CHARACTERIZATION OF JATROPHA AND CHLORELLA VULGARIS METHYL ESTER IN CRDI DIESEL ENGINE

M. Arangarajan[1], A. Raja[2], W.Christraj[3]

[1]*Research scholar, Department of Mechanical Engineering, Annamalai University, India*
[2]*Associate Professor, Department of Mechanical Engineering, Annamalai University, India*
[3]*Professor, Department of Mechanical Engineering, Angalamman Engineering and Technology, Tamil Nadu, India*

ABSTRACT

To make better utilization of biodiesels in diesel engine, the electronically controlled common rail direct fuel injection system was used in this work. The conventional injector was replaced using CRDI piezo electric injector. In this work, the biodiesels derived from chlorella vulgaris algae and Jatropha blends (B10, B20, B30 and B40) were used to run the engine. The exhaust emissions were measured using AVL di-gas and AVL Hatridge smoke meter analysers. The combustion data were derived using AVL pressure transducer and combustion analyser. The standard fuel injection pressure of 300bar was maintained throughout the experimental work. The performance, emission and combustion were analysed using chlorella vulgaris algae and Jatropha methyl ester blends and compared with diesel fuel.

KEYWORDS: Biodiesel, CRDI Diesel engine, Emission, Combustion, Performance.

1. INTRODUCTION

Exploitation of the clean and renewable energy develops as a drift in current scenario. Biofuel, which generally consists of the monoesters of free fatty acids amid the carbon molecular chain span with 14-18, which increases the flash point, cetane index and lubricating property [1-3]. In past few years, wide researches regarding the catalyst used for transesterification process to make methyl ester have been performed. They analysed the long life and high activity characteristics [4-6]. Now, the transesterified methyl ester largely employs the homogeneous catalysts like $NaCH_3O$, NaOH and KOH, etc. The catalytic capabilities of above homogeneous catalysts are strapping, except the ensuing separation process. In the case of heterogeneous catalysts, they can be easily divided and reemployed, are so make growingly interests [7,8]. Algae have exhibited to be a capable bio energy source since in compare to sugarcane, soybean, mahua and rice bran. Chlorella vulgaris algae are not edible, they are less pricey, cultivate faster and rate of yield per hectare. Also they do not need clean water to cultivate, and they have the prospective of diminishing the carbon emission [9]. The developed and developing countries have turned to algae as a proficient and passable choice for the energy predicament by reason. Some of microalgae like Chlorella vulgaris, Spirullina and Dunaliella could accrue extensive amount of oil content up to 60% when harvest under convinced environmental circumstances, for instance high in temperature and light intensity [10]. Chlorella is a type of micro algae that can cultivate heterotrophically and also photoautotrophically. Heterotrophic growth of Chlorella vulgaris abounding with glucose, acetate and carbon source as organic compounds, which results in high yield of biomass and higher content of lipids [11].

In this work, vegetable oils derived from Jatropha seeds and Chlorella vulgaris used to produce the biodiesel through catalytic transesterification. The Soxhlet apparatus was used to extract the vegetable oil from Chlorella vulgaris in this work. The characterization of thermo physical characters of both biodiesel were conducted and listed as per ASTM standards. In this work to avoid the damage of piezo electric fuel injector, the blends of B10, B20, B30 and B40 were analysed in CRDI diesel engine and discussed about the performance, emission and combustion characteristics of Jatropha seeds and Chlorella vulgaris biodiesel blends.

2. BIODIESEL CHARACTERIZATION

Both the oils extracted from of Jatropha seeds and Chlorella vulgaris oils undergo catalytic transesterification to produce biodiesel. The process of transesterification to synthesis biodiesel requires an alcohol and catalyst wherein, the triglycerides with larger molecules are broken into mono glyceride and esters. In the work, the extracted Jatropha seeds and Chlorella vulgaris oils were transesterified using potassium hydroxide and methanol to produce Jatropha seeds and Chlorella vulgaris methyl ester. For synthesizing one litre of methyl ester 180ml of methanol and 8g of KOH was used for the conversion process. The formed glycerol has been drained out and the left out methyl ester was washed with distilled water to take away the impurities and the remaining glycerol [12].

Afterwards, the Jatropha seeds and Chlorella vulgaris methyl esters are heated up to 90°C to remove the traces of water present in the final product. Finally, the fuel properties of Jatropha seeds and Chlorella vulgaris methyl esters were analysed as per ASTM standard methods and tabulated in the Table 1. The Jatropha seeds and Chlorella vulgaris methyl esters properties reveal that the raw oils have higher viscosity, which does not sustain its direct employ in diesel engine. Thus, it is important to transesterifying the extracted Jatropha seeds and Chlorella vulgaris oils to reduce their viscosity, and acquire it to the adequate biodiesel standard in an attempt to make it potential to operate diesel engine. The schematic of transesterification kit is shown in Figure 1.

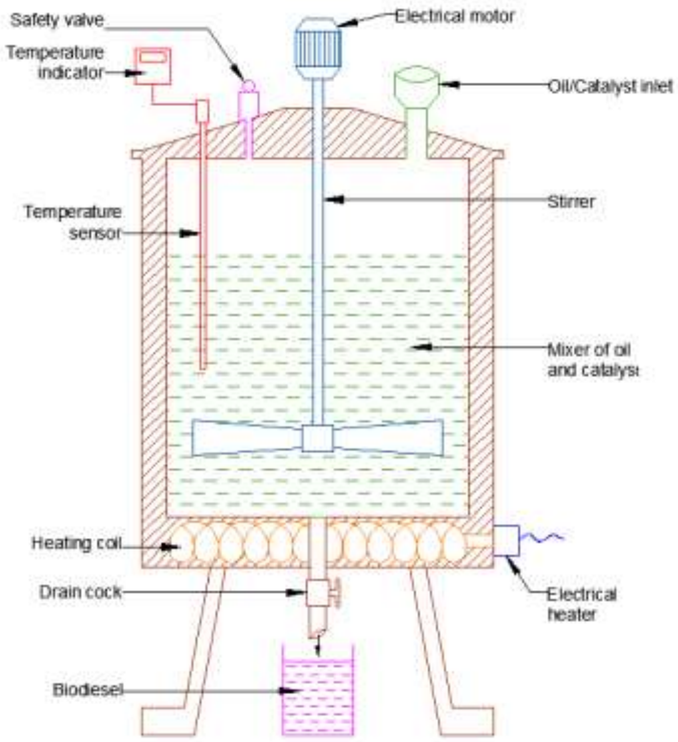

Figure 1 schematic diagram of transesterification plant

Table 1 Properties of biodiesels

Properties	Jatropha methyl ester	Chlorella vulgaris methyl ester	Diesel
Specific gravity	0.8614	0.854	0.83
Kinematic viscosity in cst	4.23	4.10	3.6
Flash point	143°C	135°C	74°C
Fire point	153°C	147°C	84°C
Gross calorific value in KJ/kg	42220	42340	42700
Pour point	< -9°C	< -12°C	<-23°C
Density in kg/m3	871	857	822

3. EXPERIMENTAL SETUP

Trials were performed on Kirloskar AV1 made four stroke stationary single cylinder and water circulated cooled diesel engine supported by a common rail direct injection fuel feed system. The rated power of the CRDI diesel test engine was 3.7 kW. The CRDI diesel engine was driven at a steady speed of 1500 rpm. The duration of fuel injection was sustained at 600–1000 µsec to retain the engine speed of 1500 rpm for the corresponding load conditions. The schematic view of the CRDI assisted diesel test engine setup is depicted in Figure 2. In the CRDI fuel injection system it contains two segments. The low pressure segment consists of a small pump which is employed to suck the fuel from the tank and deliver it to high pressure pump. The high-pressure segment was organized by a model consisting of a Kirloskar made high-pressure pump obsessed by an electrical motor with a single piezo electric fuel injector. The speed of the CRDI diesel test engine was managed via increasing the fuel injection period when the load was increased. The fuel injection pressure is managed through an inlet-metering valve in the piezo electric injector which allows the requisite quantity of fuel.

