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Experimental Evaluation of Emission Characteristics of CIDI Engine Fuelled with Jatropha Curcas Oil Methyl Easter

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Abstract
In the last few decades, the search for renewable energy sources is getting indispensable and imperative for many countries across the globe in order to meet the current and future energy demand as well as to reduce the air pollution. The past research results revealed that non-edible oils are emerging as the prospective substitute to edible oils for biodiesel production as alternative renewable energy source, because edible oils are impacting on the food security. The aim of the present paper is to evaluate the emission characteristics of diesel engine fuelled with Jatropha curcas oil methyl ester (JCOME). The experimental results of single cylinder, 4-stroke, water cooled, compressive injection direct injection engine fuelled with JCOME and different blends (BJ20, BJ40, BJ60 and BJ100) of JCOME were shown that neat JCOME bio-diesel has lower CO emission, lower smoke density, lower particulate matter, and relatively higher NOx emission when compared with neat diesel fuel.

Keywords
Biodiesel, Emission Characteristics, Methyl Ester, Vegetable oils, Non-edible Oils, Transesterification

I. Introduction
Ever increasing global energy consumption in various forms for various purposes, many countries have focused their research for alternative energy sources to meet their present and future energy demand. In developing countries like India, the fuel has assumed serious economic consequences in the forms of budget deficits caused by oil imports and ecological degradation caused by pollution. Production of plant-based biodiesels not only helps to enrich the economy and employment at rural areas but also reduces the environmental pollution.

Use of vegetable oil as an engine fuel in diesel engine dates back to 1900 when Rudolph diesel, the inventor of compression ignition engine. He first used peanut oil as engine fuel at the world exhibition in Paris. Those days, the fossil fuel was abundantly available fuel for cheaper price. After 1974, due to energy crisis, many researchers such as Bruwer et al. have started to focus their attention on biodiesels that are made from vegetable oils and his team has performed experiments using sunflower oil as biodiesel [1,2] which is the beginning of the reconsidering the vegetable oils as biodiesel after World War-II. Schlick et al. have conducted experiments to evaluate the performance of a direct injection 2.59 L, three cylinder, 2600 series Ford diesel engine operating on mechanically expelled-unrefined soybean oil and sunflower oil blended with no:2 diesel fuel on a 25:75 v/v basis and observed that the power persistently constant throughout 200 h of operation [3]. Rakopoulos et al. have carried-out an extended experimental study to evaluate and compare the use of various vegetable oils such as soybean oil, rapeseed oil, cotton seed oil, sunflower oil, palm oil, corn oil and olive kernel oil and their corresponding methyl esters at blend ratios of 10/90 and 20/80, in a standard, 4-stroke, direct injection diesel engine. The tests were conducted at two different engine speeds and three different loads and revealed that the vegetable oil blends show reduction of emitted smoke combined with slight increase in NOx with no influence on the thermal efficiency [4]. G. Lakshmi Narayana Rao et al. studied the combustion and emission characteristics of diesel engine fuelled with Rice Bran oil methyl ester (RBME) and its diesel blends. The ignition delay and its peak heat release for RBME and its diesel blends were found to be lower than that of diesel and the ignition delay decreases with increase in RBME in the blend. Maximum heat release was found to occur earlier for RBME and its diesel blends than diesel. It was also observed that, as the amount of RBME in the blend increases the HC, CO and soot concentrations in the exhaust decreased when compared to mineral diesel. The NOx emissions of the RBME and its diesel blends were slightly higher than diesel [5].

