

Emission Analysis of Sapodilla seed oil as bio-diesel

G.V.Churchill, C.Ananda Srinivasan

Department of Mechanical Engineering, Annamalai University, Tamil Nadu, India

Abstract— The study is made to replace the existing diesel fuel with the bio – fuels, for this fruit like Sapodilla seed oil as bio – diesel is utilized. The main objective of this work is to discuss the impact of biodiesel from Sapodilla fruit seed oil bio-diesel on performance, combustion and emission characteristics diesel. In this study, the effect of bio-diesel from fruit seed oil [Sapodilla seed oil] and its blends on a single cylinder Kirloskar TV-1 diesel engine were investigated.

In this work, the performance, combustion and emission analysis were conducted. The tests were performed at steady state conditions with the blend ratio of B25, B50, B75 and B100. These represent the ratio of biodiesel in the blend and the rest diesel. The aim of this investigation was to reformulate the fuel to utilize the biodiesel and its blend to enhance the fuels performance, combustion characteristic and to reduce the pollution from the engine. In this work only Sapodilla seed oil bio-diesel is utilized for the experimental work. The experimental results reveal a marginal decrease in brake thermal efficiency when compared to that of sole fuel. In this investigation, the emission test were done with the help of AVL DI gas analyzer, in which CO, HC and NOx are appreciably reduced on the other hand smoke, CO2 have marginal increased when compared to that of sole fuel. In this work combustion analysis also made with the help of AVL combustion analyzer in which bio diesel blend shows the better result when compared with diesel.

Keywords— Fruit seed oil, SP - Sapodilla seed oil Biodiesel, NOx - Oxides of nitrogen, Smoke.

I. Introduction

In the past few decades, fossil fuels, mainly petroleum-based liquid fuels, natural gas and coal have played an important role in fulfilling this energy demand. However, because of their non-renewable nature, these fossil fuels are projected to be exhausted in the near future. This situation has worsened with the rapid increase in energy demand with significant worldwide population growth. Therefore, the demand for clean, reliable, and yet economically feasible renewable energy sources has led researchers to search for new sources. Global energy demand is increasing dramatically because of rising

population. According to the International Energy Agency estimation, global energy demand is expected to increase by 53% by 2030. Currently, a major part of energy demand is fulfilled by fossil fuels, globally; we consume the equivalent of more than 11 billion tons of oil in fossil fuel every year. Crude oil reserves are vanishing at a rate of 4 billion tons a year. If this rate continues, oil deposits will be exhausted by 2052. Therefore, fossil fuel stock will run out in the near future. Consequently, the world is moving toward an energy crisis; driving the world to look for alternatives many renewable energy sources have drawn the attention of researchers. Among these sources, biodiesel is the most popular choice. Biodiesel is derived from renewable resources that can be produced by a simple chemical process. Many potential feed stocks are available for biodiesel production. Moreover, 60–80% of biodiesel production cost depends on feedstock cost. The demand for both food and bio fuel has increased rapidly because of population growth. Bio diesel is useable in diesel engines in pure form (or) by blending it with petroleum diesel. Biodiesel is environment friendly and non – toxic, it emits lesser pollutants. [1].

The issue of global climate change is currently a main focus of debate and will remain as an imperative issue within the next few decades. Emissions of greenhouse gases [GHGs] from combustion of fossil fuels due to anthropogenic activity are the prime suspect for the exacerbated situation. [2]

Biodiesel has been proposed as a viable option for the supplementation of fossil fuels and is likely to be a key contributor to the global energy demand. The primary constraint for the production of biodiesel is the lack of available feedstock to produce biodiesel on a large enough scale. However, due to competition for land use space with food crops, edible oils are less of a viable option, and currently microalgae production is too expensive to be produced on a large scale, leaving non-edible oils as the best source of oils for biodiesel.[3].

Fang-xia yang et al (4) have investigated the feasibility of producing biodiesel from *Idesia polycarpa* var. *vestita* fruit oil was studied. A maximum yield of over

99% of methyl esters in *I. polycarpa* fruit oil biodiesel was achieved using a 6:1 molar ratio of methanol to oil, 1.0% KOH (% oil) and reaction time for 40 min at 30 °C. The fuel properties of the *I. polycarpa* fruit oil biodiesel obtained are similar to the No. 0 light diesel fuel and most of the parameters comply with the limits established by specifications for biodiesel. R.Sathish kumar et al (5) have studied, the optimization of transesterification process parameters for the production of Manilkara Zapota Methyl Ester (MZME) has been studied. The experimental study revealed that 50 °C temperature of reaction, 90 min of time of reaction, 6:1 M ratio of methanol to oil and 1 wt% of concentration of catalyst are the optimal process parameters. Also the study revealed that out of the four parameters considered, methanol to oil molar ratio is most effective in controlling the optimal biodiesel production.