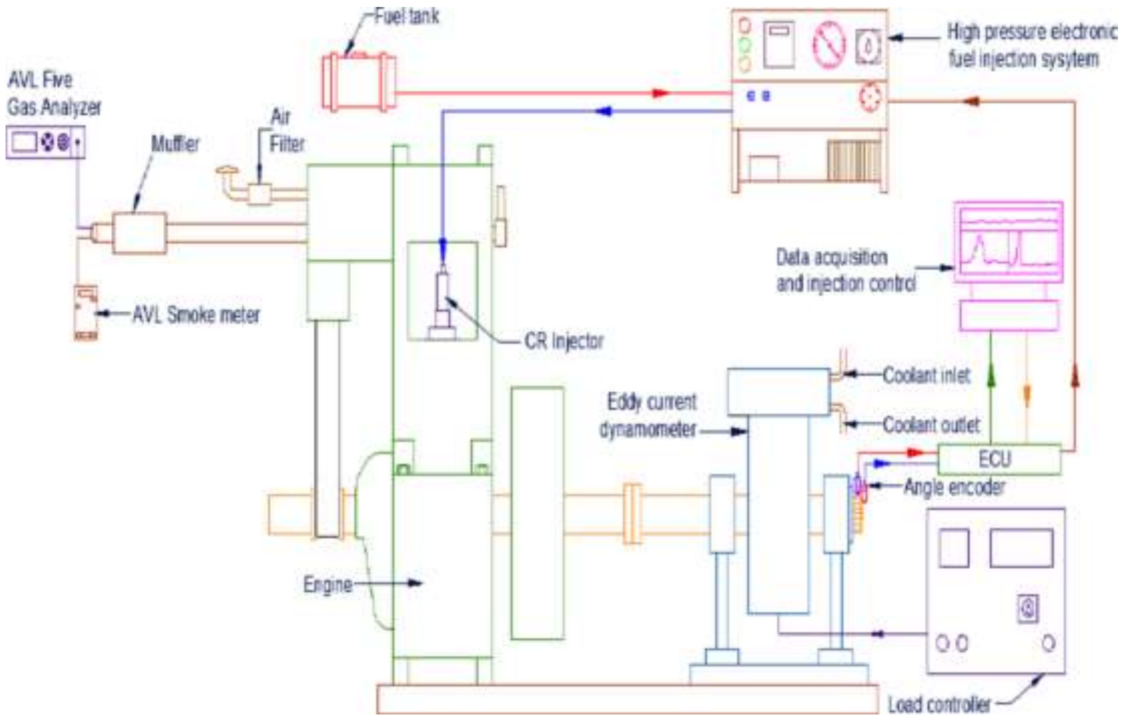

Figure 2 Schematic of Experimental test engine

4. RESULTS AND DISCUSSION

4.1 IMPACT OF BIODIESELS AND THEIR BLENDS IN CRDI DIESEL ENGINE PERFORMANCE CHARACTERISTICS

The function of the test engine was found to be extremely smooth all over the rated load condition, without any working troubles for the chlorella vulgaris and Jatropha methyl esters blended diesel fuel (B10, B20, B30 and B40). The brake thermal efficiency (BTE) for jatropha methyl ester and chlorella vulgaris algae methyl ester and their blends with respect to brake power is depicted in Figure 3 and 4 respectively. In both the cases of methyl esters, BTE was found increased with increase of brake power. From the data attained by Jatropha methyl ester (Figure 3), it is clear that the BTE was found decreased in the cases of Jatropha methyl ester when compared with diesel. The blend ratio increased from 10% to 40% the BTE was significantly decreased. The BTE for the 10% of Jatropha methyl ester (B10) have the nearer value to diesel when compared with other Jatropha methyl ester blends (B20, B30and B40). The similar trends of BTE were found in the case of Chlorella vulgaris methyl ester fuel blends (Figure 4). From both the cases of biodiesels, B10 (10% BIODIESEL + 90% DIESEL) have the similar performance characteristics with diesel. The diesel fuel has the BTE of 24.83%. Whereas Jatropha methyl ester blend (B10) has 24.15% and Chlorella vulgaris methyl ester fuel blend (B10) has 24.28% respectively. Compared with Jatropha methyl ester blend (B10), Chlorella vulgaris methyl ester fuel blend (B10) have 0.13% higher BTE.

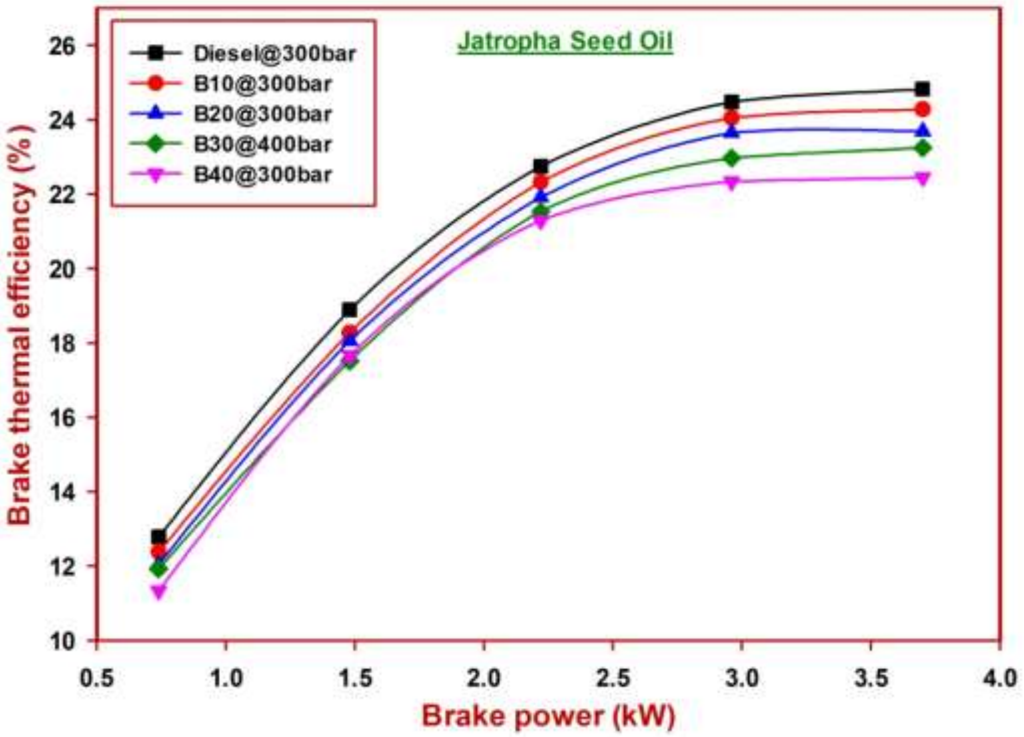

Figure 3 Brake thermal efficiency against brake power with Jatropha biodiesel blends