Usage of edible oils especially in over population countries such as India and china is not advisable and preferable, because it is impacting on food security. Moreover, the non-edible oil plants can be grown in the dry, infertile lands with low rain fall. Biodiesels are biodegradable, non-toxic and emits very less emission when compared with conventional fuels. Vallinayagam et al., were studied the combustion performance and emission characteristics using pine oil in a diesel engine and revealed at full load condition, 100% pine oil has very less carbon monoxide, hydrocarbon and smoke emissions. The brake thermal efficiency and maximum heat release rate increase by 5% and 27%, respectively. However, the oxide of nitrogen emission is higher than that of diesel fuel at full load condition. The experimental work reveals that 100% pine oil can be directly used in diesel engine and potential benefits of pine oil biofuel have been reaped. [7]. S.R. Kalbande et al. prepared the Karanja bio-diesel using alkali catalyzed transesterification and utilized it in diesel engine generator for power production. The generator was operating very smoothly without any noise and knocking on pure bio-diesel and its blends. It was observed that the overall efficiency of B20 and B100 blend proportions were found more than other blending proportions. The engine was run more efficiently on B20 and B100 fuel proportions for the production of 6000 watt electricity [8]. The past research reviews revealed that karanja, jatropha, rubber, neem, pongamia and simarouba are most widely available in biodiesel production in India [6]. Azam et al. were evaluated 75 non-edible oils as a source of biodiesel and identified Jatropha curcas as one of the most promising plants [9]. Jatropha Curcas plants are drought resistant, perennial plant that can grow under hostile conditions in unfertile non-agriculture lands and has drawn attention across the developing world, especially in India, as a feed stock for biodiesel production [10].

Even though, vegetable oils of commercial and non commercial have almost similar chemical properties as petro-diesels, but they have significantly higher viscosities and moderately higher densities, lower heating values, rise in stoichiometric air/fuel ratio and the possibility of thermal cracking at the temperatures encountered by the fuel spray in naturally aspirated diesel engines [11]. These differences contribute in poor atomization, choking tendency, carbon deposits, heavy smoke emissions and wear that were generally encountered and which adversely affect the durability of the engine. These problems have been mitigated by developing vegetable oil derivatives that approximate the properties and performance and make them compatible with the hydrocarbon based diesel fuels through Pyrolysis, Micro-emulsification, Dilution and Transesterification [12]. The present work used transesterification method to prepare biodiesel from Jatropha Curcas oil.

II. Materials and Methods

The principal source of Jatropha oil is seeds of Jatropha curcas. The collected seeds of Jatropha plant were dried with natural sun heat for few days and then oil was extracted by using oil expeller. The crude Jatropha Curcas oil will have higher viscosity and density which creates problems to the engine and for the present work, transesterification process was used to prepare Jatropha Curcus Oil Methyl Ester (JCOME). In the trans-esterification process, the carbonyl carbon of the starting ester (RCOOR) undergoes nucleophilic attack by the arriving alkoxide (R2O−) to give a tetrahedral intermediate, which either reverts to the starting material, or proceeds to the transesterified product (RCOOR2). The various species exist in equilibrium, and the product distribution depends on the relative energies of the reactant and product.

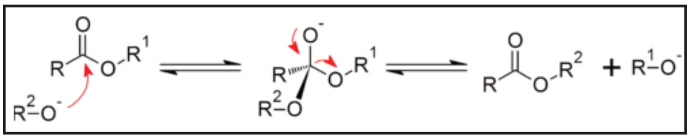

Fig. 1: Transesterification Process

III. Experimental Setup

For the present experimental study, a single cylinder, 4-stroke, water cooled compression ignition direct injection (CIDI) engine was used. The experiment setup is illustrated as schematic diagram below at fig. 2. It consists of 3.7 KW Kirloskar Type 1 engine, eddy current dynamo-meter, smoke meter and exhaust gas analyzer.

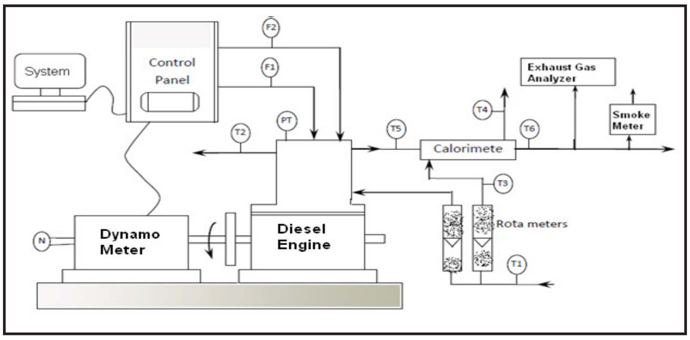

Fig. 2: Experimental Setup

The specifications of the engine are given below in table 1.