Jibrail Kansedo et al (1) have studied the feasibility of converting *Cerbera odollam* (sea mango) oil into biodiesel. The transesterification reactions were carried out using three different catalysts; sodium hydroxide (NaOH) as a homogenous catalyst, sulfated zirconia alumina and montmorillonite KSF as heterogeneous catalysts. The seeds were found to contain high percentage of oil up to 54% while the yield of FAME can reach up to 83.8% using sulfated zirconia catalyst.

Mortadha A. Ali et al (7) have studied the Oil extraction from date palm seeds (Iraqi date palm) is done by standard solvent extraction method using a Soxhlet apparatus. This work is aiming to investigate the extraction of palm seed oil as a cheap feedstock for producing bio-oil and determine the fatty acid composition of bio-oil. The extraction process was carried out on a laboratory scale with particle size 2mm, 1mm and 0.425mm for different time 1h, 2h, 4h and 6h. Particle size of 2 mm was chosen in order to study the effect of solvent type. The optimal conditions to obtain the highest oil yield of 8.5 % (w/w) were 120 min, 0.425 mm and n-hexane extracted time, particle size of grounded seed and type of solvent, respectively.

Silitonga et al., (2) have examined the engine performance and emission characteristic of *C. pentandra* biodiesel diesel blends in internal combustion. The experimental results showed that CPB10 blend give the best results on engine performance such as engine torque and power at 1900 rpm with full throttle condition. Besides, the brake specific fuel consumption at maximum torque (161g / kWh) for CPB10 is higher about 22.98% relative to diesel fuel (198 g/kW h). This is shown that the lower biodiesel diesel blends ratio will increase the performance and reduce the fuel consumption. Moreover, the exhaust emissions

showed that CO, HC and smoke opacity were reduced for all biodiesel diesel blends.

Orkun Ozener et al., (3) have studied the combustion, performance and emission characteristics of conventional diesel fuel and biodiesel produced from soybean oil and its blends (B10, B20, B50) were compared. The experimental results, showed that, relative to diesel, biodiesel had a 1–4% decrease in the torque and an approximately 2–9% increase in the brake-specific fuel consumption (BSFC) due to the lower heating value (LHV) of the biodiesel. However, biodiesel significantly reduced carbon monoxide (CO) (28–46%) and unburned total hydrocarbons (THCs), while the nitric oxides (NO_x) (6.95–17.62%) and carbon dioxide (CO₂) emissions increased slightly 1.46–5.03%. The combustion analyses showed that the addition of biodiesel to conventional diesel fuel decreased the ignition delay and reduced the premixed peak. These results indicated that biodiesel could be used without any engine modifications as an alternative and environmentally friendly fuel.

II. EXPERIMENTAL PROCEDURE

A. Experimental fuels

The commercial diesel fuel employed in the tests was obtained locally. The biodiesel produced from Sapodilla seed oil was prepared by a method of alkaline-catalyzed transesterification.

B. Preparation of Biodiesel

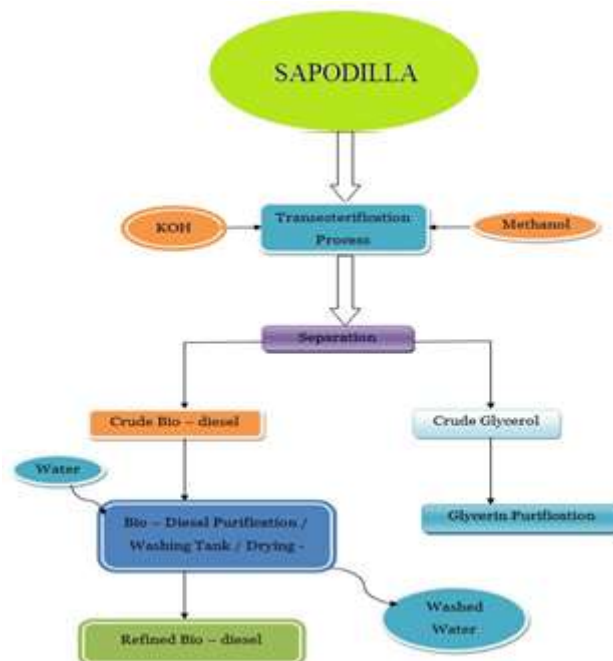


Fig.1: Sapodilla Seed Oil – Bio-diesel

Production Process Flow Chart.

