2. Brake thermal efficiency with different load and different blend.**



**Fig. 3. Specific fuel consumption with different load and different blend.**



**Fig. 4. Exhaust gas temperature with different load and different blend.**



**Fig. 5. Unburned HC with different load and different blend.**

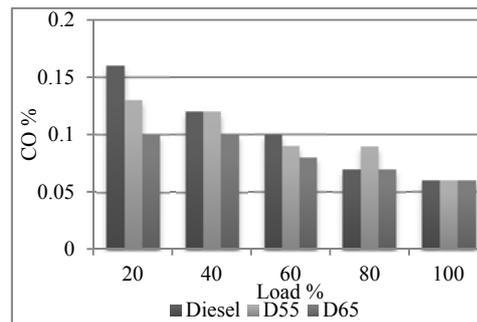
effect due to fast vaporization and lesser viscosity of blending fuel causes of reduced specific fuel consumption. Improve the injection spray quality it chooses to make effective combustion. The fuel viscosity further reduced when increasing the alcohol fuels (10% of butanol and propanol). It causes to affect the injection pressure and timing. It was observed, 10% of alcohol fuel consumed most amount of fuel compared with 5% of alcohol fuel blend with 25% of biodiesel.

### 3.2 Exhaust Gas Emissions

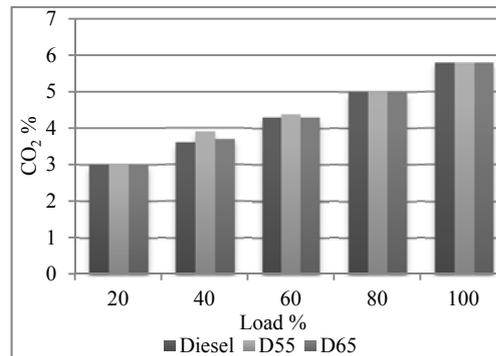
Figure 5 shows that the effect of 1-Butanol, n-Propanol and biodiesel with base diesel fuel on hydrocarbon (HC) production as a function of engine load. It was observed that the 41% of HC reduction in D65 fuel at 20% of load, but D55 increases 44% of HC at 40% of load compared with base diesel fuel. D65 reduced HC

for entire engine load due to biodiesel concentration. Sun (2010) mentioned that the impact of biodiesel emission. Most of the researcher biodiesel produced minimum HC, CO and PM and maximum NOx, due to has a high rate of evaporation of alcohol fuels and biodiesel ignition delay.

Much amount of alcohol fuel (10%) its touch with the cylinder wall fuel condensed and its make hydrocarbon pollutant. It is clearly indicated in exhaust gas temperature (EGT). D55 produced lesser amount of EGT, which is shown in Fig. 4. The 5% of alcohol blend with diesel and biodiesel blend makes effective combustion.



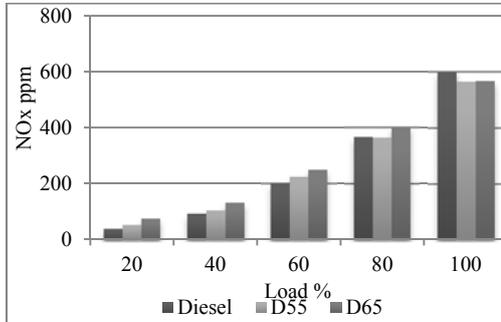
**Fig. 6. Carbo monoxide with different load and different blend.**



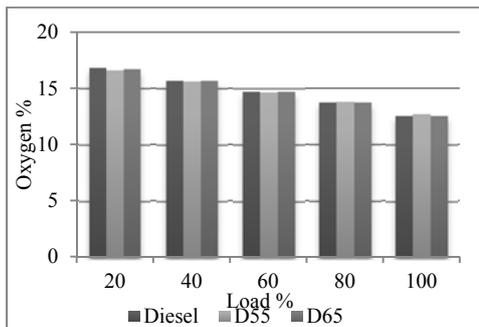
**Fig. 7. Carbon dioxide with different load and different blend.**

