

# An Experimental Study of 3-Pentanone and Hexane on NO<sub>x</sub> Emission Derived Ci Engine from a Soya Biodiesel

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**Abstract:** Use of biodiesel in compression ignition engines is increasing since it offers cleaner combustion with low regulated emissions. Most technical literatures in alternate fuels research indicate a slight increase in NO<sub>x</sub> emission with biodiesel as a consequence of injection advance (low compressibility of biodiesel). Very few researches have suggested the means to improve the poor cold flow properties of biodiesel. Use of viscosity reducing agents is an effective way to counteract the high viscosity of biodiesel. This paper investigates the effect of viscosity reducing agents on oxides of nitrogen emission in a soya biodiesel fueled DI diesel engine. The viscosity reducing agents 3-pentanone and hexane were tested on computerized four strokes, single cylinder, air cooled, direct injection diesel engine. Results indicate significant changes in combustion and emission characteristics appear when viscosity reducing agents were used with biodiesel. NO<sub>x</sub> emission was observed to be reduced with increase in addition of viscosity reducing agents in biodiesel. However a slight increase in HC and CO emission was found to occur with increasing concentrations of viscosity reducing agents in biodiesel.

**Keywords:** Biodiesel, Oxides of nitrogen, Hexane, 3-Pentanone, Diesel engine

## 1. INTRODUCTION

High NO<sub>x</sub> emission from biodiesel fuelled engines is one of the potential barriers to increase the use of biodiesel as a compression ignition engine fuel. Oxides of nitrogen are generated when atmospheric nitrogen reacts with oxygen at elevated temperatures around (1880 K). At these temperatures, the diatomic nitrogen disintegrates into monoatomic nitrogen, which is highly unstable and reacts with oxygen to form NO<sub>x</sub> emission. Nitrous oxide in the presence of sunlight reacts with oxygen to form ground level ozone and smog. Fuel bound nitrogen is not present in biodiesel; hence either thermal or prompt NO<sub>x</sub> mechanism is responsible for biodiesel NO<sub>x</sub> emission. Viscosity of fuel is important for efficient and reliable engine operation. High viscosity of biodiesel causes injector hole clogging and lubricant contamination. The poor cold flow property of biodiesel also leads to cold starting problem in compression ignition engines.

Many researchers suggested possible reasons for increase in NO<sub>x</sub> emissions from biodiesel fuelled engines; however the significant factor is not yet determined. The reasons for increase in NO<sub>x</sub> emissions from biodiesel fuelled diesel engines have been extensively studied by J. Sun et al. and they concluded the following properties injection timing, injection pressure and spray mixing, ignition delay and combustion temperature have significant effect on NO<sub>x</sub> formation [1]. The early injection due to low compressibility of biodiesel was the significant factor leading to early pressure rise and NO formation [2]. Moreover, the higher cetane number of biodiesel fuel also leads to an early heat release. Fuels with high viscosity like, biodiesel have deep fuel spray penetration which will lead to increase in physical delay and NO<sub>x</sub> formation. Furthermore, the spray cone angle is shorter for biodiesel fuels which affect drop distribution [3]. McCormick et al. found a relationship between iodine value (increase in number of double bonds or unsaturation) and NO<sub>x</sub> emission. Increase in iodine value leads to increase in NO formation [4].

Earlier methods adopted to reduce NO<sub>x</sub> emissions include exhaust gas recirculation, water-fuel emulsion, injection timing retardation, cetane enhancers and antioxidant additives. With the use of viscosity reducing agents the fuel properties like density, viscosity, surface tension, heat of vaporization, and fuel compressibility can be altered

## 2. EXPERIMENTAL SETUP

A four stroke, single cylinder, air cooled, NA, DI diesel engine attached with eddy current dynamometer and computer control module was used for experimental work. The specifications of the engine are presented in Table 1. The experiment was conducted using neat biodiesel and blend of biodiesel containing 10%, 15% and 20% volume concentrations of 3-pentanone and hexane respectively. AVL 444 gas analyzer was used to measure HC, CO and NO<sub>x</sub> emissions. The measurement range for the emission analyzer is given in Table 2. The specification of viscosity reducing

agent is displayed in Table 3. The properties of soya bean oil are shown in Table 4. The mean ambient temperature was 28<sup>o</sup> C and 82% relative humidity. All emissions were expressed in ppm basis.