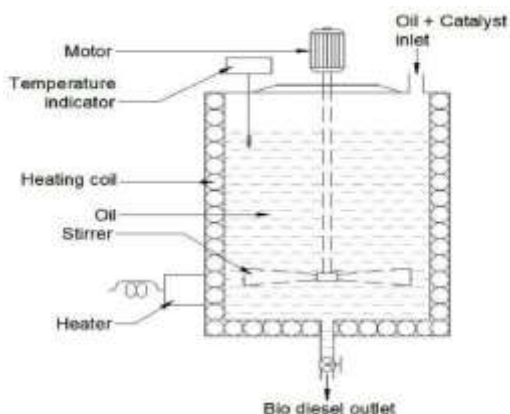


Fig.2: Schematic diagram of Biodiesel Plant

Raw Sapodilla seed oil has been purchased from local market. Biodiesel is prepared from raw oil by transesterification process. ‘Alcohol mixture’ is produced by mixing 200 ml of methanol with 18 grams of Potassium Hydroxide (KOH). Raw Sapodillae seed oil is heated. When the temperature reaches around 60C ‘Alcohol mixture’ is added to the raw oil. Then temperature is maintained at around 65C and the mixture is stirred for about 30 minutes.

Chemical reaction took place and biodiesel got yielded. The resultant product contained biodiesel and Glycerol. The products were allowed to settle down in an inverted beaker. Separation took place and glycerol which is heavier got settled down at the bottom. Glycerol was removed and pure biodiesel was collected.

Table.1: Properties of samples

Sample Name	Specific gravity	Density kg/m ³	Calorific values kJ/ kg
Sole Fuel	0.823	823	44,710.66
Sample 1	0.843	843	43,955.13
Sample 2	0.850	850	43,364.76
Sample 3	0.851	851	42,795.33
Sample 4	0.852	852	42,221.71

C. Experimental Setup

The investigation was carried out in Kirloskar TV I Engine. The eddy current dynamometer is coupled with the engine and is used to load the same. AVL smoke meter, AVL Di - gas analyzer and AVL combustion analyzer are connected with the engine suitably.

The engine was allowed to run using diesel at various percentages of loads (20%, 40%, 60%, 80% and maximum possible load). At each percentage of load readings related to fuel consumption, smoke density, CO, CO₂, O₂, HC, NO_x and EGT were recorded. The

same procedure is repeated with various blends of biodiesel (B25, B50, B75 & B100). With each blend the engine is run at various percentages of loads (20%, 40%, 60%, 80% and maximum possible load). At each load readings corresponding to performance, emission and combustion characteristics are recorded. The results of these experiments are analyzed and discussed.

Table.2: Specification of the test engine

Type	Vertical, Water cooled, Four stroke
Number of cylinder	One
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1
Maximum power	5.2 kW
Speed	1500 rev/min
Dynamometer	Eddy current
Injection timing	23 before TDC
Injection pressure	220kg/cm ²

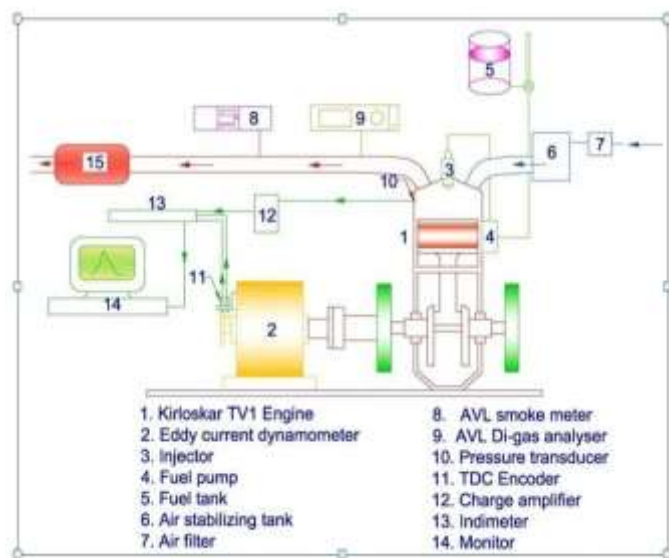


Fig.1: Experimental setup

III. RESULTS AND DISCUSSION

Engine performance with biodiesel or its blends with diesel fuel depends largely on the combustion, air turbulence, air-fuel mixture quality, injector pressure, actual start of combustion and many other singularities that make test results vary from one engine to another. In addition, it can vary depending on the quality and origin of biodiesel as well as engine operating parameters like speed, load, etc. Generally, the blend of non-edible biodiesel with mineral diesel can be applied directly to CI diesel engines. However, the effect of using this

biodiesel must be evaluated by determining engine power/torque, brake thermal efficiency, brake specific fuel consumption and emissions production. Extensive research has been conducted worldwide to utilize non-edible biodiesel as a possible fuel for use in a diesel engine. Series of experiments by using blended non-edible bio-diesel for compression ignition engines have focused on engine performances and emissions. This section reviews the effects of blending non-edible biodiesel on engine performance, emission and combustion characteristics in DI diesel engine.