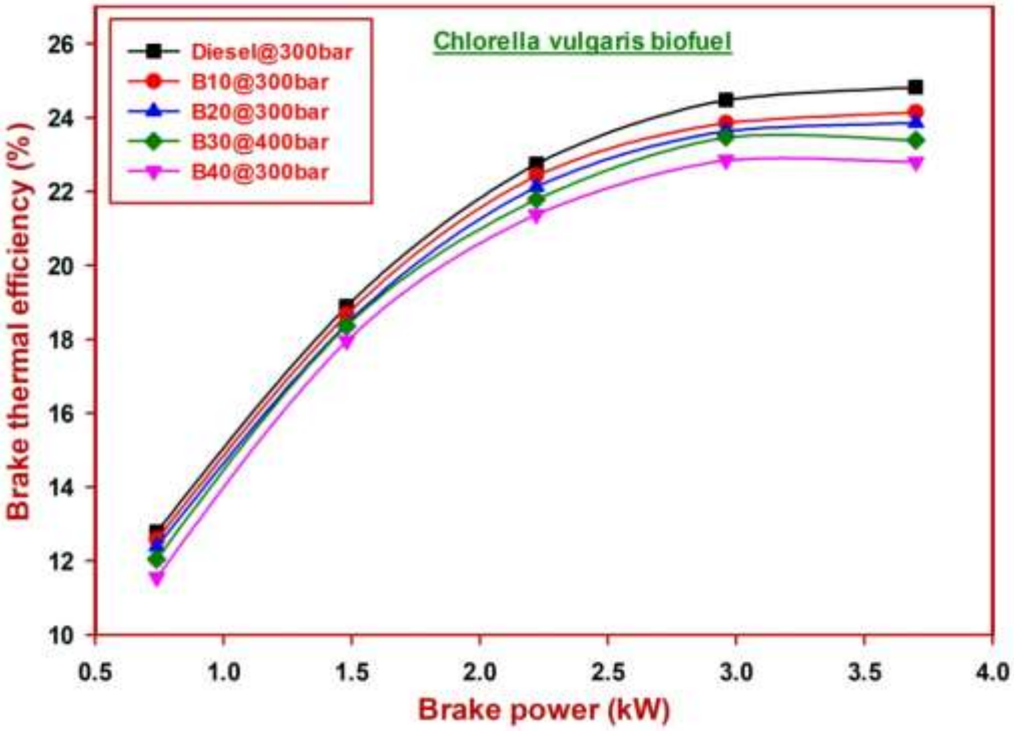

Figure 4 Brake thermal efficiency against brake power with CV biodiesel blends

4.2 IMPACT OF BIODIESELS AND THEIR BLENDS IN CRDI DIESEL ENGINE EMISSION CHARACTERISTICS

Figure 5 depicts the hydrocarbon emissions with of Jatropha biodiesel blends and Figure 6 depicts the hydrocarbon emissions of Chlorella vulgaris biodiesel blends. To find the emission characteristics of the CRDI test engine with these biodiesels, 10%, 20%, 30% and 40% blends with diesel were employed in this work. The percentage of biodiesel have ended with 40%, because of higher percentage of biodiesel may cause damage to the piezo electric fuel injector which is used in this work. In the case of Jatropha biodiesel, hydrocarbon emission was found increased with increase of biodiesel quantity. The higher hydrocarbon emission was found in the case of B40 as 136ppm. The least hydrocarbon emission was found in the case of B10 as 120ppm which is nearer to diesel value. The similar trends of hydrocarbon emission were found in the case of Chlorella vulgaris biodiesel blends. This may due to Chlorella vulgaris biodiesel blend (B40) requires rich air for proper combustion than diesel. The hydrocarbon emission for B40 of Chlorella vulgaris biodiesel blend was 129 ppm and it was significantly reduced to 116 ppm for B10 fuel blend. B10 emit the least amount of hydrocarbon emissions when compared with other Chlorella vulgaris biodiesel blend. In both the biodiesels, B10 blends were have least hydrocarbon emission which nearer to diesel.

The oxides of nitrogen emission (NOx) for Jatropha methyl ester and Chlorella vulgaris algae methyl ester and their blends with respect to brake power were depicted in Figure 7 and 8 respectively. From the Figure 7, it is obvious that the NOx emission was found decreased with the increase the percentage of Jatropha methyl ester blends. The least NOx emission of 628ppm was found in the case of B40 and maximum NOx of 730ppm was found in the case of B10. This may due to lower peak temperature ensued during diffusion combustion phase when the biodiesel blends used as fuels [13]. Diesel has the NOx emission of 761ppm. From the Figure 8, it is found that the NOx emission was found decreased also with the increase the percentage of Chlorella vulgaris algae methyl ester. The least NOx emission of 675ppm was found in the case of B40 and maximum NOx of 745ppm was found in the case of B10.

Figure 9 shows the Carbon monoxide (CO) emissions with of Jatropha biodiesel blends and Figure 10 shows the Carbon monoxide emissions of Chlorella vulgaris biodiesel blends with respect to brake power. From the results observed, the CO emission for Jatropha biodiesel blends was increased with increase the percentage of biodiesel with diesel. This may be attributed due to higher density and viscosity of biodiesels which leads to poor atomization. The higher CO emission of 0.72 (%by volume) was found in the case of B40 of Jatropha biodiesel blend and whereas least CO emission of 0.61 (%by volume) was found in the case of B10 of Jatropha biodiesel blend. The similar trend of Carbon monoxide (CO) emission was found in the case of Chlorella vulgaris biodiesel blends also. The higher CO emission of 0.67 (%by volume) was found in the case of B40 of Chlorella vulgaris biodiesel blend and whereas least CO emission of 0.58 (%by volume) was found in the case of B10 of Chlorella vulgaris biodiesel blend. When compared with Jatropha biodiesel blend (B10), Chlorella vulgaris biodiesel blend (B10) has the lower CO emission and which is nearer to diesel fuel.