**Table 1: Specification of test engine**

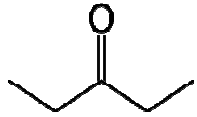
Parameter	Specification
Model	Kirloskar (TVA) Single cylinder, four stroke, direct injection, bowl-in-piston, constant speed, diesel engine
Capacity	661 cc
Bore and stroke	87.5 mm x 110 mm
Compression ratio	17.5 :1
Speed (constant)	1500 rev/min
Rated power	4.4 kW
Loading type	Eddy current dynamometer
Injection pressure	200 bar
Injection timing	21 <sup>o</sup> BTDC

**Table 2: Exhaust gas analyzer**

Gases Measured	Measured Range	Resolution
CO	0...10% Vol.	0.01% Vol.
HC	0...20.000 ppm	10 ppm (0 – 2.000 ppm) 10 ppm (> 2.000 ppm)
CO <sub>2</sub>	0...20% Vol.	0.1% Vol.
O <sub>2</sub>	0...22% Vol.	0.01% Vol.
NO	0...5.000 ppm	1 ppm
Lambda	0...9.999 errechnet	0.001
Rotating Speed	400...20.000 min <sup>-1</sup>	1 min <sup>-1</sup>

**Table 3: Specification of viscosity reducing agent**

Viscosity reducing agent	Chemical structure	Specification
Hexane		CAS Number 110- Density Kg/m <sup>3</sup> 54-3 Viscosity cP 655 @40 <sup>o</sup> C 0.29 Boiling Point <sup>o</sup> C 69 Auto ignition 234 Temp <sup>o</sup> C 365 Latent heat of

		vaporization, kJ/kg
3-Pentanone		CAS Number 96-22- Density Kg/m <sup>3</sup> 0 Viscosity cP 815 @40 <sup>o</sup> C 0.32 Boiling Point <sup>o</sup> C 100 Auto ignition 424 Temp <sup>o</sup> C 445 Latent heat of vaporization, kJ/kg

**Table 4: Properties of soya bean biodiesel**

Density	865 kg/m <sup>3</sup>
Viscosity at 40 <sup>o</sup> C	4.78 mm <sup>2</sup> /s
Flash Point	163 <sup>o</sup> C
Cloud Point	13 <sup>o</sup> C
Calorific Value	39,660 kJ/kg
Cetane Number	51

### 3. RESULTS AND DISCUSSION

The effect of viscosity reducing agents on emissions like NO<sub>x</sub>, HC and CO, on heat release rate and specific fuel consumption were studied in this experimental investigation.

#### 3.1 COMPRISION OF NO<sub>x</sub> EMISSIONS

Fig 1 indicates the trend of NO<sub>x</sub> emissions for neat biodiesel and its blend with 3-pentanone and hexane. Results indicate a slight decrease in NO<sub>x</sub> emissions was found with biodiesel blends containing viscosity reducing agents in all proportions. Maximum reduction in NO<sub>x</sub> emission was found to be 14.32% with biodiesel-3-pentanone (20% concentration) at rated power. Furthermore, the biodiesel blend containing 20% hexane concentration has shown NO<sub>x</sub> reduction of 12.6% at rated power. The change in fuel properties such as density and viscosity might have improved the evaporation rate of the fuel leading to reduction in ignition delay. Moreover, the heat of vaporization of the viscosity reducing agents used in this investigation might have reduced the temperature attained inside the combustion during diffusion combustion period. NO formation is dependent upon the instant at which maximum temperature is attained inside the combustion chamber rather than the maximum value [5,11]. Biodiesel blends might have a delay in start of combustion due to late injection (change in blend property) leading to low thermal NO<sub>x</sub> formation. Viscosity of blends being lower than the neat biodiesel, have increased fuel leakage leading to low rate of pressure rise and delay in start of injection [6,12]. The volatility of biodiesel might be improved with the addition of viscosity reducing agents; this will be helpful in reducing the amount of

