# EFFECT OF FUEL INJECTION PRESSURES ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF D. I. DIESEL ENGINE WITH BIODIESEL BLENDS COTTON SEED OIL METHYL ESTER

**C.V. Subba Reddy [1], C. Eswara Reddy[2] & K. Hemachandra Reddy[3]**
1 Associate Professor, Mechanical Department, P.B.R.V.I.T.S, Kavali, Nellore, A.P. INDIA
2 Director, Padmavathi Mahila University, Tirupati, Chittor, A.P. INDIA
3 Professor, Mechanical Department, J N T U College of Engineering, Anantapur. A.P. INDIA
Corresponding Author [Email: cvs_reddi @yahoo.co.in ]
Phone No's: +91 9849737134 [H], 08626-243930 [O].

## ABSTRACT

The world's rapidly dwindling petroleum supplies, their rising cost and the rapid growing of automobile pollutions from fossil petroleum fuels have led to an intensive search for alternative fuels to replace diesel fuel. Agriculture and transport sectors consume maximum percentage of petroleum based fuels where diesel engine happens to be the prime mover. Diesel fuelled vehicles discharge significant amount of pollutants such as CO, UHC, NOx, smoke, etc which are harmful to the environment. There is a wide variety of alternative fuels available as renewable fuels to replace diesel fuel. Vegetable oils, their properties being close to diesel fuel, may be a promising alternative for use in diesel engines. The high viscosity and low volatility of these vegetable oils are the major problems for their use in diesel engines. Such problem can be solved by the process of transesterification. In the present work, experiments are conducted on 3.72 kW(5 BHP) single cylinder, four stroke, water-cooled diesel engine using cotton seed oil methyl esters blended with diesel in various proportions to study the engine performance and emissions at different injection pressures. The effect of injection pressure on the performance and emission characteristics for various biodiesel blends of 0BD, 10BD, 20BD, 30BD and 100BD at six different test pressures of 170, 180, 190, 200, 210 and 220 bar are studied.

The experimental investigations reveal that the better performance and emission characteristics among the biodiesel blends are obtained at injection pressure of 200 bar with 20BD of cotton seed oil methyl ester.

**Key words:** *D.I. Diesel engine, Bio- Diesel blends, Injection Pressures, Transestirification.*

## 1. INTRODUCTION

Fuels derived from triglycerides (vegetable oils/animal fats) present a promising alternative to substitute diesel fuels. Although triglycerides can be used as fuel in the diesel engines, their high viscosities, low volatilities and poor cold flow properties have led to the investigation of various derivatives. Fatty acid methyl esters, known as biodiesel, derived from triglycerides by transesterification with methanol have received the most attention [1, 2]. From the literature it's evident that the injection pressure has an effect on the spray formation of biodiesel blends in a C.I engine [3,6]. Earlier the studies have shown that the combustion characteristics alter with the changes in injection pressure. Therefore, in the present work a solemn attempt is made to conduct experiments on D.I .Diesel engine and obtain better performance characteristics with bio-diesel blends of cotton seed oil methyl ester.

## 2. BIO-DIESEL PREPARATION

The experimental work starts with preparation of Bio-Diesel by transesterification.

### 2.1 Transesterification

Transesterification process is used to reduce the viscosity of vegetable oils and produce the biodiesel [4]. In the transesterification process of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol [5, 6]. About 2 gm of catalyst (NaOH) is mixed in 100 ml methanol to prepare alkoxide, which is required to activate the alcohol. Vigorous stirring was done for 30 minutes in a closed container until the alkali is dissolved completely. The alcohol-catalyst mixture is then transferred to the reactor containing moisture free cotton seed oil. Stirring of the mixture is continued for another one hour between 65 and 70$^o$ C of temperature The mixture is then taken out and poured into the separating vessel. The mixture is allowed to settle by gravity in a separating vessel.