Figures 11 and 12 depict the result of smoke emission from the test engine at different brake power for different blends of Jatropha biodiesel blends and Chlorella vulgaris biodiesel blends. From the figure 6.9, it is apparent that the smoke density of Jatropha biodiesel blends is increased when contrasted to that of diesel fuel. The cause for this trend is due to the higher viscosity of Jatropha biodiesel blends which directs to deprived combustion [14]. It has shown enhancement of 14.94% for B40 of Jatropha biodiesel blend when contrasted to that of diesel. In the case of B10, it has shown enhancement of 4.71% when contrasted to that of diesel. From the consequences, it is disclosed that the smoke emission of B10 blend of Jatropha biodiesel blend have the closer assessment to the diesel fuel. From the figure 6.10, it is found that the smoke density of Chlorella vulgaris biodiesel blends is increased when contrasted to that of diesel fuel. From the figure, it has shown enhancement of 8.75% for B40 of Chlorella vulgaris biodiesel blend when contrasted to that of diesel. In the case of B10, it has shown enhancement of 1.72% when contrasted to that of diesel.

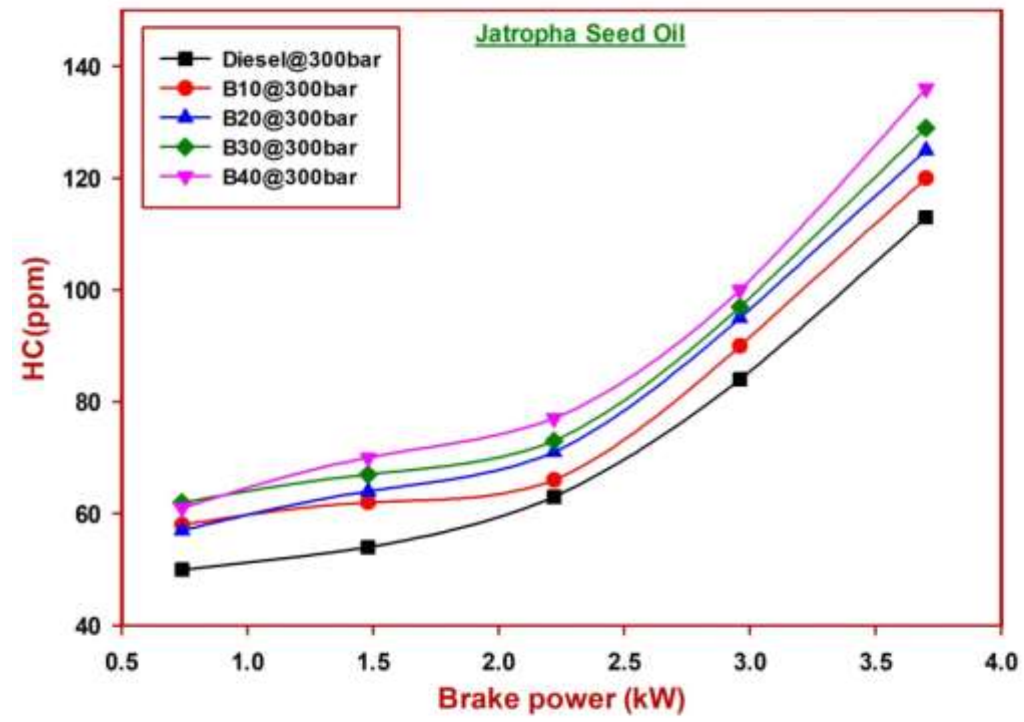

Figure 5 Hydrocarbon against brake power for Jatropha biodiesel blends

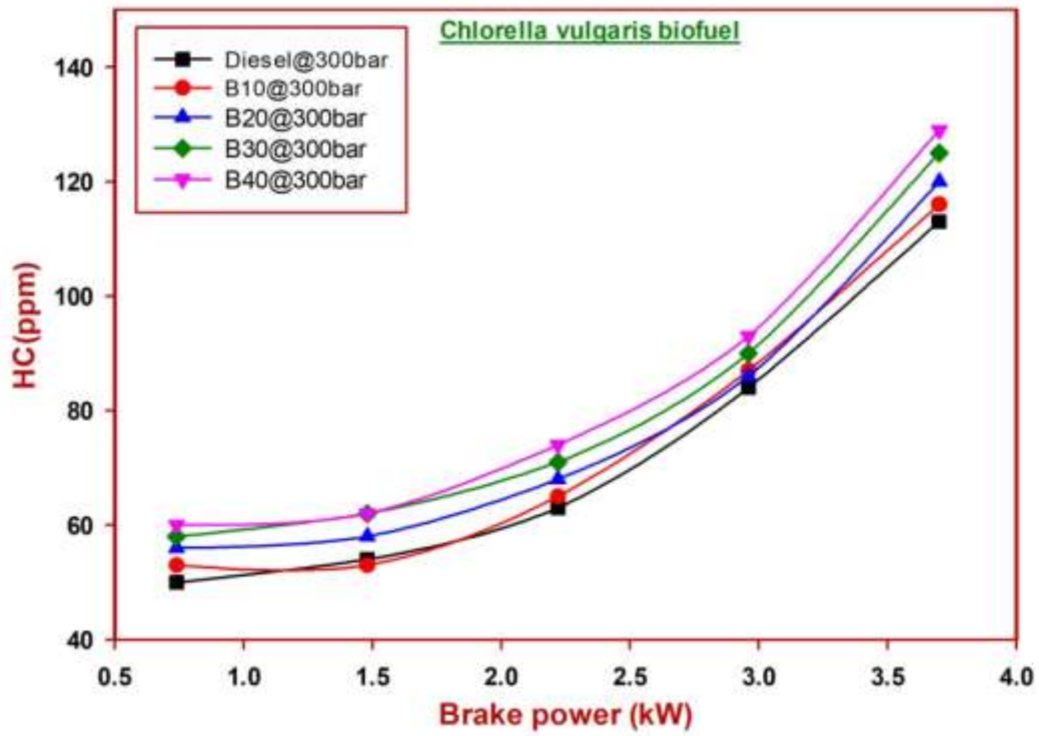

Figure 6 Hydrocarbon against brake power for CV biodiesel blends

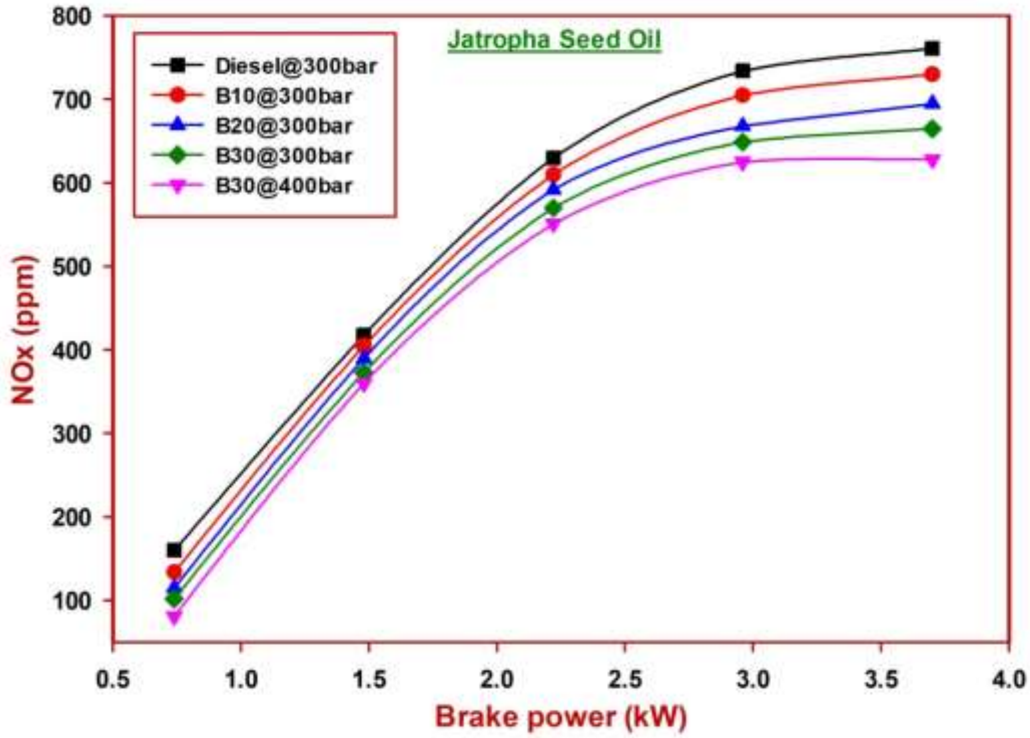

Figure 7 Oxides of nitrogen against brake power for Jatropha biodiesel blends

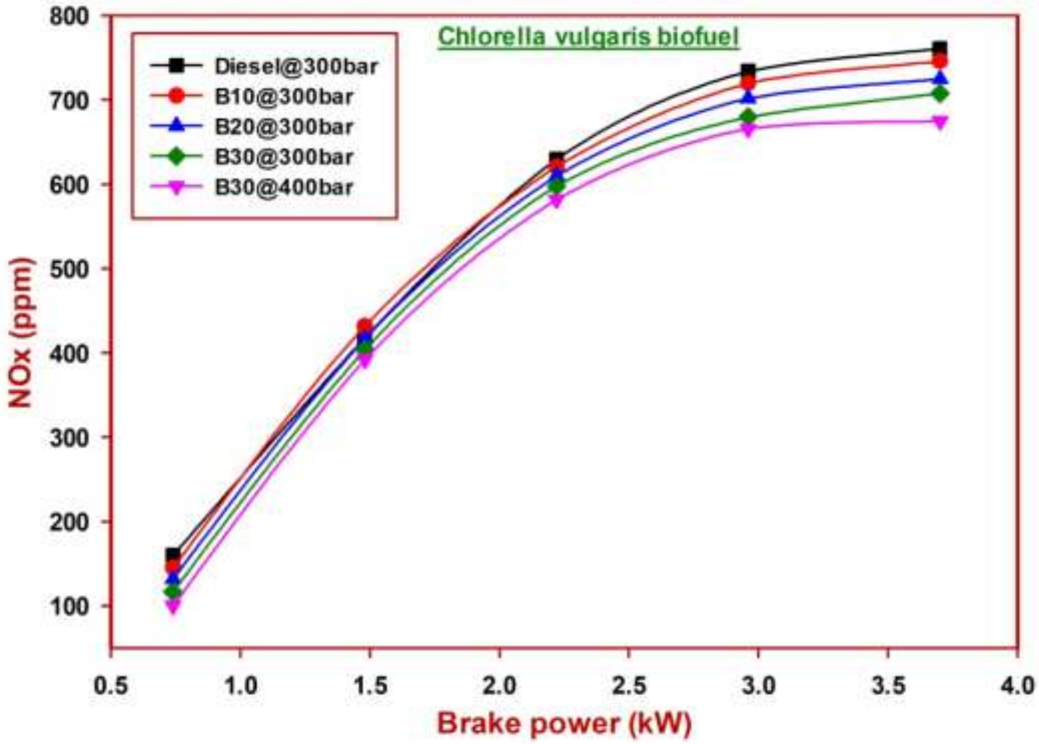

Figure 8 Oxides of nitrogen against brake power for CV biodiesel blends

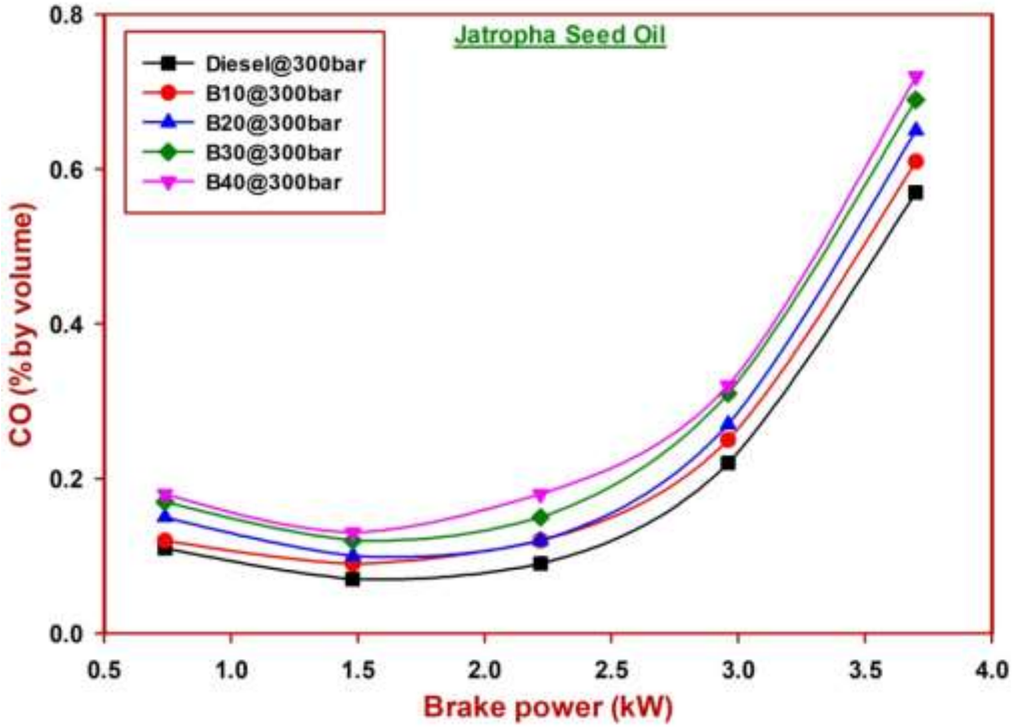

Figure 9 Carbon monoxide emission against brake power for Jatropha biodiesel blends