premixed air-fuel present during rapid combustion period even with retarded injection. The reduction in fuel viscosity will lead to low fuel mass injection rate, hence reduces the amount of combustible air-fuel mixture leading to low NO<sub>x</sub> emissions.

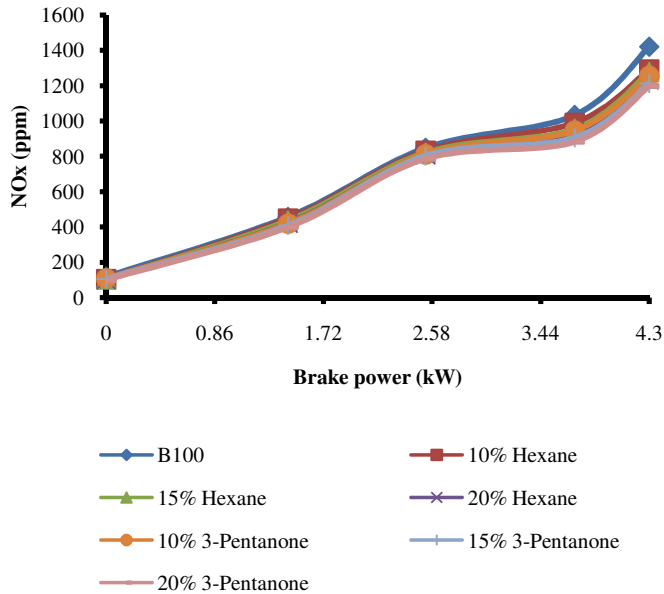


Fig. 1. Variation of NO<sub>x</sub> emissions with brake power

### 3.2 COMPARISON OF HEAT RELEASE RATE

Fig. 2 (a) & 2(b) indicate the variation of heat release rate for neat biodiesel and its blends with 3-pentanone and hexane. Results show that with the presence of viscosity reducing agents in biodiesel, the rate of heat release rate has been lowered and deviated compared to neat biodiesel. The maximum reduction in heat release rate was observed with biodiesel blend with 20% concentration of 3-pentanone, also indicating low NO<sub>x</sub> emission. With early injection, the amount of premixed heat release rate would be much higher than with a delayed injection. A delay in start of injection would delay the start of combustion, which reduces the reaction leading to low NO<sub>x</sub> formation [7, 8].

The peak value of heat release rate occurring slightly after TDC which is comparatively late than neat biodiesel would generate low diffusion combustion temperature as the piston starts descending down. The high heat of vaporization of the viscosity reducing agents used in this study has reduced the peak temperature during later phases of fuel injection, leading to low NO formation rate.

### 3.3 COMPARISON OF HC EMISSIONS

Fig.3 shows the variation of HC emissions with brake power for biodiesel and its blends with 3-Pentanone and hexane.

Maximum reduction in HC emissions was found with biodiesel blend with 10% 3-Pentanone at full load. The reduction in HC emission is mainly attributed to high volatility of the said viscosity reducing agent enhancing better mixing of fuel with air. The secondary heat release rate indicated in Fig 2 (a) has led to oxidation of unburned hydrocarbon. The low heating value of the blend calls for more quantity of fuel to be injected into the combustion chamber; this can lead to under mixing or over leaning of fuel with air leading to increased HC emissions [9].