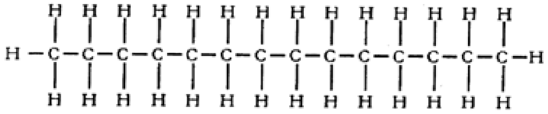


Figure.1.a Structure of Diesel

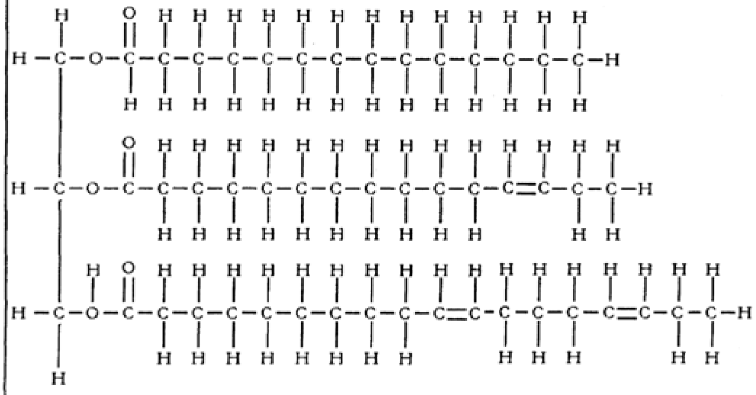


Figure.1.b Structure of Vegetable oil

*Figure-1: Structures of Diesel and Vegetable Oil*

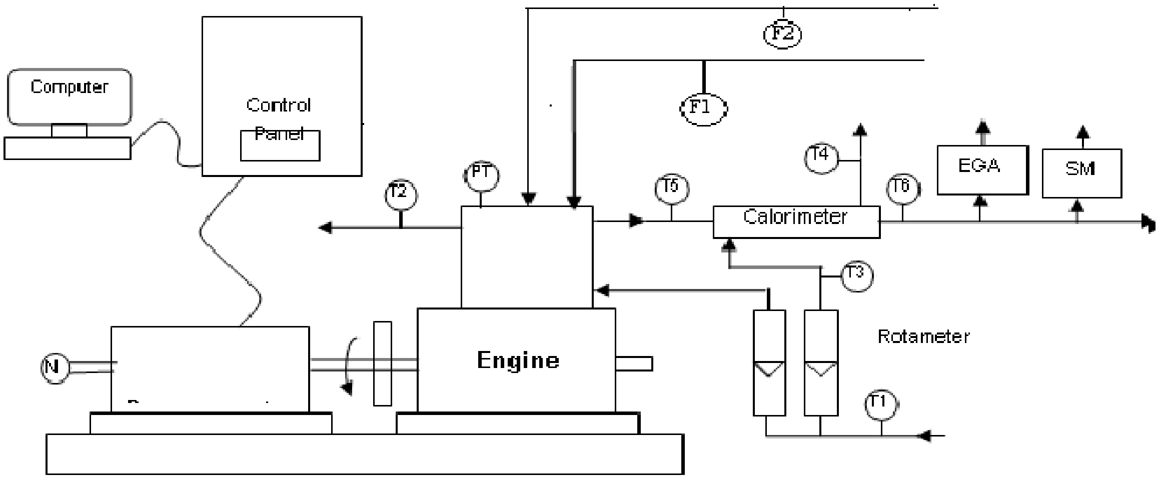
Without disturbing the vessel, the bottom layer of glycerol is separated out. The remainder in the vessel, i.e., methyl ester of cotton seed oil is washed by pure water to remove impurities in the biodiesel. Important properties of cotton seed oil, its methyl ester and its blends with diesel such as Density, Specific Gravity, Kinematic viscosity, Flash point, and Calorific values are measured and noted. The properties of cotton seed oil methyl ester blends are shown in Table-1 and diesel blends of cotton seed oil methyl esters are shown in Table-3.

*Table-1: Properties of Cotton seed Methyl Ester & Blends with Diesel*

| **Properties** | **10BD** | **20BD** | **30BD** | **100BD** | **Cotton seed oil** | **Diesel** |
|---|---|---|---|---|---|---|
| Density (kg/m$^3$) at 40˚C | 832 | 835 | 840 | 870 | 911 | 828 |
| Specific Gravity at 40˚C | 0.832 | 0.835 | 0.840 | 0.870 | 0.911 | 0.828 |
| Kinematic Viscosity (cSt) at 40˚C | 3.92 | 4.06 | 4.20 | 5.18 | 25.03 | 3.78 |
| Calorific Value (kJ/kg) | 42580 | 42191 | 41826 | 39128 | 38062 | 42960 |
| Flash Point (˚C) | 101 | 110 | 121 | 161 | 260 | 56 |

*Table-2: Blends of Cotton Seed oil Methyl Ester*

| S.NO | Blends | Cotton Seed Oil Methyl Ester (COME) (%) | Diesel (%) |
|---|---|---|---|
| 1 | 0 BD | 0 | 100 |
| 2 | 10 BD | 10 | 90 |
| 3 | 20 BD | 20 | 80 |
| 4 | 30 BD | 30 | 70 |
| 5 | 100 BD | 100 | 00 |



$T_1$, $T_3$=Inlet Water Temperature.
$T_4$ = Outlet Calorimeter Water Temp.
$T_6$ = Exhaust Gas Temp. outlet to Calorimeter
$F_2$= Air Intake Differential Pressure unit
EGA = Exhaust Gas Analyzer
$T_2$ = Outlet Engine Jacket Water Temperature.
$T_5$ = Exhaust Gas Temp. inlet to Calorimeter.
$F_1$ = Fuel Flow Measuring unit.
PT = Pressure Transducer
SM= Smoke Meter

Figure-2: Experimental Setup

## 3. EXPERIMENTAL SETUP

The experimental setup is shown infigure-3 with accessories and measuring instruments. A Kirloskar make single cylinder four stroke, naturally aspirated, direct injection, water-cooled diesel engine test rig of 3.72 kW(5BHP) with 1500 RPM, is directly coupled to an eddy current dynamometer. The engine and the dynamometer are interfaced to a control panel, which is connected to computer for automatic recording the experimental observations such as fuel flow rate, temperatures, air flow rate, loads, water flow rate, etc., are measured. An exhaust gas analyzer along with smoke opacity is attached to record the exhaust emissions such as, CO, UHC, etc.

## 4. EXPERIMENTAL PROCEDURE

The engine setup is checked for proper connections. Then the engine is started and run the engine at 1500 rated RPM for 16.5:1 compression ratio. Experiments are conducted starting with no load at the injection timing of $23^o$ b TDC and six different injection pressures of 170,180, 190, 200, 210 and 220 bars. Then the load is increased to 25% load, 50% load, 70% load and full load with diesel fuel. Data such as exhaust gas temperature, water inlet and outlet temperature, fuel consumption rate, air flow rate, brake power, torque, smoke opacity, UHC, CO are recorded at these conditions. Subsequently, similar data are collected for the entire load range at different blends of 0BD, 10BD, 20BD, 30BD and 100BD.

