Effects of Papaya Methyl Ester on DI Diesel Engine Combustion, Emission and Performance Characteristics

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Abstract - *In this study, the combustion, emission and performance analysis of diesel engine using methyl ester produced from papaya seed oil and its blends (PME25, PME50, PME75 and PME100) were compared with conventional diesel fuel. The tests were performed at steady-state conditions in a single-cylinder direct injection diesel engine over the constant rpm range (1500 rpm). During the tests, the fuel consumption, exhaust emissions, heat release rate and in-cylinder pressures were measured. Combustion analysis revealed that the addition of papaya methyl ester to diesel fuel considerably decreased the ignition delay period and results in maximum in-cylinder pressure. The performance results revealed that, relative to diesel, papaya methyl ester had a 1.18% increase in the brake specific fuel consumption (BSFC) because of the lower heating value of the papaya methyl ester. As an outcome of this study, papaya methyl ester was found to show improved brake thermal efficiency, with remarkable decrease in major pollutants such as hydrocarbon, carbon monoxide and smoke. However, due to increase in in-cylinder temperature, the NO_X emission was increased.*

Key Words: **Papaya methyl ester, Transesterification, Diesel engine, Emissions, Combustion**

1.INTRODUCTION

Nowadays, diesel engines are part of the axis of world transportation, provide high torque, economical fuel usage and durability under a variety of conditions. Diesel engines are controlled the sectors such as road and train transport, agricultural, construction, maritime, propulsion and stationary electricity production [1]. On the other hand, the fuel requirement of most diesel engines still has to be met by conventional petroleum products, and because of this, alternative fuel studies are focused by the need for renewable energy sources and the need to save from harm the environment [2-3]. Currently, the use of biodiesel, which is produced from vegetable oils, has received a lot of attention because biodiesel can be used in a diesel engine without major engine modifications [4,5]. Many researchers have concluded that biodiesel has promise as an alternative fuel for diesel engines [6-9]. Biodiesel is non-toxic, biodegradable and a renewable diesel fuel that can be used alone or in blends with petroleum diesel fuels. Biodiesel has many advantages compared with diesel fuels. Biodiesel has a higher cetane number compared with diesel fuel and contains no aromatics, almost no sulphur and 10-12% oxygen by weight [10]. The properties of both the pure and blended biodiesel have great influence on the engine performance and emissions, since it has different physical and chemical properties from those of diesel fuel. Further research is required to find out more about the properties of biodiesel and their effects on the combustion and the fuel injection system, if this fuel is used in the diesel engines without any modification [11]. Though several advantages can be obtained with the application of biodiesel, few of its inherent properties are to be ameliorated in order to overcome the limitations [12]. Biodiesel has higher viscosity than petroleum diesel. Studies have shown that increasing blend ratios and thus viscosity, can lead to reduced atomization quality of the injected fuel. The consequences are increasing in the average droplet diameter of the sprayed fuel and the breakup time [13-15]. The injected fuel quantity, injection timing, and spray pattern can be affected by the higher viscosity and specific gravity of the biodiesel. Combustion and HRR characteristics of biodiesel must be known in order to achieve the reduction of brake specific fuel consumption (BSFC) and emission while keeping other engine performance parameters at an acceptable level. The differences in physical properties between diesel and biodiesel fuels affect the combustion and heat release characteristics [5,8,10]. In this study the performance, emission and combustion charecteristics of DI diesel engine was analysed using papaya methyl ester and its blends.