The experiment is performed for Sapodilla seed oil biodiesel. The results of the experimental investigations carried out have been furnished hereunder for Jujube seed oil biodiesel.

A. Brake Thermal Efficiency

The effect of Biodiesel blend on brake thermal efficiency is shown in figure 1. It can be seen from the figure 3.1 that Brake thermal efficiency in general reduced with the increasing proportion of biodiesel in the test fuels. The brake thermal efficiency for B25, B50, B75 and B100 was less than that of sole fuel by about approximately 14% for B25, B50, B75 and 17.5% for B100 in the maximum load of 5.2 kW. This is due to the effect of biodiesel blend. This may also be due to the higher viscosity, density and lower heating value than the sole fuel. The higher viscosity leads to decreased atomization, fuel vaporization and combustion and hence the thermal efficiency of biodiesel is lower than that of the sole fuel. Fuel consumption increases due to higher density and low heating value consequently, thermal efficiency decreases. Whereas the thermal efficiency is higher in case of blend fuels as compared to pure biodiesel (B100).

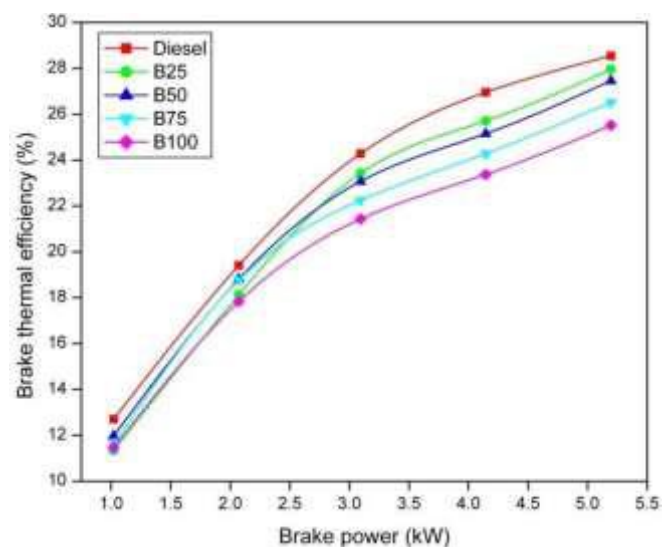


Fig.3.1: Brake Thermal Efficiency against Load

B. Exhaust Gas Temperature

The effect of biodiesel blend on exhaust gas temperature is shown in figure 3.2. It can be seen from the figure 3.2 that the exhaust gas temperature is reduced for the entire biodiesel blend with the increasing proportion of biodiesel in the test fuels. Due to the effect of biodiesel blend the minimum exhaust gas temperature is 180°C at 20% load for B75 which is minimum when compared to that of other samples.

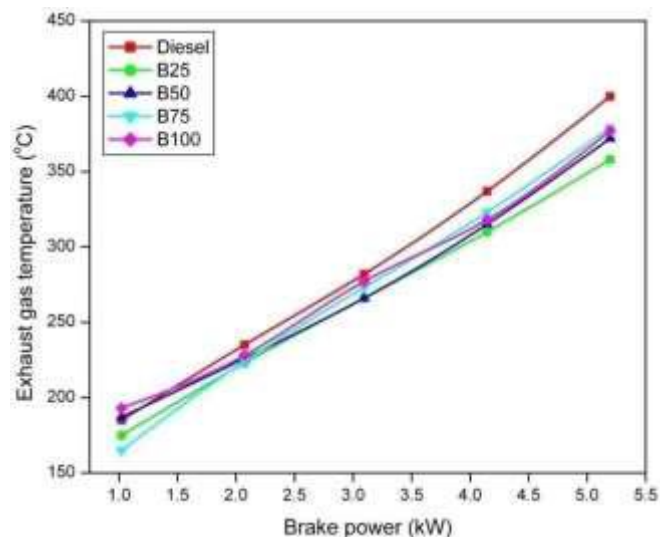


Fig.3.2: Exhaust Gas Temperature against Load

The reduction in temperature may be due to faster combustion rates of biodiesel blend. Due to the improvement in the diffusion combustion rate, late burning of biodiesel is reduced and thus results in a reduced exhaust gas temperature. Also biodiesel has high latent heat of vaporization property which cools the charges and thus reduced the peak combustion temperature. Hence lower exhaust gas temperature. Also, the presence of oxygen in the biodiesel decreases the heating value of biodiesel by 10% to 13% compared to the heating value of diesel fuel.