## 5. RESULTS AND DISCUSSION

The results obtained at six different injection pressures of 170, 180, 190, 200, 210 and 220 bars respectively for all blends of cotton seed methyl ester with 0BD, 10BD, 20BD, 30BD and 100BD blends are analyzed. The results thus obtained are compared with that of diesel fuel at different injection pressures. Based on the output results, the discussions are presented in the following.

### 5 (a) Brake Thermal Efficiency (BTE)

The performance characteristic curves are drawn for the injection pressure vs brake thermal efficiency as shown in

Figure-3 for 50% load and 70% load and Figure-4 for blends of 10BD, 20BD, 30BD, and 100BD and (0BD) diesel fuel. It is observed from Figure-3 that at 200 bar injection pressure (IP) the maximum brake thermal efficiencies of 26.3% and 25.82% (at 50% load condition) are obtained for 20BD and 30BD respectively. The thermal efficiency of all blends at lower injection pressures are low due to coarse spray formation and poor atomization and mixture formation of biodiesel during injection. With the increase in injection pressure to 200bar, the BTE has increased, which may be due to the fine spray formed during injection and improved atomization, which reduces the physical delay period resulting in better combustion. Beyond 200 bar IP, the reduction in BTE may be because of ineffective combustion due to decreased depth of penetration of fuel particles. It is observed that for both 20BD and 30BD blends, the BTE is higher than that for diesel fuel at 200 bar IP. Hence, 200 bar may be considered as the optimum injection pressure (IP) for running the engine with cotton seed oil methyl ester blends because of the higher brake thermal efficiencies. Figure.4 shows the BTE variation with different IPs at 70% load. The trend is similar to that of 50% load operation.

### 5(b) Brake Specific Energy Consumption (BSEC)

Figure-5 and Figure-6 show the variation of BSEC with injection pressures for the various test fuels at 50% and 70% load operations. It is observed that the BSEC has decreased with increase in injection pressure. The lowest BSEC for 20BD blend is found to be at 200 bar injection pressure (IP) and is 12.67 MJ/kW-hr respectively. This is better than that for baseline diesel BSEC of 13.25 MJ/kW-hr. At higher injection pressure of 210 and 220 bar (IP), the reduction in BSEC may be lower due to improved combustion as the atomization has improved. Figure-6 shows the similar trends for 70% load operation interns lowest in BSEC at 200 bar.

### 5(c) Carbon Monoxide (CO)

The trend of carbon monoxide emissions at different injection pressures (IP) for 10BD, 20BD, 30 BD and 100BD are shown in Figure-7 and Figure-8 respectively. It is observed from the Figure-7 at 50% load condition that the CO emissions are higher at injection pressures other than 200bar for biodiesel blends. This may be due to improper mixing of fuel particles with air, less penetration of fuel particles and ineffective combustion of the blend at these pressures. The CO emission for 20BD blend at 180 bar is 9.16% is less than that of diesel fuel at 50% load. With increasing the injection pressure to 200 bar, the CO emission is dropped by 14.7%. Both figure-7 and Figure-8 at 50% and 70% load operations show that the CO emission for different blends is very low compared to neat diesel fuel. Therefore, the 200 bar and 20% diesel blended fuel are the best conditions.

### 5(d) Unburnt Hydrocarbons (UHC)

Unburnt hydrocarbons are the result of incomplete combustion of fuel. As the injection pressure (IP) is increased, the UHC emission is reduced for blended fuels as well as for 100BD as seen from Figure-9 at 50%l load operation. At 200 bar injection pressure (IP) there is minimum UHC emissions for 20BD blends and for 100BD. It reaches the minimum level at 0%diesel at 220 bar injection pressure (IP). For 20BD blend, 8.7% reduction in UHC is observed from 190 to 200 bar IP. At higher pressures of 210, 220 bar, there seems to be an increase in UHC emissions which may be because of finer fuel spray and results in momentum and penetration of the droplets resulting incomplete combustion. Also from the same Figure-9, it is seen that the diesel has the highest UHC emissions at all the pressures indicating that the heavier hydrocarbon particles that are present in diesel fuel increase UHC emissions. The 70% load trend-lines for UHC emissions are depicted in Figure-10.

### 5(e) Smoke Opacity

From the Figure.11 and Figure.12, it can be seen that at 50% load, highest smoke opacities for blends have been observed at 170 bar injection pressure. With the increase in injection pressure from 180 to 200 bar for 20BD blend at 70 % load, the smoke opacity has reduced by 6.7%. It can also be seen that all the blends have less opacity than the baseline diesel fuel. The presence of oxygen in the blends in addition to good atomization of fuel at higher pressure may be the reason for lower opacity at higher injection pressures. At 200 bar injection pressure, better combustion reduces opacity still further. The 70 % load smoke opacity trends has been shown in Figure-12.

## 6. CONCLUSIONS

It is concluded that as the injection pressure increases from 170 to 200 bar, the brake thermal efficiency has increased and the brake specific energy consumption has reduced. At 200 bar , the BTE of all blends is higher compared to other IPs. Therefore, it is observed that at 70% load operation, the BTE for 20BD blend has improved by 0.88% when the IP has risen from 180 to 200 bar and found to be maximum at 200 bar. After that it falls down. Similarly the BSEC for 20BD blend is reduced by 4.57% at 200 bar compared to with pure diesel fuel. Therefore UHC, CO and Smoke opacity are lower for biodiesel blends at 200 bar injection pressure (IP) at 70% load. A reduction of 6.94% in UHC is observed from 180 to 200 bar IP with 20BD as the blended fuel. With the increase in injection pressure from 180 to 200 bar for B20 blend at 50% load, the smoke opacity has reduced by 6.54% at 200 bar. Later on it increases.