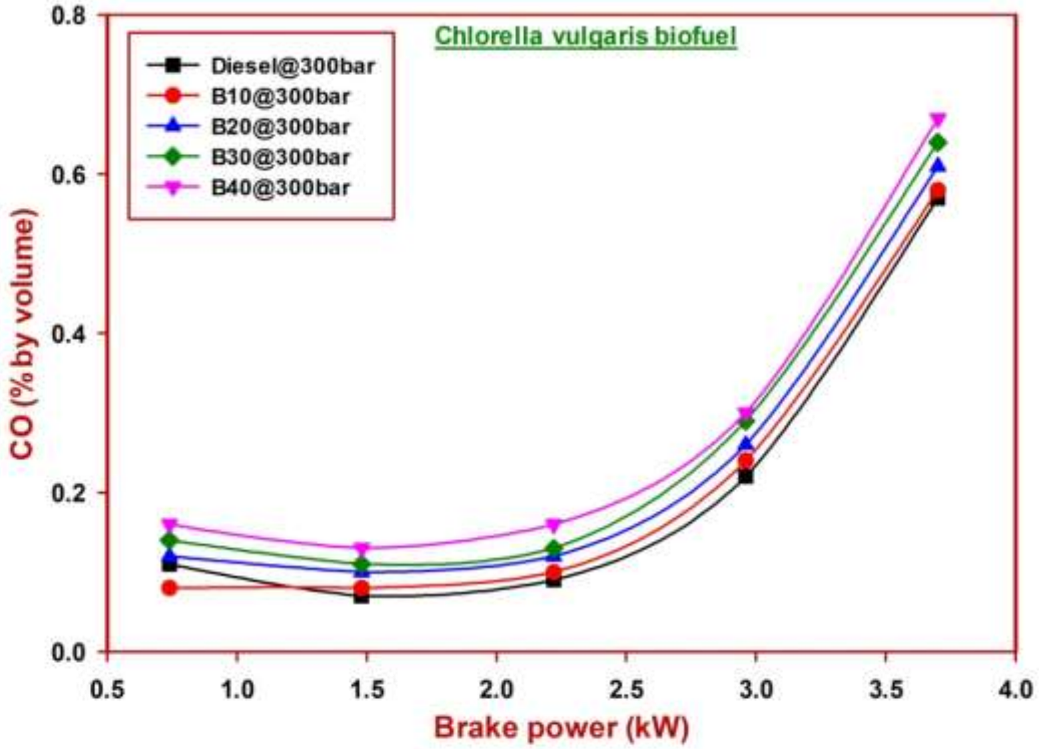

Figure 10 Carbon monoxide emission against brake power for CV biodiesel blends

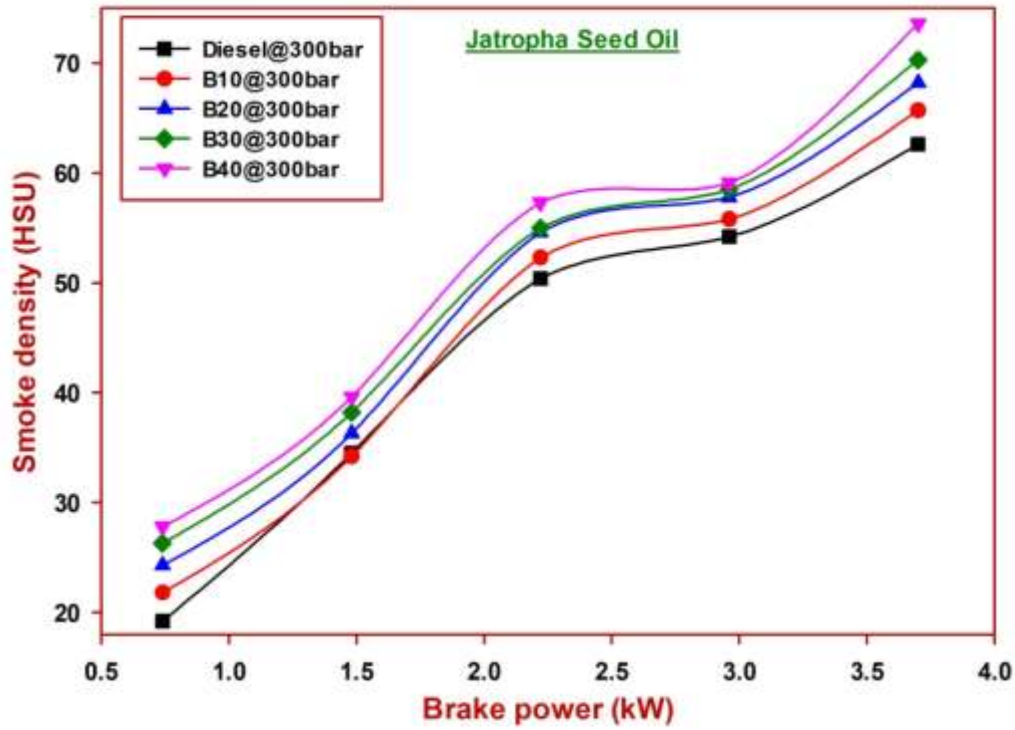

Figure 11 Smoke density against brake power for Jatropha biodiesel blends

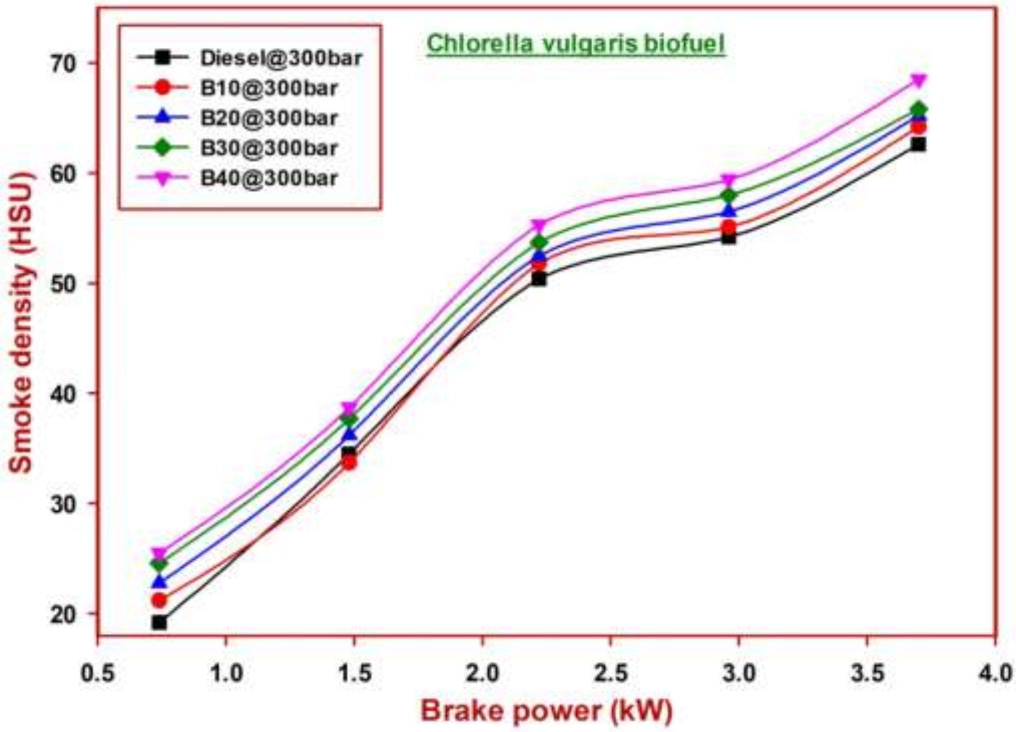

Figure 12 Smoke density against brake power for CV biodiesel blends

4.3 IMPACT OF BIODIESELS AND THEIR BLENDS IN CRDI DIESEL ENGINE COMBUSTION CHARACTERISTICS

In this work, data derived from the in cylinder pressure and heat release rate for Jatropha biodiesel blends and Chlorella vulgaris biodiesel blends are conspired against crank angle. The figure 13 depicts the variation of in cylinder pressure of Jatropha biodiesel blends with crank angle. The peak cylinder pressure was found decreased in all the cases of Jatropha biodiesel blends. It also observed that the peak pressure decreases with the increase of the percentage of Jatropha biodiesel with diesel. The B40 blend of Jatropha biodiesel has the very low peak pressure compared with other blends like B30, B20 and B10. The peak cylinder pressure of 44.16bar and 46bar was found in the cases of B40 of Jatropha biodiesel and B30. Similarly, the peak cylinder pressure of 46.76bar and 48.24bar was found in the cases of B20 of Jatropha biodiesel and B10. This may occurs due to poor air fuel mixing of Jatropha biodiesel blends during combustion phase. The similar trends were also observed in the case of Chlorella vulgaris biodiesel blends. The B40 blend of Chlorella vulgaris biodiesel has the very low peak pressure compared with other blends like B30, B20 and B10. The peak cylinder pressure of 48.26bar and 48.43bar was found in the cases of B40 of Jatropha biodiesel Chlorella vulgaris biodiesel and B30. Similarly, the peak cylinder pressure of 48.83bar and 48.95bar was found in the cases of B20 of Chlorella vulgaris biodiesel and B10.

The Figures 15 and 16 shows the heat release rate of different blends of Jatropha biodiesel blends and Chlorella vulgaris biodiesel blends. From the Figure 15, it is clear found that the Jatropha biodiesel blends having the lower heat release rate compared to diesel. The heat release rate found decreased with the increase of Jatropha biodiesel in diesel blend. The higher heat release rate found in the case of B10 compared to diesel fuel. The heat release rate at no load and half load are also analyzed, which furnishes the important information on the ignition delay period in case of diesel and Jatropha biodiesel blends. As a result of the longer delay period in the cases of Jatropha biodiesel blends, exposed minimum heat release rate take places earlier in comparison with diesel. The similar trends of heat release rate were found in the cases of Chlorella vulgaris biodiesel blends. The heat release rate found decreased with the increase of Chlorella vulgaris biodiesel in diesel blend. From the Figure 16, the heat release rate of B40 of Chlorella vulgaris biodiesel blend was 18.6571kJ/m^{3}deg and whereas it was 18.8713kJ/m^{3}deg for B30 of Chlorella vulgaris biodiesel blend. Also the heat release rate of B20 of Chlorella vulgaris biodiesel blend was 19.1917kJ/m^{3}deg and whereas it was 20.1104kJ/m^{3}deg for B10 of Chlorella vulgaris biodiesel blend. The heat release rate of B10 Chlorella vulgaris biodiesel blend has nearer value of diesel (20.43kJ/m^{3}deg).