Table 1: Engine Specifications

Type	Kirloskar
Details	Single cylinder, Direct injection, 4-Stroke, Water cooled engine
Bore & Stroke	87.5 × 110 mm
Rated Power	3.7 KW at 1500 rpm
Compression Ratio	17.5 :1
Speed	1500 rpm

IV. Test Results and Discussions

A. CO Emission

Fig. 3 shows the variation of carbon monoxide emission with brake power. The CO emissions of different blends of JCOME (BJ20, BJ40, BJ60 and BJ100) are much lower than the neat diesel fuel and neat JCOME (BJ100) has the lowest CO emission for each load condition. CO emission is decreased with the increase of percentage of JCOME blend. It was observed that CO emission from neat JCOME is less than the emission of neat diesel and for every 20% addition of JCOME in the blend, the CO emission is reduced by an average of 20%. As load increases, the CO emission is also increased. The lower CO emission at low and medium loads and significantly higher CO emission at high load conditions was observed with all fuel modes.

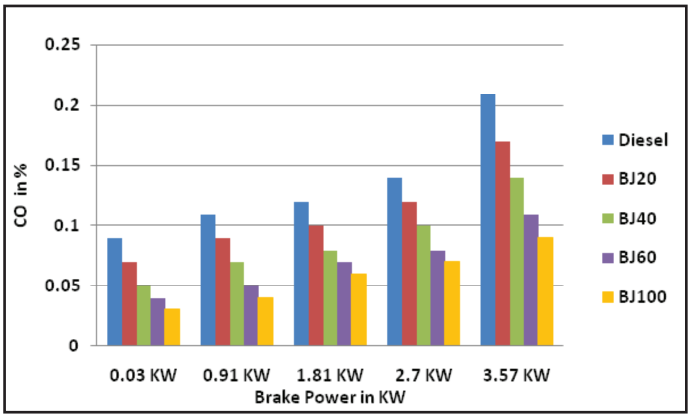

Fig. 3: Brake Power vs. CO Emission

As shown in fig. 4, the graph is clearly revealing that the BJ100 has very low CO emission among all the blends and diesel and diesel has highest among all the JCOME blends.

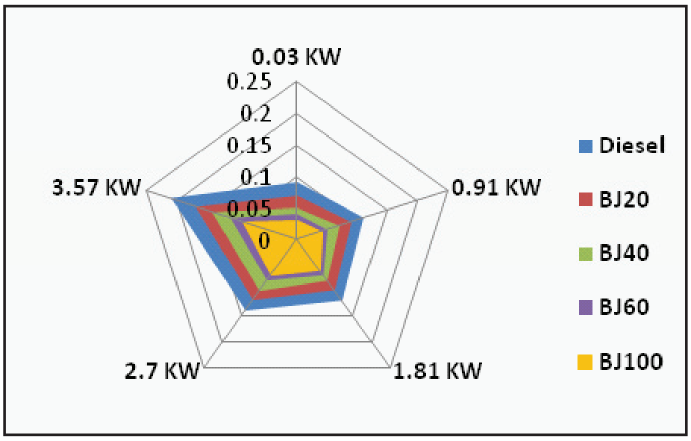

Fig. 4: Brake Power and CO Emission

B. Smoke Density

Variations of smoke density with brake power for diesel and various blends of JCOME at constant speed of the engine are depicted in fig. 5. It is observed that smoke density is increasing with the increasing of brake power for all blends and decreasing with the increase of percentage of JCOME. The smoke density has decreased an average of 26% of neat JCOME when compared with neat diesel and reduced by approximately 8% for every 20% addition of JCOME biodiesel.