2. TRANSESTERIFICATION

The process of transesterification to synthesis bio diesel entails an alcohol and catalyst wherein, the triglycerides with larger molecules are broken into smaller components, esters As such, in the current study, the extracted papaya oil was transesterified using KOH (potassium hydroxide) has catalyzed and methanol has solvent to produce papaya methyl ester (PME). For synthesizing one liter of PME 200 ml of menthol and 10 g of KOH was found in the required after the Trans-esterification process, the formed glycerol has been drained out and the left out methyl ester is washed with distilled water to remove the impurities and the remaining glycerol. Subsequently, the bio diesel is heated up to 100°C to remove the last traces of water. Finally, the fuel properties of PME were identified by ASTM standard method and are shown in the table 1. It is worthwhile to note that after the trans-esterification process all the properties of PME were found in the incompliance with biodiesel standards for the current experimental investigation. The fuel properties reveal that the raw papaya oil has higher viscosity and boiling point, which does not support its direct use in diesel engine. Therefore, it is essential to transesterify the extracted papaya oil in order so to reduce its viscosity, and bring it to the permissible biodiesel standard so as to make it feasible for diesel engine operation.

Table -1: Properties of PME and diesel

Properties	Papaya raw oil	B100	B50	Diesel
Specific gravity @15c/15c	0.9211	0.8811	0.8506	0.836
Kinematic viscosity@40c in cst	36.47	4.52	3.63	3.6
Flash point	295 °c	159° c	86 °c	74° c
Fire point	308 °c	171°c	92° c	84° c
Gross calorific value in KJ/kg	41351	42429	43664	42700
Pour point	< -4° c	< -7° c	< -10° c	<-23° c
Density @15 c in kg/m³	920.3	880.2	849.8	822

3. FT-IR ANALYSIS

The FTIR spectrums of diesel and papaya methyl ester were recorded and shown in figures 1 and 2. The Table 2 represents the functional group, compositional analysis for the diesel and papaya methyl ester. For diesel, the strong absorbance frequencies 2923 and 2954 cm^{-1} represents C-H stretching. The absorbance peaks 1741 cm^{-1} represented the C=O stretching which indicates the presence of aldehydes or keytones. For papaya methyl ester strong absorbance peaks 2923 cm^{-1} and 2954 cm^{-1} represented the C-H stretching. The absorbance peaks 1741 cm^{-1} and 722 cm^{-1} represented the C-H bend and out of C-H plane bend respectively indicating the presence of alkanes. Quite subtle differences can be observed between the spectra, since the product of the transesterification is chemically similar to its forerunner. In the region from 1850-1720 cm^{-1}, it can be observed peaks that can be assigned to the stretching of C=O bond, typical of esters, and thus are common in both FAME and refined oil spectra. The spectrum region that allows for chemical discrimination of papaya methyl ester is in the range 1600-1000 cm^{-1}, known as "fingerprint" region. The peak at 1436 cm^{-1} corresponds to the asymmetric CH_3 present in the papaya methyl ester spectrum. The peak in the spectrum at 1169 cm^{-1} can be attributed to the glycerol group CH_2-O (mono, di and triglycerides). The stretching of oxygen absorbance at 722 cm^{-1} , is typical of methyl ester. One more region of papaya methyl ester in spectrum covering the asymmetric axial stretching of O-Ce-CH_2-CH_2-OH, with respective peaks is 1100–1250 cm^{-1}. Based on the above discussion it is clear that both of diesel and mahua methyl ester are saturated hydrocarbon. The presence of hydrocarbon groups (C-H) indicates that the liquid has a potential to be used as fuels.