It could be concluded from the above results, that at the injection pressure of 200 bar, the performance and emission characteristics of 20BD are better as compared to180 bar for diesel fuel operation. The blends of biodiesel with diesel substantially reduced unburnt hydrocarbons, carbon monoxide and smoke opacity in exhaust gases, and slightly higher $NO_x$ due to higher combustion temperature than diesel fuel. Therefore, it is established that the blend 20BD is better alternative fuels for D.I. diesel engines at higher fuel injection pressure of 200 bar.

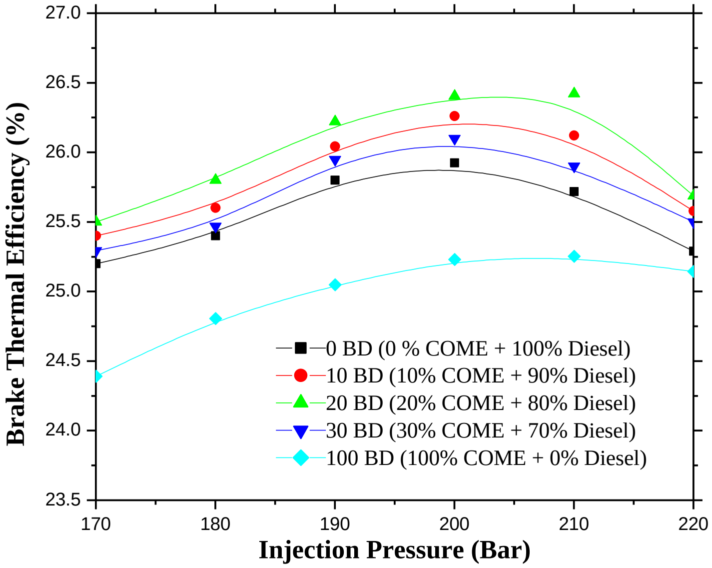


*Figure -3. Injection Pressures vs Brake Thermal Efficiency at 50% Load*

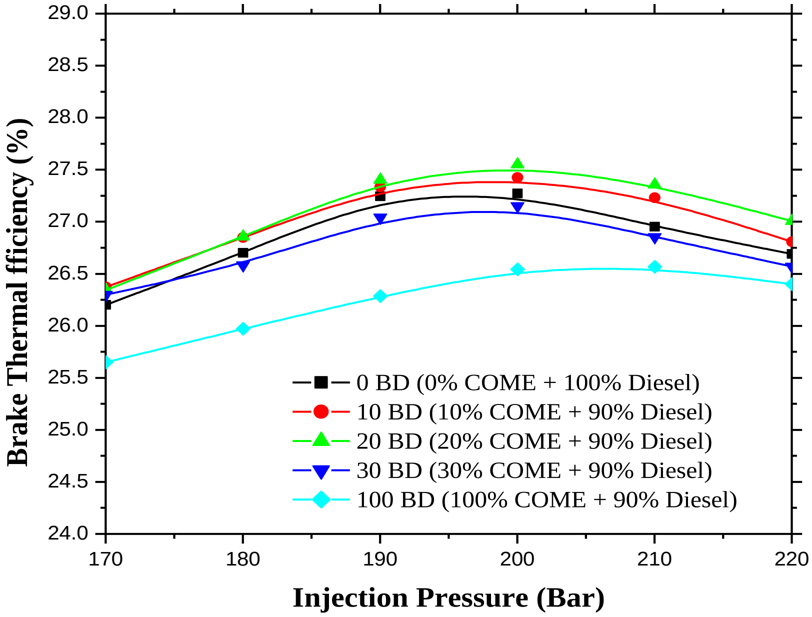


*Figure-4: Injection pressure vs Brake Thermal Efficiency at 70% Load*

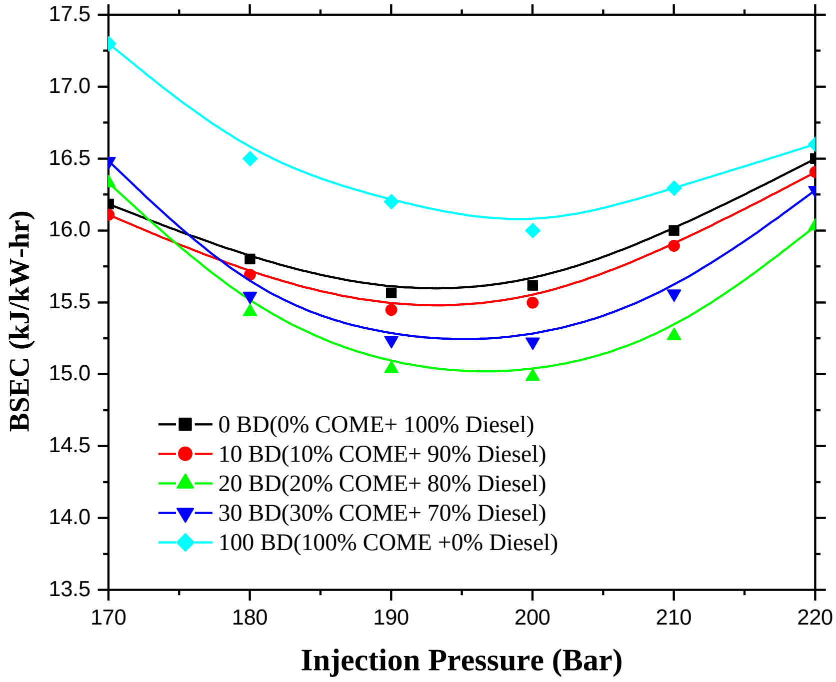