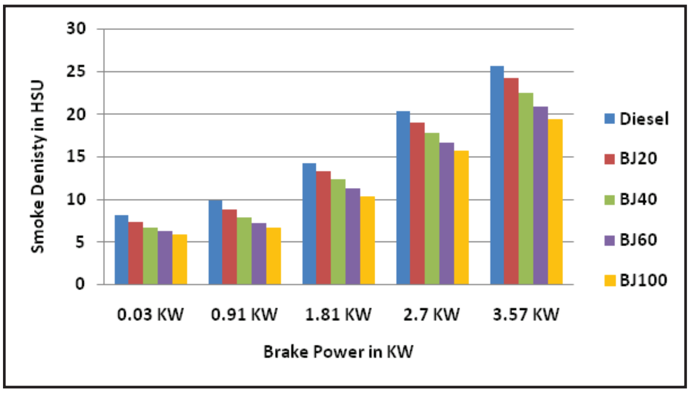

Fig. 5: Brake Power Vs Smoke Density

The graph shown in fig. 6 is prominently showing that the BJ100 has very less smoke density and diesel has highest among all the JCOME blends.

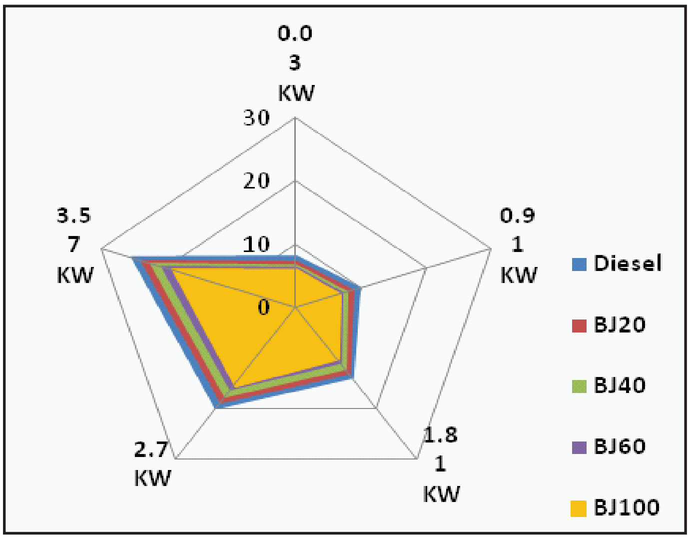

Fig. 6: Brake Power and Smoke Density

C. Particulate Matter

The variations of Particulate Matter (PM) with brake power for diesel and blends of JCOME are shown in figure 7 for constant speed of diesel engine. The particulate matter is increasing with the increasing of load for diesel and all blends but decreasing with the increasing of percentage of JCOME blend. It was observed that the particulate matter is decreasing by about an average of 15% of neat JCOME when compared with neat Diesel and reduced by around 5% for every 20% addition of blend JCOME in biodiesel. It was also observed that the lower particulate matter at low and medium loads and considerably higher particulate matter at high load conditions was observed with all fuel modes.

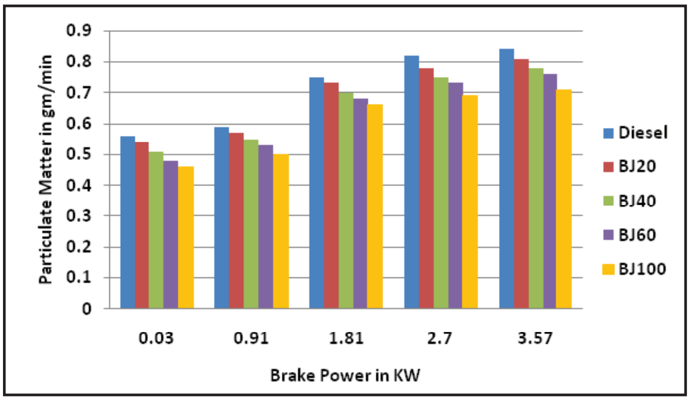

Fig. 7: Brake Power Vs Particulate Matter

As shown in Fig. 8, the radar graph is establishing that the neat JCOME has very low particulate matter (PM) and neat diesel has highest PM among all the JCOME blends and diesel.