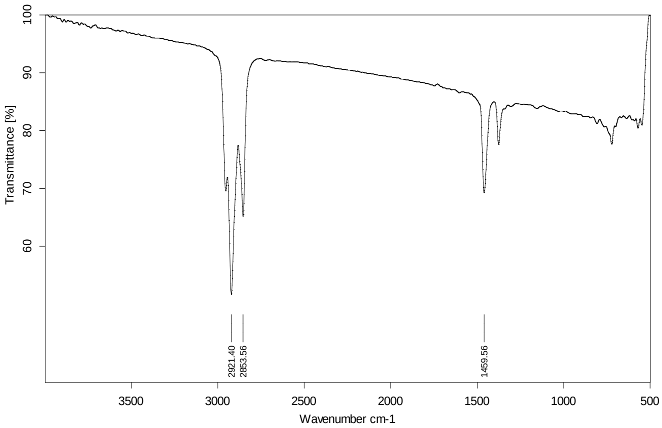

Fig -1: FTIR spectrum of neat diesel fuel

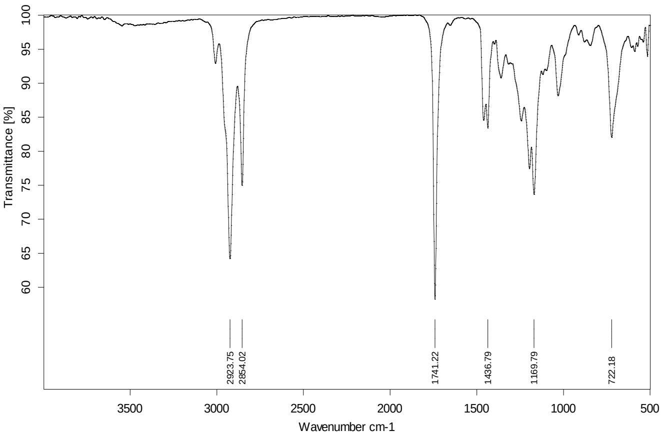

Fig -2: FTIR spectrum of Papaya methyl ester

Table -2: Properties of PME and diesel

Neat DF			Neat PME		
Frequency range (cm^{-1})	Bond	Family	Frequency range (cm^{-1})	Bond	Family
2923.9-2954.5	C-H stretching	Alkanes	2923-2954	C-H stretching	Alkanes
1485.3	C-H bending	Alkanes	1741	C=O stretching	Aldehydes/keytones
1377.1	C-X	Fluoride	1436	C-H Bending	Alkanes
723.3	=C-H Bending	Alkanes	722	C-H out of plane bending	Alkanes

4. GC-MS ANALYSIS

The composition of methyl esters were determined in a gas chromatography – mass spectrometry (GC-MS), with the column specification; 200°C operating temperature, 2°C/min ramp rate, 2µl/min flow rate and 80:1 split ratio. The GC-MS spectrum of papaya methyl ester is shown in figure 4, identifies methyl esters of linoleic acid and palmitic acid as two major constituents of PME. The individual esters were determined from the retention time, noted above the peak of each compounds, with the standard library of database. Deeper scrutiny of their structure reveals that both are unsaturated hydrocarbon, perhaps with longer hydrocarbon chain length and inherent oxygen in their structure, in the likes of other contemporary biodiesel. In the papaya methyl ester, two compounds, methyl behenate (C22:0) and methyl linolenate (C18:3), displayed nearly identical retention times, as shown in Figure 3. Because of the disproportion in their absorption spectra (the first compound being unsaturated, while the second saturated).

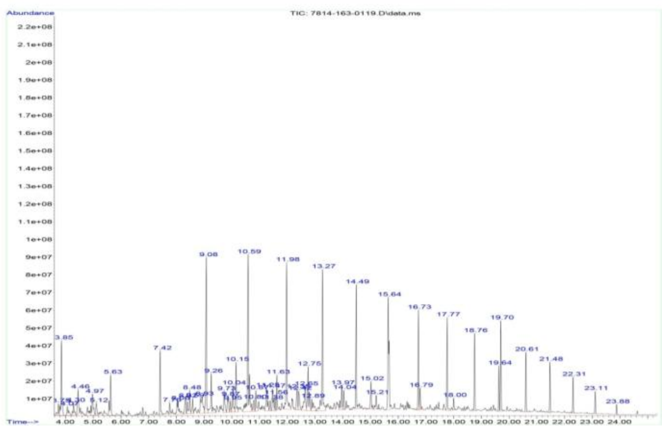

Fig -3: GC-MS spectrum of papaya methyl ester

5. EXPERIMENTAL SETUP

In this investigation, a single cylinder DI diesel engine was used, generally it is employed for marine, agriculture and power source application. It is coupled with eddy current dynamometer, with the help of the dynamometer varying the load 20, 40, 60, 80 and maximum load. The schematic view of the experimental setup is shown in figure 4. The specifications of the engine are furnished in the Table 2. The engine was started manually and fuel supplied to the engine. The exhaust emissions were measured using AVL di-gas analyzer. The combustion was measured by AVL combustion analyzer. The air cooled pressure transducer was mounted in the cylinder head and connected to charge amplifier and Indimeter, the data's are recorded in the pc using Indiwin software. Initially engine was started by sole fuel after reaching the steady state condition above mention parameter was recorded for every load. The same procedure was followed for all blends.