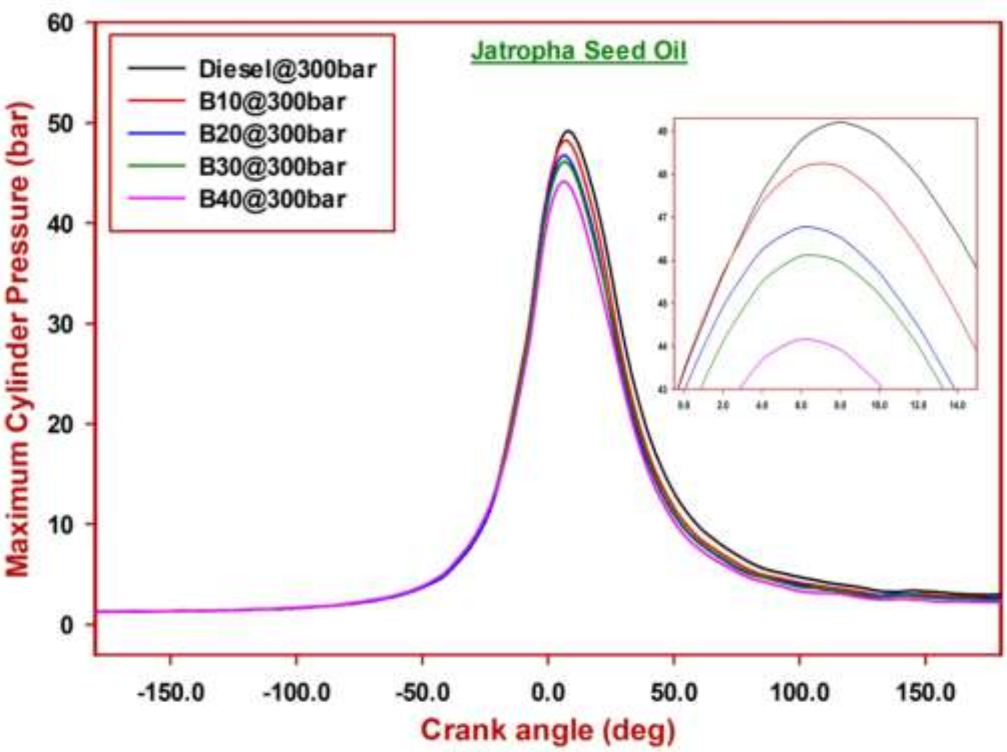

Figure 13 Cylinder pressure against crank angle for Jatropha biodiesel blends

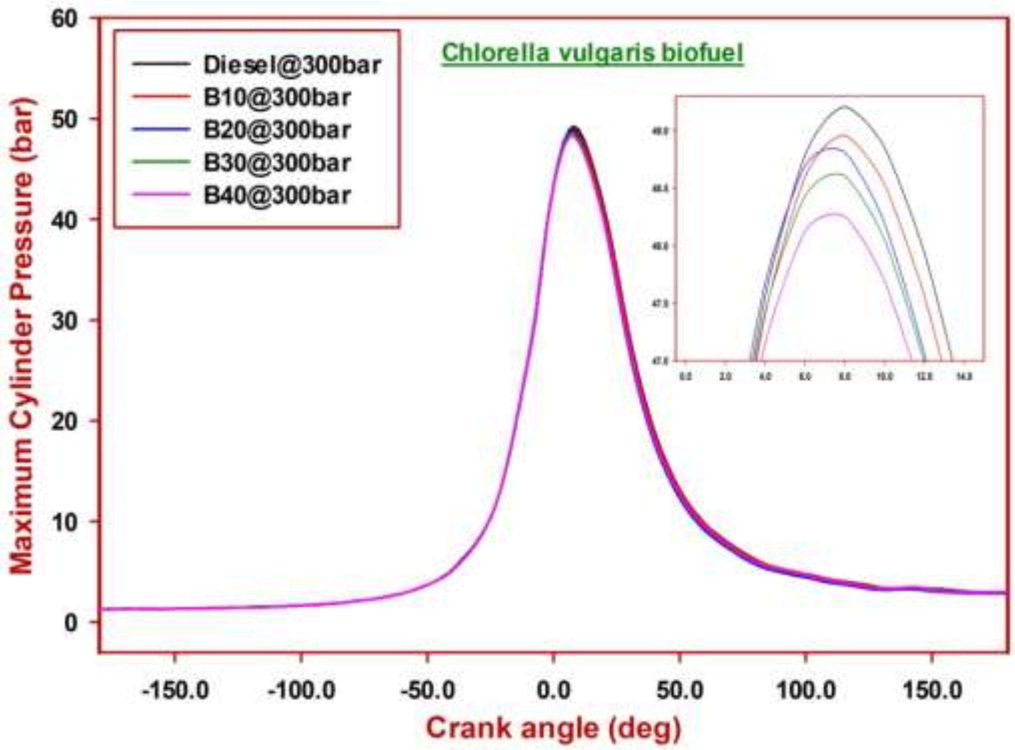

Figure 14 Cylinder pressure against crank angle for CV biodiesel blends

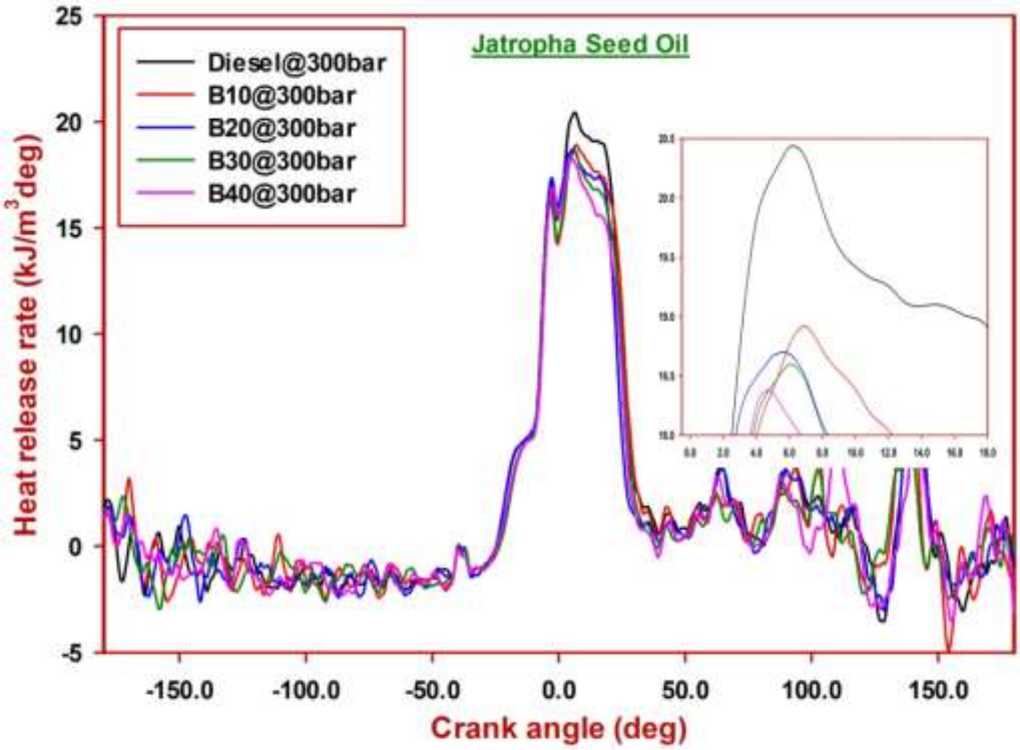

Figure 15 Heat release rate against crank angle for Jatropha biodiesel blends

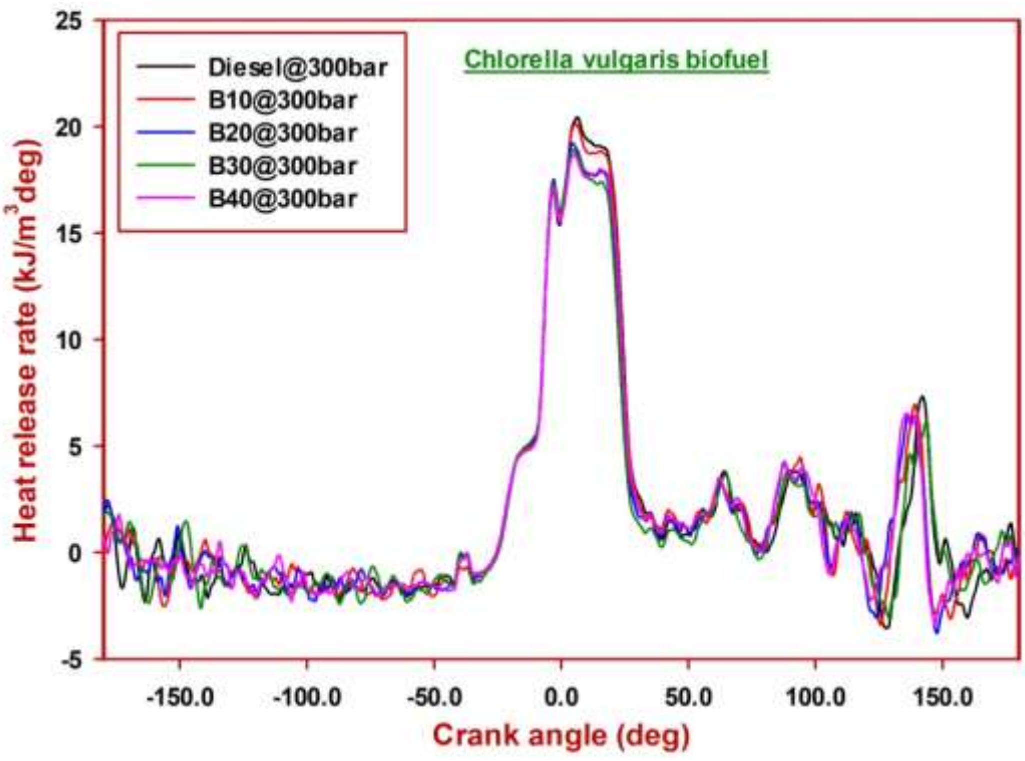

Figure 16 Heat release rate against crank angle

CONCLUSION

In this experimental investigations carried out on CRDI diesel engine with Jatropha seeds and Chlorella vulgaris methyl ester blends and the following conclusion is drawn.

- The brake thermal efficiency for B10 of both Jatropha seeds and Chlorella vulgaris methyl esters shows the higher compare to that of other blends like B20, B30 and B40.
- B10 of Jatropha seeds and Chlorella vulgaris methyl esters with standard injection pressure (300bar) shows minimum smoke density emission compared to other blends like B20, B30 and B40.
- The HC and CO emissions of B10 of both Jatropha seeds and Chlorella vulgaris methyl esters show the lesser to other blends and nearer value to diesel.

- The combustion parameters like in-cylinder pressure and heat release rate of B10 of both Jatropha seeds and Chlorella vulgaris methyl esters have similar trend like diesel fuel

From the above discussion, it is concluded that the B10 of Jatropha seeds and Chlorella vulgaris methyl esters have suitable to run the CRDI diesel engine without any major modification.

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