EMISSION CHARACTERISTICS

C. CO emission

The effect of the biodiesel blend on the CO emission is shown in figure 3.3 for the biodiesel and its blends, the CO emissions were less than that of sole fuel. The least CO emissions have been obtained for the B25 with the value of 0.05 % by volume at 40% load to be found approximately 12% for B25 and B50, 6% for B75 and 2% for B100 reductions in CO emissions. The reduction of CO is due to the oxygen content on the biodiesel.

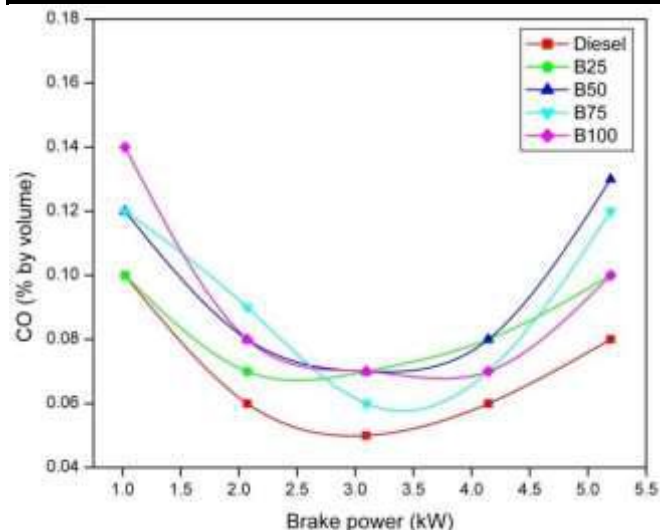


Fig 3.3: CO against brake power

In comparison with sole fuel, CO emissions showed a trend of decreasing with the increase in biodiesel blend ratios. CO emission decreased due to fuel properties of biodiesel such as higher oxygen content, which promote the complete combustion. The variation of CO emission at different loads is shown in Fig. At low and medium loads, CO emissions of the blends were not much different from those of sole fuel. However, at full load, CO emissions of the blends decreased significantly when compared with those of standard diesel. This can be explained by the enrichment of oxygen owing to the bio-diesel addition, in which an increase in the proportion of oxygen promotes further oxidation of CO during the engine exhaust process. There was a 30% reduction of CO emission for the B25 and B50 blend.

D. CO₂ emission

The effect of the biodiesel blend on the CO₂ emission is shown in figure 7.4 for the biodiesel and its blend, the CO₂ emission is where less up to 40% load after that the CO₂ emission is increased for all the biodiesel blends. The CO₂ emission is maximum for B100 at maximum load with a value of 7.1 % by volume. This is because of availability of excess oxygen for complete combustion of fuel and also the effect of the increasing in the Bio-diesel % it is observed that Emission increases gradually as the load increases for all the blended fuels. This is due to the effect of lower operating temperature with high latent heat of vaporization.

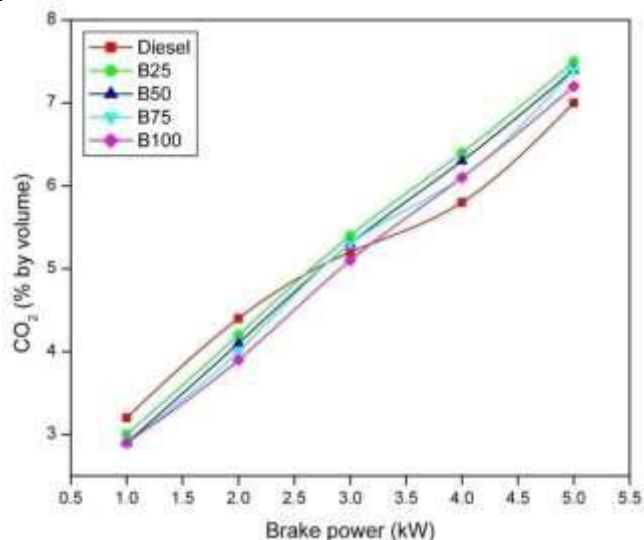


Fig.3.4: CO₂ against Load

E. HC Emissions

The effect of Biodiesel on hydrocarbon emission is shown in figure 3.5. It is observed that the HC emission is minimum for B100 with a value of 34 ppm at maximum load. The HC emission is lower when compared to that of the sole fuel for all the samples. There is marginal decrease of HC emission for all the samples. But for the B100 HC emission is decreased effectively when compared to other samples. The HC emission increases up to 60% and decrease after that. This may be due to the presences of higher amount of oxygen content in Bio-diesel with high latent heat of vaporization. For 100% Bio-diesel the HC emission level is less when compared to the sole fuel.