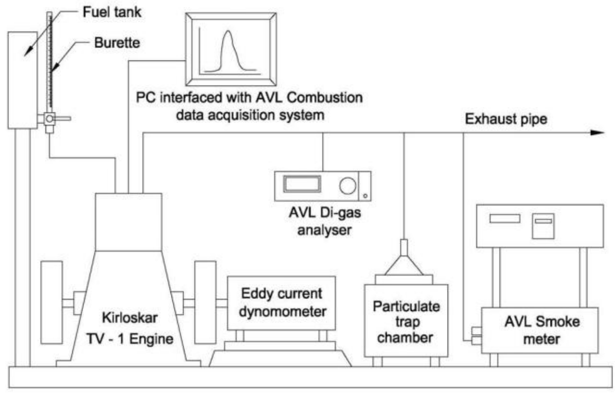

Fig -4: Experimental Setup

Table -3: Engine Specifications

Specification of diesel engine used	
Make	Kirlosar-TV 1
General details	Four stroke, compression ignition, constant speed, vertical, water cooled, direct injection
Number of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Rated speed	1500 rpm
Rated output	5.2 kW
Injection Pressure	220 bar
Fuel injection timing	23° bTDC
Type of combustion chamber	Hemispherical open combustion chamber
Lubricating oil	SAE 40

6. RESULTS AND DISCUSSION

The operation of the engine was found to be very smooth throughout the rated load, without any operational problems for the papaya methyl ester blended diesel fuel. In the present section, based on the combustion data, cylinder pressure and heat release rate are plotted against crank angle. The papaya methyl ester effectively reduces the NO_x emissions.

6.1 Performance Analysis

Figure 5 shows the variations of brake power with specific fuel consumptions. Blends of biodiesel have more specific fuel consumption as compared to that of neat diesel fuel. B25 has more specific fuel comsumption as compared to neat diesel , followed by B50, B75, B100 respectively. As brake power increases, specific fuel consumption increases. The SFC of the PME100 with has shown higher fuel consumption when compared to that of standard diesel fuel and other blends. This is due to higher density and viscosity of methyl ester and its blends.

Figure 6 shows the variations of brake thermal efficiency with brake power. The Brake thermal efficiency of neat diesel is more than other blends, i.e PME25 has lower brake thermal efficiency followed by PME50, PME75 and PME100 respectively. The reason may be the lower viscosity of the blend that leads to better atomization in the injector. PME 20% (20% of PME with 80% of diesel fuel) has shown better results than other blends since it has lower viscosity when compared to others. The BTE of blend PME20 shows an increase of 1.18% when compared to that of other blends at full load.