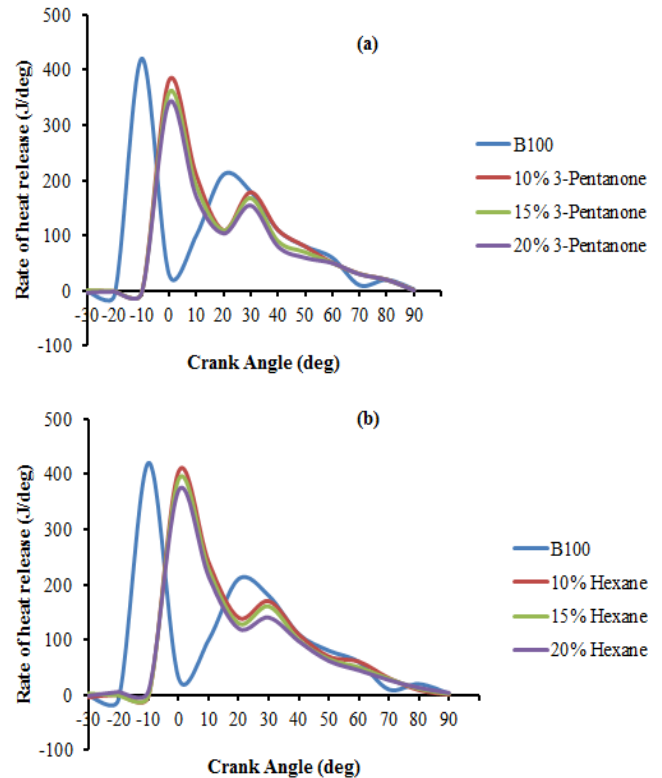


Fig. 2. Variation of heat release rate at rated power

### 3.4 COMPARISON OF CO EMISSIONS

Fig.4 shows the variation of CO emissions with brake power for biodiesel and its blends. Maximum increase in CO emissions was observed with biodiesel blend containing 20% concentration of 3-Pentanone compared with neat biodiesel. The high heat of vaporization of 3-Pentanone might have caused over mixing of air and fuel, making the mixture outside the combustible range. This effect seems to be increasing with increasing concentrations of 3-Pentanone in the blend. A slight decrease in cetane number with the addition of viscosity reducing agent can lead to formation of fuel rich zones and more CO emissions [10]. The decreased post flame oxidation due to low in-cylinder temperatures might have led to poor oxidation of CO.