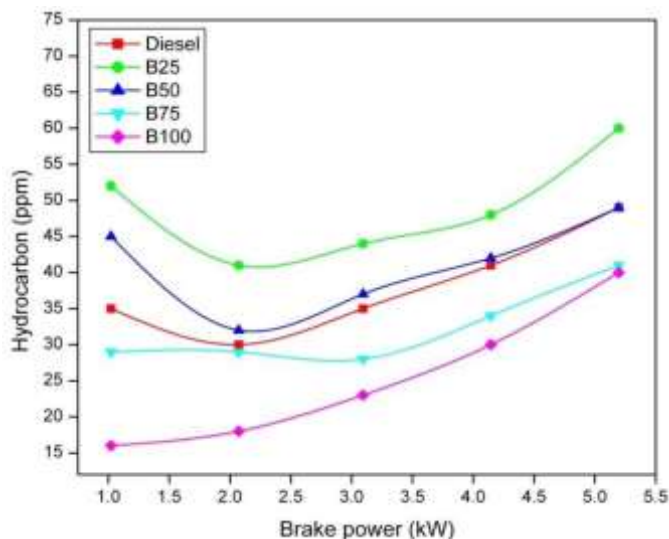


Fig.3.5: HC Emission against Load

F. NO_x Emission

The effect of biodiesel on NO_x emission is shown in figure 3.6. for the biodiesel and its blend the NO_x

emission where less than that of sole fuel. The NO_x emission is minimum for B100 with a value of 230 ppm at 20%. Similarly for B100 at maximum load is 10.2 ppm which is less when compared to all other samples at maximum load. This is due to the effect of oxygen content in the biodiesel. This is also due to high latent heat of vaporization and lower calorific value of the Bio-diesel blends, which reduces the in-cylinder temperature and thus reduces the No_x emission.

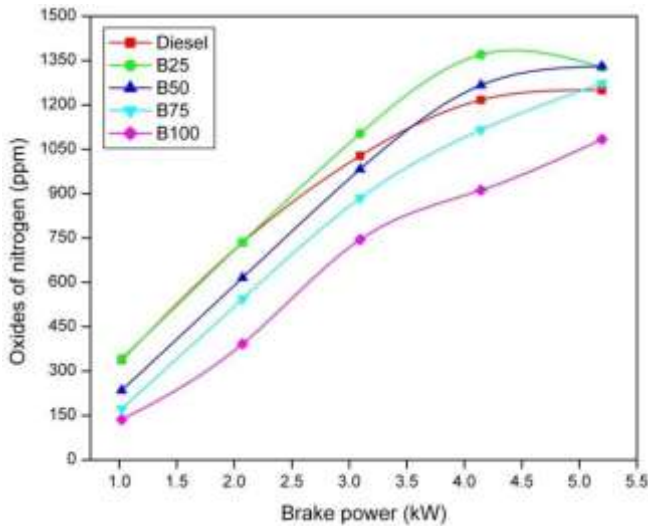


Fig.3.6: Nox Emission against Load

G. Smoke Density

The effect of biodiesel on smoke emission is shown in figure 3.7 for the biodiesel and its blends the smoke emission is higher when compared to the sole fuel. It is observed for all the samples the smoke emission is higher than that of sole fuel. The maximum smoke value is 94.1 HSU for B100 at maximum load.