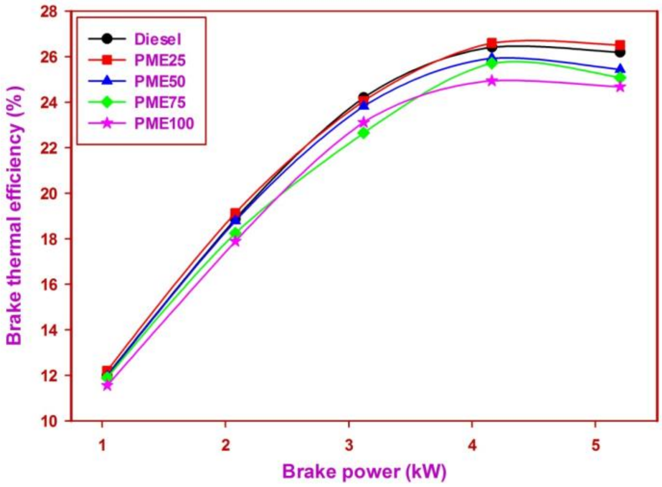

Fig -5: Brake thermal efficiency against brake power

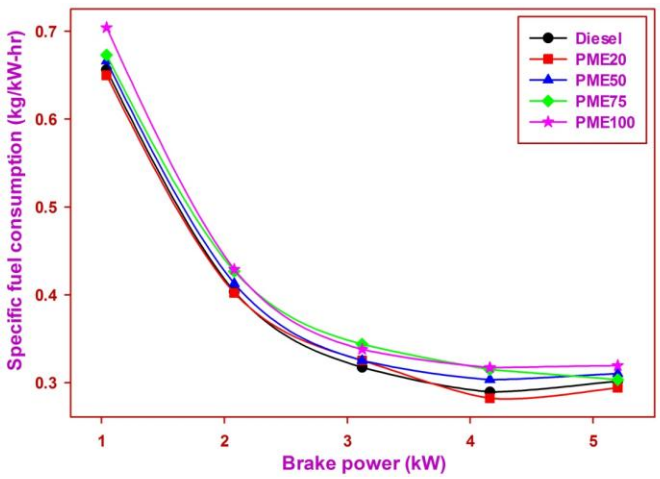

Fig -6: SFC against brake power

6.2 Emission Analysis

Figure 7shows the variations of carbon monoxide (CO) with brake power. The carbon monoxide (CO) emission of neat diesel is less than other blends. From the graph, it is clear that the CO emission is decrease for the blend WTF 25% with when compared to all other blends. It has shown a decrease of 5.56%. At lower papaya methyl ester concentration, the oxygen present in PME blend aids for complete combustion. Hence the reason is that the addition oxygen content available in the PME facilitates the conversion of CO to CO_2.

Figure 8 shows the variations of hydrocarbon emissions with brake power. The hydrocarbon emission of neat diesel is less than PME25. Where as emission of hydrocarbon decreses further in case of PME50, PME75 and PME100 respectively. As the load increases there is appreciable increase in HC emissions of diesel fuel. From the graph, it is clear that the HC emission of the blend PME25 was decreased when compare to all other PME blends. It has shown decrease of 0.5%. This is due to, PME25 has the required amount of oxygen which results good combustion condition.

Figure 10 shows the variations of smoke density with brake power. The smoke density of neat diesel is more than other blends, i.e B100 has the less Smoke density than neat diesel followed by B75, B50, B25 respectively. From the graph it is clear that the smoke density of PME20 decreased when compared to that of diesel fuel and other papaya methyl ester blends. PME100 have the higher smoke opacity compared with other blends of PME. The reason for this trend may be the higher viscosity of PME which leads to poor combustion. PME20 has shown decrease of 1.69% when compared to that of diesel fuel.

Figure 11 shows the variations of brake power with oxides of nitrogen.The oxides of nitrogen (NOx) emission after combustion is less in pure diesel compared to B25. Where as oxides of Nitrogen (NOx) produced in B50, B75, B100 is less than that of pure diesel. From the graph it is clear that the NOx emission of the PME100 is minimum when compared to that of diesel fuel. The reason is the reduced combustion temperature that prevails inside the combustion chamber due to the higher heating value of the PME blends. The blend PME100 has shows an decrease of NOx emission 8.47% when compared to that of diesel fuel at full load.