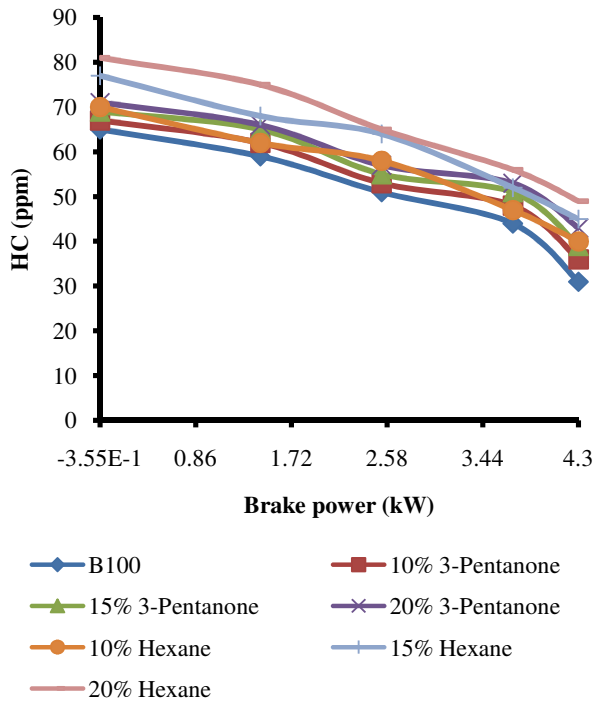


Fig. 3 Variation of HC emissions with brake power

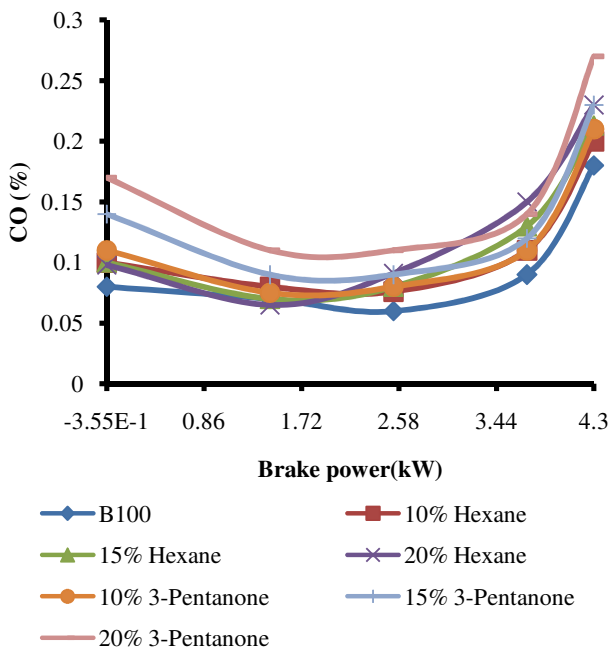


Fig. 4 Variation of CO emissions with brake power

### 3.5 COMPARISON OF BREAK SPECIFIC FUEL CONSUMPTION

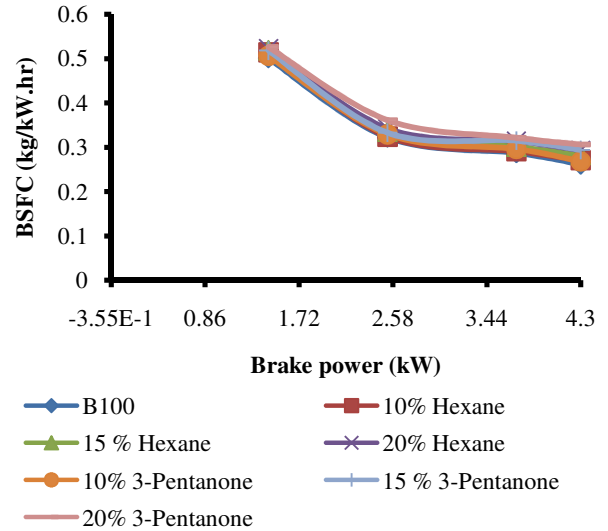


Fig. 5 Variation of break specific fuel consumption with brake power

Fig.5 indicates the variation of brake specific fuel consumption for biodiesel and its blend with 3-Pentanone and hexane with brake power. Maximum BSFC was observed with biodiesel blend containing 20% 3-Pentanone at all loads and minimum BSFC was noted with 10% Hexane concentration in biodiesel. The decrease in heating value of the blend might have led to increase in fuel consumption. More fuel needs to be injected to compensate the power loss due to low heating value of fuel, increasing the BSFC.

### 4. CONCLUSIONS

- The experimental investigation discusses the effect of viscosity reducing agents on  $\text{NO}_x$ , HC and CO emissions in soya bean biodiesel fuelled diesel engine at various power outputs. Based on the performance and emission trends of biodiesel-viscosity reducing agents blends the following conclusions can be made:
- The addition of viscosity reducing agents to neat biodiesel has shown significant reduction in  $\text{NO}_x$  emission. However, a slight increase in HC and CO emissions was observed.
- A reduction in heat release rate was observed with biodiesel-viscosity reducing agent blends which can be conclude as the reason for decrease in  $\text{NO}_x$  emission.
- The 20%vol. concentration of 3-Pentanone in biodiesel blend has shown a maximum  $\text{NO}_x$  reduction of 14.32% at maximum rate power and next to this was 20% concentration of hexane in biodiesel has a  $\text{NO}_x$  reduction percent of 12.6% at maximum rated power.

- Maximum increase in BSFC was observed with blend containing 20% concentration of 3-Pentanone in biodiesel compared to neat biodiesel.

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