*Figure-5: Injection pressure vs Brake specific Energy Consumption at 50% Load*

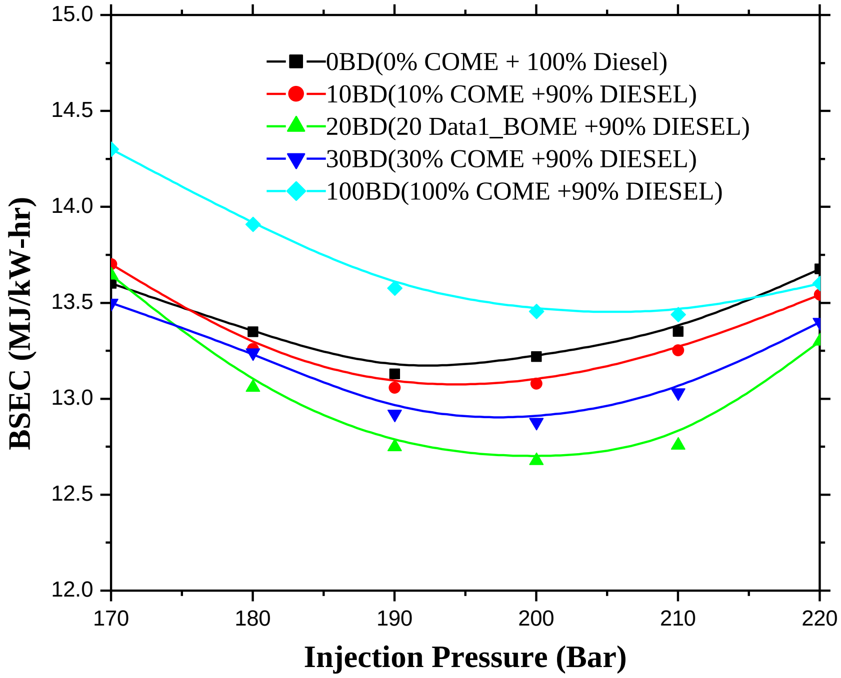


*Figure-6: Injection Pressure vs BSEC at 70% Load*

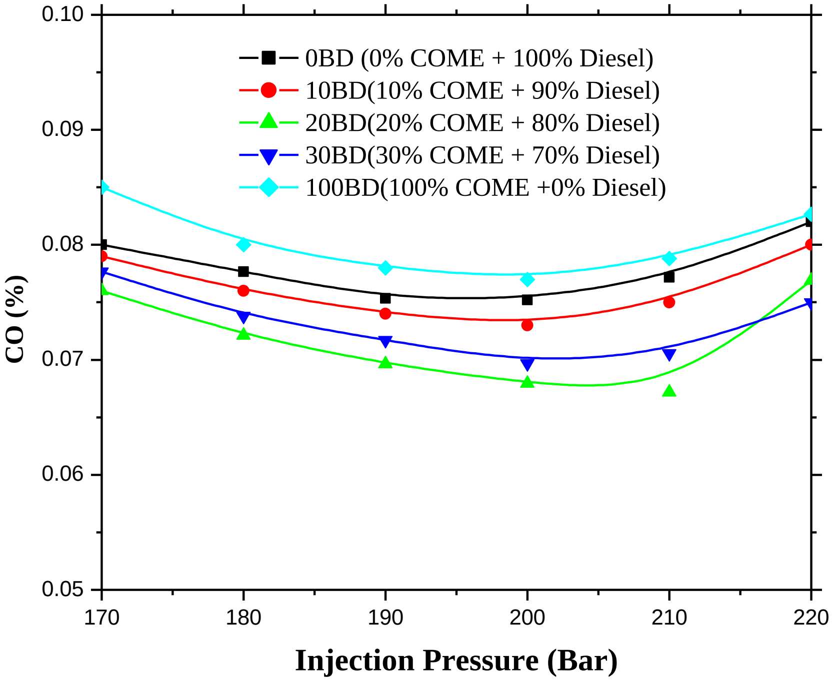


*Figure-7: Injection Pressure vs Carbon monoxide at 50% Load*

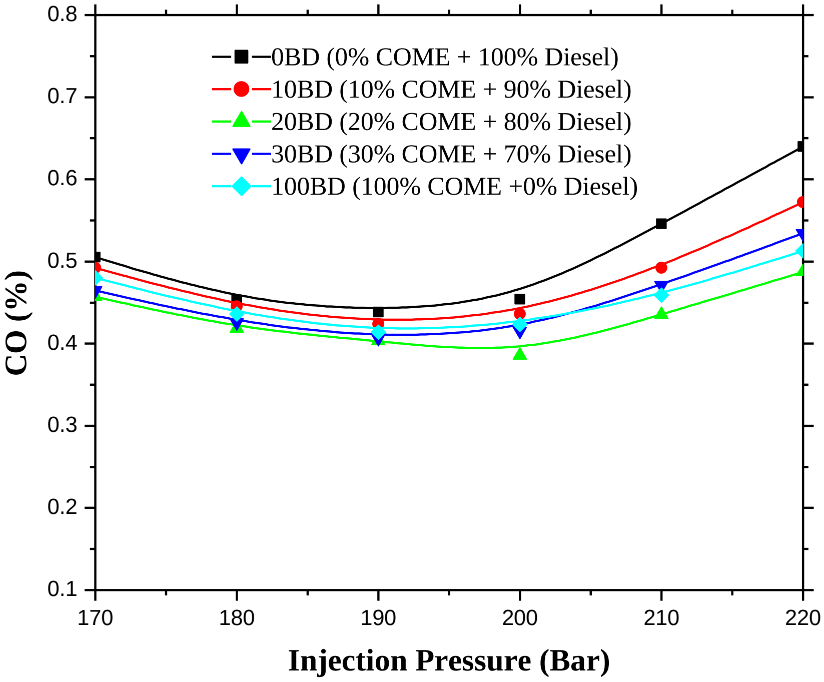


*Figure-8: Injection Pressure vs Carbon monoxide at 70% Load*