Figure 6 shows the comparisons of carbon monoxide (CO) of different alcohol/biodiesel and diesel fuel blends. The minimum CO emitted by D65 fuel during all engine loads. The 5% of each alcohol fuel reduces the CO emissions effectively. However, D55 produced higher CO compare with D65. Fig. 7 shows the effect of different alcohol/biodiesel and diesel fuel blends on CO<sub>2</sub>. The minimum CO<sub>2</sub> observed from D65 fuel at entire engine loads. The percentage of CO<sub>2</sub> increases with increasing engine loads. The 5% of each alcohol fuel reduces the CO<sub>2</sub> emissions effectively. However, D55 produced higher CO compare with D65. Fig. 8 shows that the effect of different concentration of different alcohol fuel/biodiesel and diesel fuel blends on NOx formation. The NOx formation increases with increasing engine loads due to increasing combustion temperature. Results show that the maximum NOx formation observed with D65 fuel

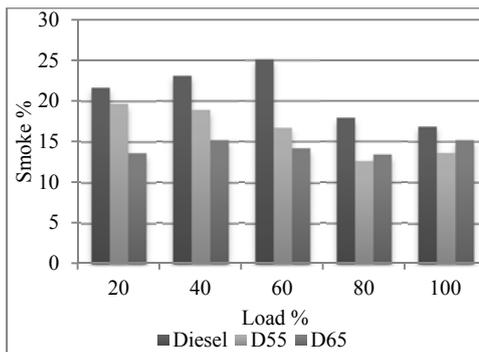
blends. The 1-Butanol and n-Propanol blend increases with decreasing engine exhaust NO<sub>x</sub> level. The lower heating value of fuel blend with diesel and biodiesel, it causes to reduce the combustion temperature which is very important mechanisms of (Zolodich method) NO<sub>x</sub> formation. The lower combustion temperature observed in exhaust gas temperature.



**Fig. 8. Nitrogen oxide with different load and different blend.**



**Fig. 9. Excess oxygen with different load and different blend.**



**Fig. 10. Smoke with different load and different blend.**

Figure 9 shows that the excess oxygen level in the exhaust gas of different alcohol fuel/biodiesel and diesel fuel blends with various engine loads. The excess oxygen percentage decreases with increasing engine loads. The Figs. 6, 7 and 9 clearly show that the CO, CO<sub>2</sub> and excess oxygen percentage in exhaust emissions. Carbon monoxide reacts with oxygen, it causes to produce carbon dioxide. CO and O<sub>2</sub> level decreases with increasing CO<sub>2</sub> level.

The smoke particulate matter is shown in Fig. 10. The maximum smoke particulate observed D55 at 20%, 40% and 60% loads. The D65 fuel blends produced maximum smoke particulate emissions by 80% and 100% loads. All the alcohol blends produced lower smoke particulate compare with base diesel fuel. The biodiesel and alcohol fuel make negative effect on smoke particles [Nabi & Dogan] Oxygen content of fuel and ignition delay is a causes to produced minimum smoke in alcohol fuel.

#### 4. CONCLUSION

In this present work, the performance and emission of diesel engine were investigated for different load by using different percentage of 1- diesel, Butanol and n-Propanol mixed with 25% of biodiesel. The results showed that 1-Butanol and n-Propanol content of fuel blends has an important effect on diesel engine performance and emissions. The following conclusions can be drawn from the present work,

- 1-Butanol and n-Propanol can be blended with base diesel and biodiesel fuel easily without phase separation.
- D65 produced maximum BTE compared with all other fuel blend.
- The minimum SFC observed D65 blend compare with entire fuel blends. Significant performance notified with D65 fuel blend.
- D55 produced maximum HC emission
- Base diesel fuel produced maximum CO and smoke
- D65 produced maximum efficiency and minimum emission compare with all other blend.

From this work proved that 5% of alcohol fuel blends suitable with 25% of biodiesel blend with diesel fuel and 10% of alcohol fuel blend not efficient with 25% biodiesel blend with diesel fuel. D65 fuel considers for suitable blend for operating diesel fuel with biodiesel.

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