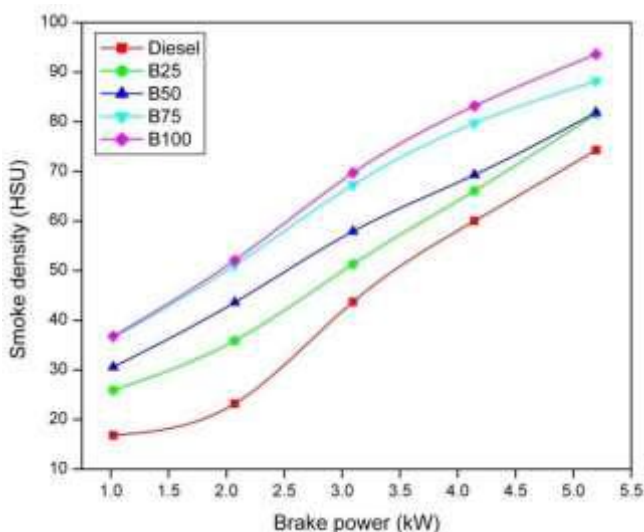


Fig.3.7: Smoke Density against Load

IV. COMBUSTION PARAMETERS

A. Cylinder Pressure

Fig 4.1 shows cylinder pressure for various values of crank angle. The peak pressure within the cylinder is 70.634 bar. The maximum peak pressure for B100. It is clear that the peak cylinder pressure is increased with the increase of engine load. The peak cylinder pressure does not vary significantly with the increase of engine speed. The combustion process of the test fuels is similar, consisting of a phase of premixed combustion following by a phase of diffusion combustion. At low engine load, only a small amount of fuel is burned and the fuel is burned mainly in the premixed burning phase. As the engine load decreases, the residual gas temperature and wall temperature decrease which leads to lower charge temperature at injection timing, and lengthens the ignition delay. Ignition delay represents the time taken in physical and chemical reactions and does not change much on a time scale of milliseconds. However, it will increase in terms of crank angle degrees with engine speed increase as a high engine speed will correspond to a larger crank angle for the same time duration. Fig

4.1 show the pressure rise rate of the tested fuels at different engine operating conditions. It is clear that the peak of pressure rise rate increases with the increase of engine load, and does not vary significantly with the increase of engine speed.

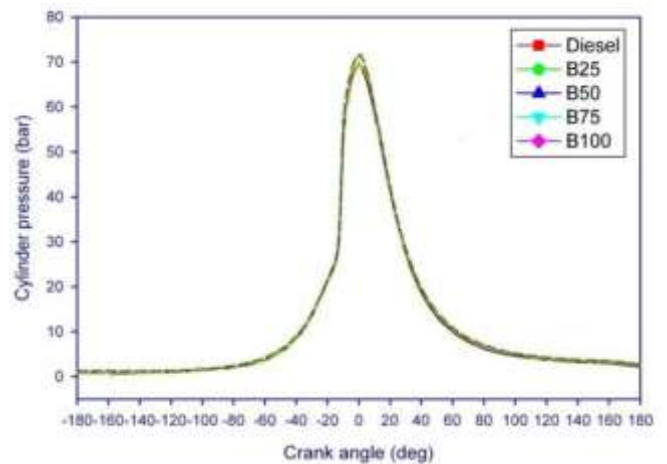


Fig.4.1: Cylinder Pressure against Crank angle

B. Heat Release Rate

Fig 4.2. Shows heat release rate for various values of crank angle. The heat release rate of conventional combustion chamber is higher than that sole fuel. The maximum heat release rate is 148.093 kJ/m³deg for B75. The variation of heat release rate at different engine operating conditions is shown in Fig

4.2. Because of the evaporation of the fuel accumulated during ignition delay period, at the beginning a negative heat release rate is observed.

After combustion is initiated, this becomes positive. After the ignition delay, premixed fuel-air mixture burns rapidly, followed by diffusion combustion, where the burn rate is controlled by fuel-air mixing velocity. At high engine load, the peak of heat release rates of B75 are evidently higher than that of other and the crank angle of the peak of heat release rate is almost the same. The reason may be that the premixed burning heat release is higher for B75.

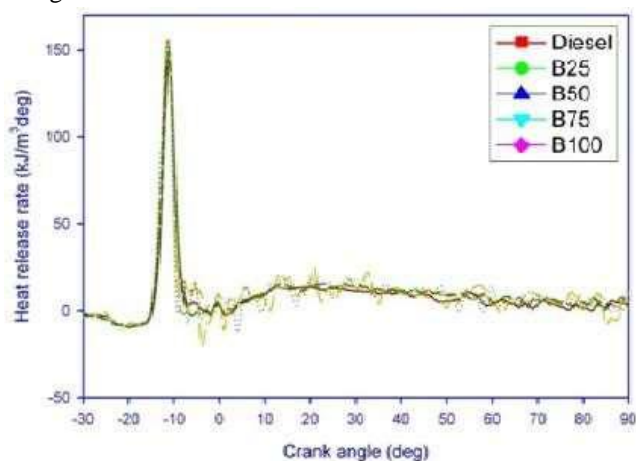


Fig.4.2: Heat release rate against Crank angle

V. CONCLUSION

Bio-diesel has attracted much research because of its economic and environmental benefits as well as its renewable origin. Bio-diesel produced from non-edible oil resources can defy the use of edible oil for Bio-diesel production. Therefore, its demand is growing steadily, and researchers are looking for possible newer sources of non-edible oil. This review concludes that non-edible oil is a promising source that can sustain Bio-diesel growth.