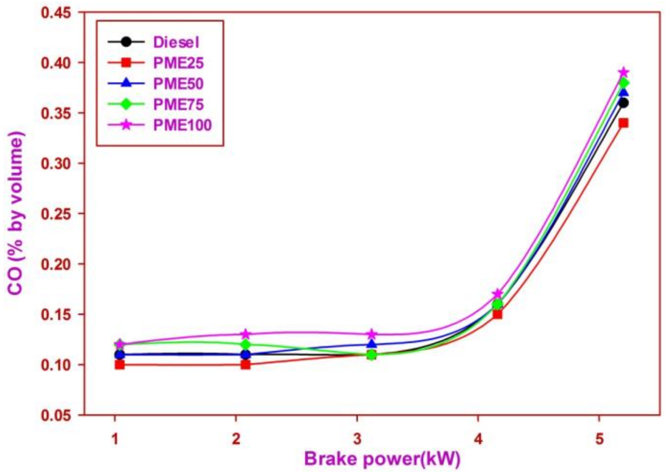

Fig -7: CO emission against brake power

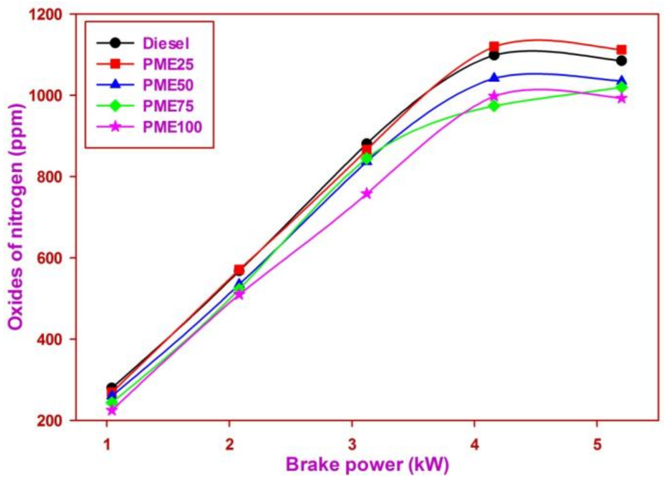

Figure 9 NO_x emission against brake power

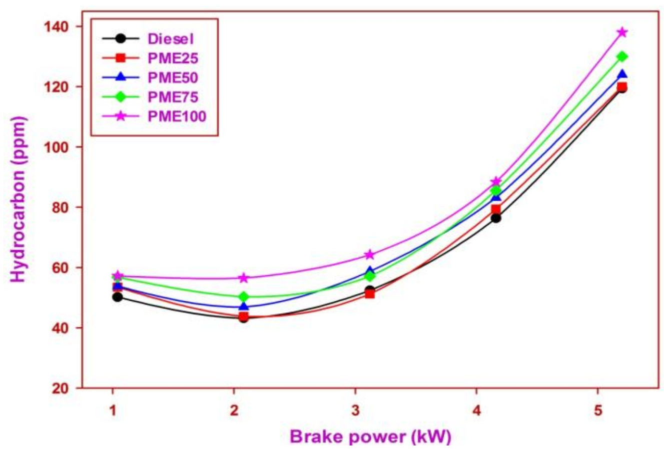

Fig -8: HC emission against brake power

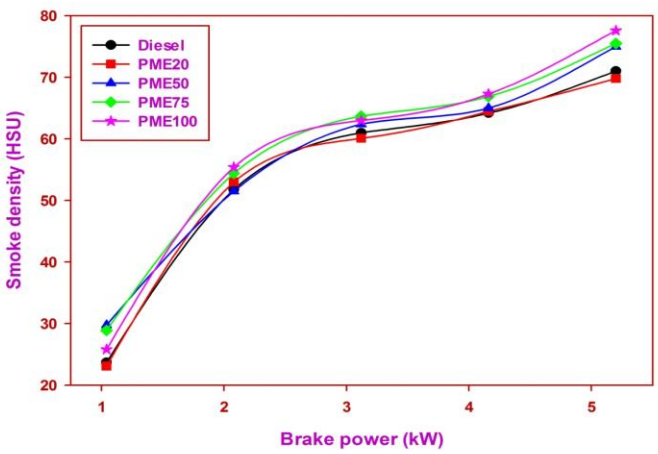

Figure 9 Smoke emission against brake power

6.3 Combustion Analysis

Figure 10 shows the variation of cylinder pressure with crank angle. The peak pressure of fuel blend B25 is higher than the all other blends. At the time of injection, methyl ester has less air fuel mixture for combustion phase. Due to the premixed combustion phase of burning, lower pressure was obtained for papaya methyl ester blends. The cylinder pressure increases as the proportion of methyl ester blends decreases. So for the biodiesel blends, cylinder pressure is higher than that standard diesel.