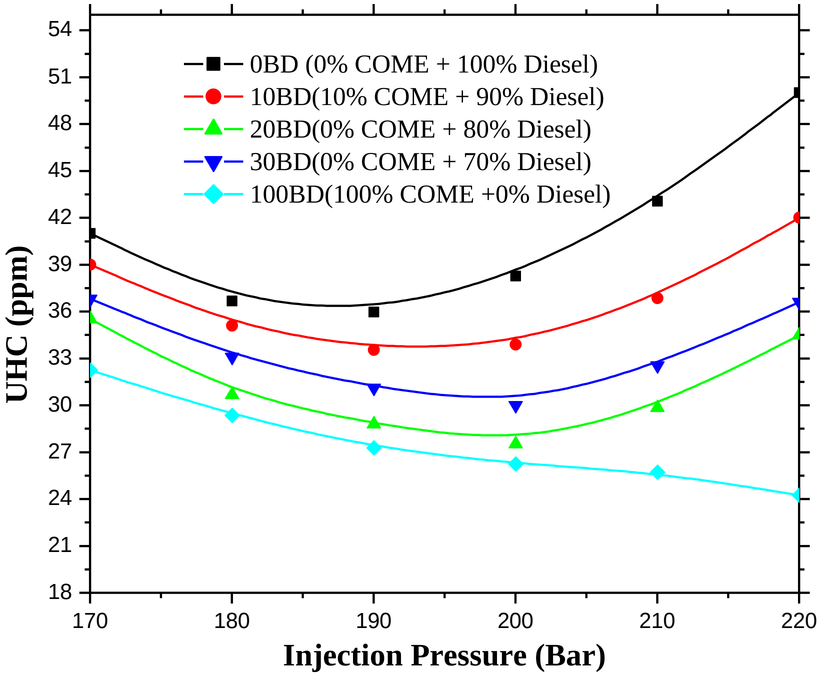


*Figure-9: Injection Pressure vs Unburnt Hydrocarbons at 50% Load*

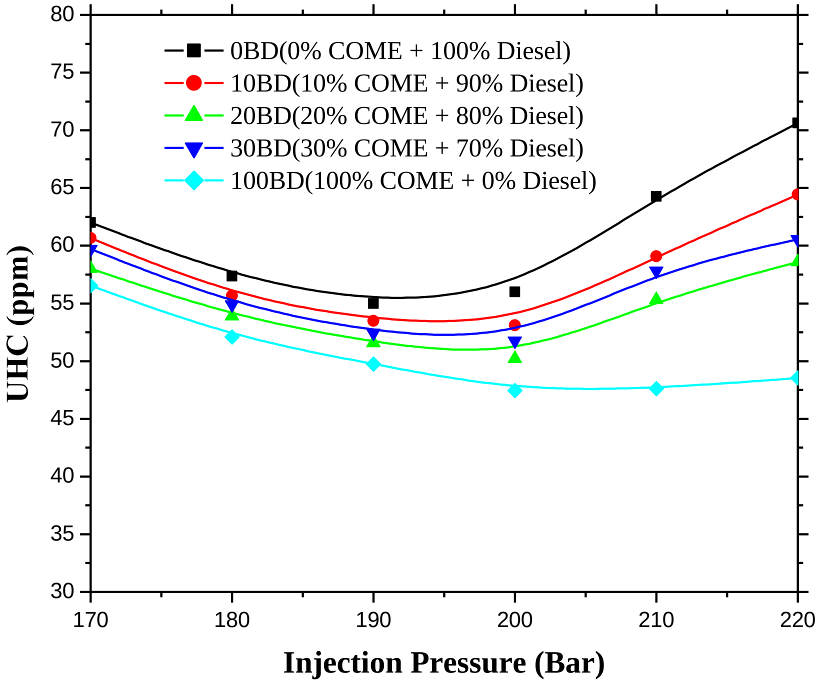


*Figure-10: Injection Pressure vs Unburnt Hydrocarbons at 70% Load*

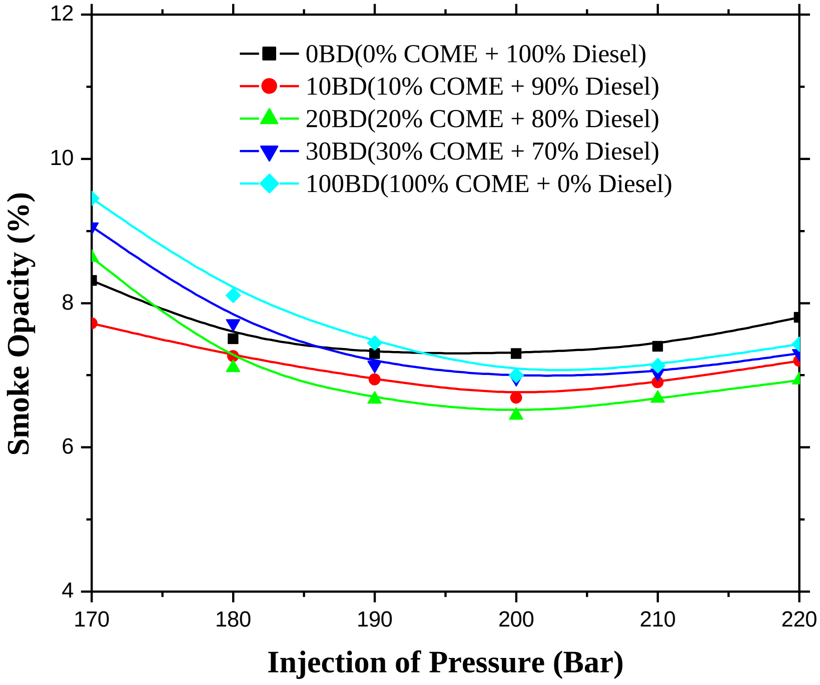


*Figure-11: Injection Pressure vs Smoke Opacity at 50% Load*

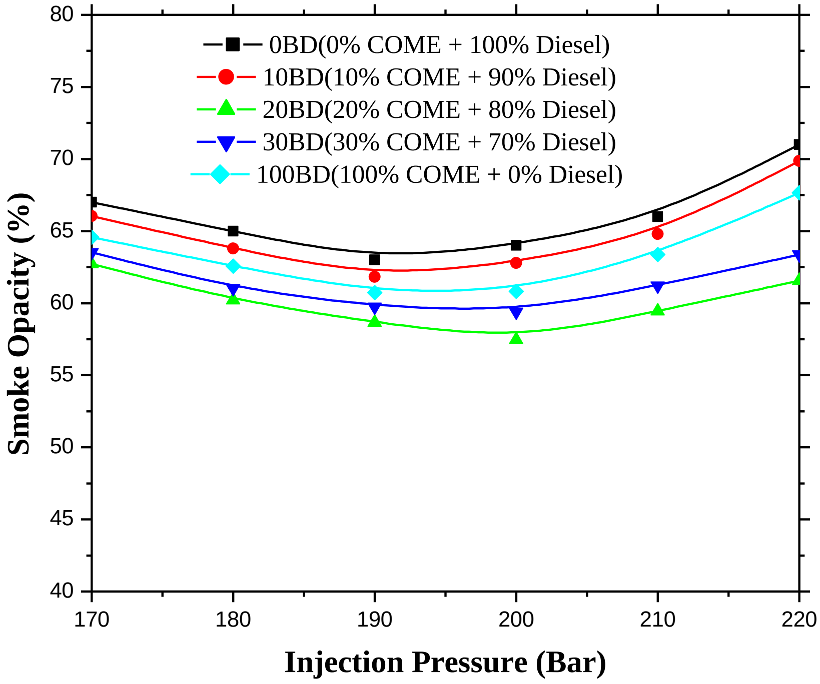
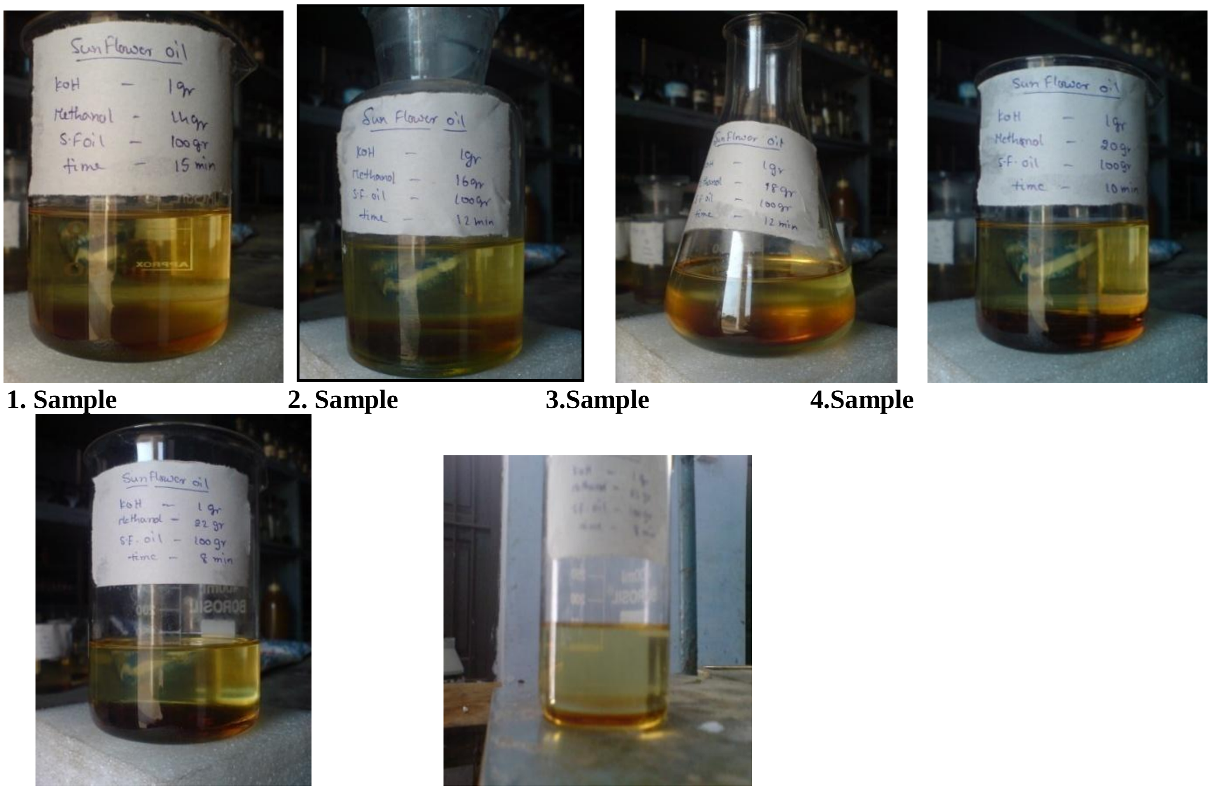