From the study this is deduced that

- The brake thermal efficiency is marginally decreased for the biodiesel and its blend.
 - The exhaust gas temperature is lower for SP 75 is 160C
 - The emission analysis for the biodiesel and its blend gave the best result when compared to the sole fuel.
 - The CO emission is reduced by 0.32% by volume at 100% of load for SP 100.
 - The CO₂ emission is decreased by 5.6% by volume at 100% of load for SP 100.
 - The HC emission is reduced by 83 ppm at 100% of load for SP 100.
 - The O₂ emission is increased by 13.05% by volume at 100% of load for SP 100.
 - The NO_x emission is reduced by 936 ppm at 100% of load for SP 100.
 - Smoke density is increased by 92.8 HSU at 100% of load for SP 100.
4. The combustion parameters for the biodiesel and its blends gave the best result.
- The maximum cylinder pressure is 73.38 bar for SP 100.
 - The maximum heat release rate is 176.517 kJ/m³deg for SP 100.
 - The peak cylinder pressure is 75.896 bar for SP 100 at 74th cycles.

REFERENCES

- A.M. Ashraful, H.H.Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, S.A. Shahir, H.M. Mobarak, "Production and comparison of fuel properties, engine performance, and emission characteristic of biodiesel from various non-edible vegetable oils", *Energy Conversion and Management* 80 (2014) PP202 – 228
2. Steven Lim, Keat Teong Lee "Process intensification biodiesel production from jatropha curcas L.seeds: Supercritical reactive extraction process parameters study" *Applied Energy* 103 (2013) pp712 – 720
- Yixin Zhu ^{a,b}, Jianchu Xu ^{a,b}, Qiaohong Li ^{a,b}, Peter E.Mortimer ^{a,b} "Investigation of rubber seed yield in Xishuangbanna and estimation of rubber seed oil based biodiesel potential in southeast Asia" *Energy* 69 (2014) pp 837 – 842
- Fang-Xia Yang^a, Yin-Quan su^a, Xiu-Hong Li^a, Qiang Zhang^a, Run-Cang Sun^{b,c*} "Preparation of biodiesel from Idesia Polycarpavar. Vestita fruit oil" *Industrial Crops and Products* 29 (2009) pp622 – 628
- R.Sathish Kumar^a, K.Suresh kumar^a, R.Velraj^b "optimization of biodiesel production from Manilara Zapota (L.) Seed oil using Taguchi method" *Fuel* 140(2015) PP90
- Jibrail Kansedo, Keat Teong Lee^{*}, Subhash Bhatia "Cerbera odollam (sea mango) oil as a promising non-edible feedstock for biodiesel production." *Fuel* 88(2009) pp1148 – 1150.
- Mortadha A. Ali^{1,*}, Tahseen A. Al-Hattab¹, Imad A. Al-Hydary² "Extraction of Date Palm seed oil (Phoenix Dactylifera) By Soxhlet Apparatus."

- International Journal of Advances in Engineering & Technology, June 2015 ISSN 223311963
- [8] Ogunsuyi H.O, “Acid and Base Catalysed Transesterification of Mango (*Mangifera Indica*) Seed Oil to Biodiesel” *IOSR Journal of Applied Chemistry (IOSR-JAC) Volume 2, Issue 2 (Sep-Oct. 2012), PP 18-22.*
- [9] Yathish. K.V, “Biodiesel Production From Custard Apple Seed (*Annona Squamosa*) Oil And Its Characteristics Study” *International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 5(May –2013).*
- [10] Nakorn Tippayawong and Phichet Chumjai, “Characterization and Performance of Biofuel from Passion Fruit Processing Residues” *Proceedings of the World Congress on Engineering and Computer Science 2012 Vol II WCECS 2012, October 24-26, 2012, San Francisco, USA.*
- [11] Singh.R.N, “SPRERI experience on holistic approach to utilize all parts of *Jatropha curcas* fruit for energy” *hermochemical Conversion Division, Sardar Patel Renewable Energy Research Institute, Vallabh Vidyanagar 388*
- [12] Gujarat, India Received 1 February 2007; accepted 21 October 2007 Available online 20 February 2008, PP 1868–1873 .
- [13] Silitonga.A.S ,“Experimental study on performance and exhaust emissions of a diesel engine fuelled with *Ceiba pentandra* biodiesel blends” *Volume 76, December 2013, PP 828–836.*
- [14] Orkun Ozener ,“Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics” *Volume 115, January 2014, PP 875–883.*