Figure 11 shows the heat release rate of methyl ester blends over crank angle. The premixed heat release of papaya methyl ester blend is lower than that of diesel, because of the lower calorific value of the papaya methyl ester blends. The heat release rate curve shows the potential availability of heat energy, which can be converted into useful work. The heat release rate of B25 blend is higher than the other blends due to reduced viscosity and better spray formation. The high viscosity of fuel leads to reduction in air fuel mixing rate. So the biodiesel blends produced less heat release rate compared to diesel.

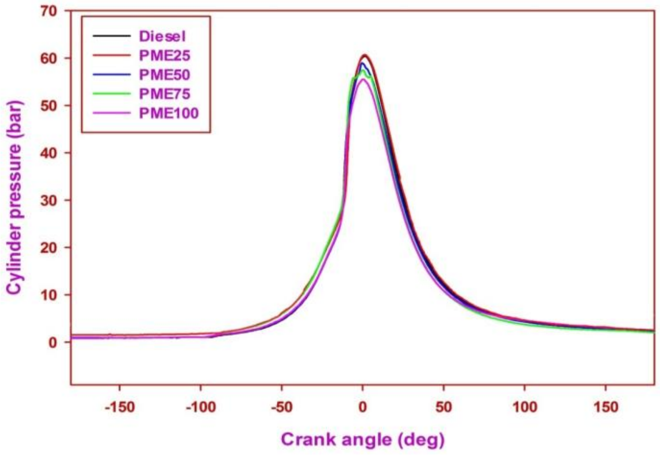

Figure-10: Cylinder pressure vs. crank angle

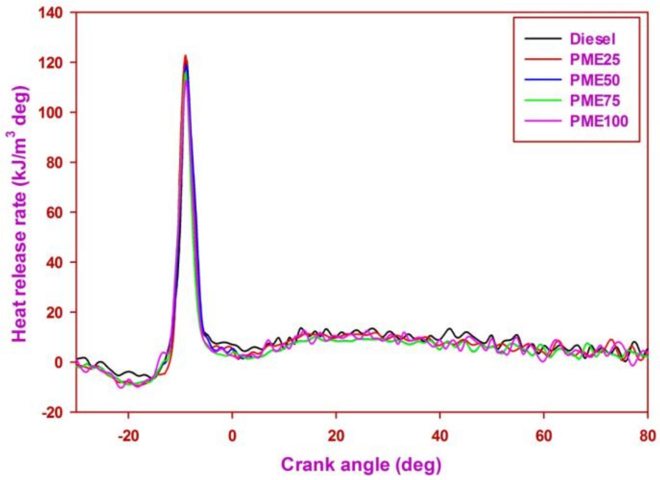

Figure-11: Heat release rate vs. crank angle

3. CONCLUSIONS

The combustion and emission characteristics of single cylinder compression ignition engine fuelled with papaya methyl ester and its blends have been analyzed and compared to the standard diesel fuel. Based on the experimental results, the following conclusions are obtained.

- ★ The brake thermal efficiency of papaya methyl ester blends is lower than that of diesel at all load conditions.
- ★ The specific fuel consumption of B25 biodiesel was low when compared to all other blends.
- ★ The CO emissions at different brake power were found to be higher for papaya methyl ester blends compared to diesel. The CO emissions of PME25 was minimum compare with all other PME blends.
- ★ The HC and smoke emissions were found to be higher for PME100 compared to diesel fuel. When decreasing the percentage of methyl ester the HC emissions are found to be decreased.
- ★ NO_x emissions of methyl ester and its blends were always lower than the diesel fuel.

From the combustion analysis, it is found that the performance of the papaya methyl ester and its blends are comparable at that of diesel.

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