*Figure-12: Injection Pressure vs Smoke Opacity at 70% Load*

*Table-3: Specifications of Experimental Setup*

| | |
|---|---|
| Engine | Four-stroke, single cylinder, constant speed, water cooled D.I. Diesel engine |
| Make | Kirloskar |
| BHP | 5BHP (3.72 kW) @ 1500 RPM |
| Bore x Stroke | 80 x 110 mm |
| Stroke Volume | 553.14cc |
| Compression Ratio | 16.5:1 |
| Connecting Rod Length | 234mm |
| Dynamometer | Eddy current type |
| Load Measurement | Strain Gage Load cell |
| Water Flow Measurement | Rota meter |
| Fuel and Air Measurement | Differential Pressure Unit |
| Speed Measurement | Rotary Encoder |



**1. Sample** **2. Sample** **3.Sample** **4.Sample**

5.**sample** **6.sample**

*Figure-13: Different Samples of Cotton Seed Oil Methyl Esters*

*Table -4: Properties of bio-diesel samples*

| Sample No. | Oil quantity (grams) | Methanol (grams) | KOH (grams) | Reaction time (min) | Viscosity (cs) | Density (Kg/m3) |
|---|---|---|---|---|---|---|
| 1 | 100 | 14 | 2 | 15 | 14.15 | 880.34 |
| 2 | 100 | 16 | 2 | 14 | 12.34 | 879 |
| 3 | 100 | 18 | 2 | 12 | 9.08 | 878.16 |
| 4 | 100 | 20 | 2 | 10 | 8.15 | 876.7 |
| 5 | 100 | 22 | 2 | 8 | 7.65 | 875.4 |
| 6 | 100 | 25 | 2 | 8 | 6.11 | 874.12 |

## 7. REFERENCES

[1]. M.A. Kalam, M. Husnawan, H.H. Masjuki,” Exhaust emission and combustion evaluation of coconut oil-powered indirect injection diesel engine”, Renewable Energy, Vol.28, pp.2405–2415, 2003.

[2]. Sukumar Puhan, Vedaraman N, Sankaranarayanan,Bharatram V “Performance and emission study of mahua oil methyle ester in a four stroke naturally aspirated DI dieel engine” Renewable Energy 30, pp 1269-1278 (2005)

[3]. Nagaraja A.M & Prabhukumar G.P “Effect of Injection pressure on the engine performance with Ricebran oil as Biodiesel”, XVIII NCICEC, pp.581-587, 2003.

[4]. Bhanodaya G. Reddy, Redy K.V and Ganeshan V, “Utilization of non-edible vegetable oil in diesel engine”, XVII NCICEC, pp. 211-214, 2001.

[5]. Anjana Srivastava, Ram Prasad, “*Triglycerides-based diesel fuels*”, Renewable and Sustainable Energy Reviews, Vol. 4, pp. 111-133, 2000.

[6]. Yamane K, Ueta Atsushi, Shimamoto Yuzuru, “ Effects of High-Pressure Injection and Biodiesel Fuel Sources on Combustion and Emission Characteristics of a DI Diesel Engine”, Transaction of Society of Automotive Engineers of Japan, **vol.**32**;no.**2, **pp** 25-30,2001.

[7]. Nwafor O.M.I, *“Emission characteristics of diesel engine operating on Rapeseed methyl ester*”,Renewable Energy, Vol. 29, pp.119-129, 2004.

[8]. Amba Prasad Rao.G & Rama Mohan P, “*Effect of supercharging on the performance of a DI diesel engine with Cotton seed oil*”, Energy Conversion and Management, Vol.44, pp. 937-944, 2003

[9]. Ramadhas A.S, Jayaraj S, Muraleedharan C “*Use of vegetable oils as I.C. engine fuels—A review*”, Renewable Energy Vol. 29 pp.727–742, 2004.

[10]. P.K. Sahoo, L.M. Das M.K.G. Babu, P. Arora, V.P. Singh, N.R. Kumar and T.S. Varyani”Comparative evaluation of performance and emission characteristics of jatropha, karanja and polanga based biodiesel as fuel in a tractor engine “volume pp 1698-170,72009

[11]. Subramanian K A, Singal S K, Mukesh Saxena and Sudhir Singhal, 2005, “Utilization of liquid biofuels in automotive diesel engines: An Indian perspective”, J. of Biomass and Bioenergy, Vol. 29, pp 65 – 72.

[12]. Syed Ameer Basha, K. Raja Gopal, S. Jebaraj,” A review on biodiesel production, combustion, emissions and performance”, Renewable and Sustainable Energy Reviews, Volume 13, Issues 6-7, August-September 2009, Pages 1628-1634

[13]. Bhanodaya Reddy, V.D. Reddy and C. Eswara Reddy “Influence of injection pressures on the performance of IC E/e with esterified”, soft proc.All India conference on engineering trends in Mechatronics and Instrumentation, IE(I) and Mechanical Engineering Department. S.V. University, Tirupati, 20 – 30, June 2007.