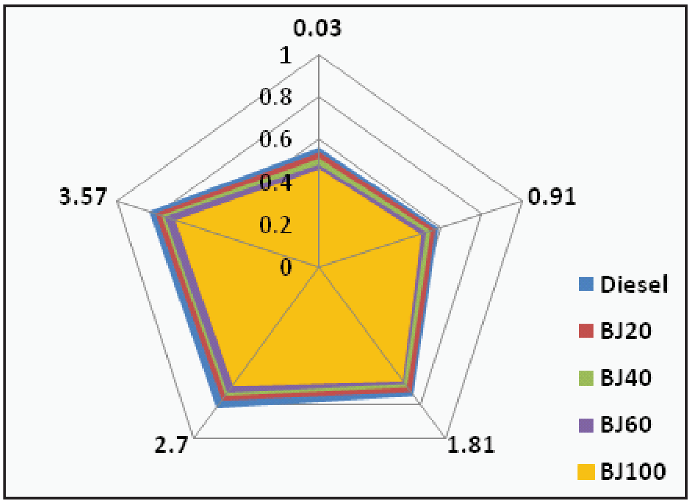

Fig. 8: Brake Power and Particulate Matter

D. Oxides of Nitrogen (NOx) Emission

Fig. 9 illustrates oxides of nitrogen emission (NOx) variations with brake power for diesel, various percentages of JCOME blends at constant speed of the diesel engine. Unlike other emissions, it is observed that NOx emission is increasing with the increasing of load for all fuels at constant engine speed and increasing with the increasing of percentage of JCOME. At part load conditions the variation of NOx emission of biodiesel and diesel are slightly discernible, but at medium and full load conditions NOx emission of JCOME are significantly distinct and neat JCOME has higher values than diesel and their other blends. The NOx emission has decreased by an average of 24% of neat JCOME biodiesel when compared with diesel and increased by an average of 7-8% for every 20% addition of JCOME blend in the biodiesel.

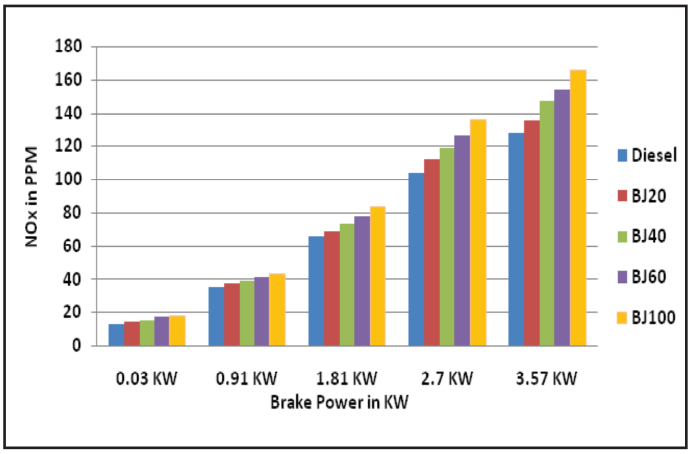

Fig. 9: Brake Power Vs NOx Emission

The radar graph shown in fig. 10 is revealing that the BJ100 has very high NOx emission and diesel has lowest among all the JCOME blends. BF20 has the lowest NOx emission among all the JCOME blends.

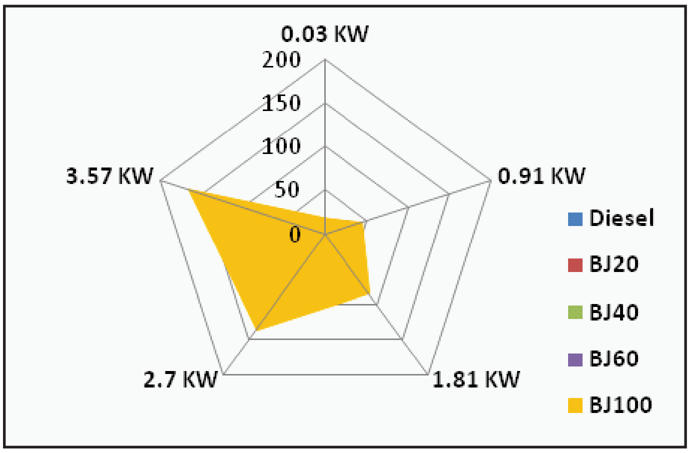

Fig. 10: Brake Power and NOx Emission

V. Conclusion

The experimental results of single cylinder, 4-stroke, water cooled, direct injection compressive injection engine fuelled with JCOME and different blends (BJ20, BFJ0, BJ60 and BJ100) of JCOME are prominently confirming that biodiesel made with Jatropha Curcas oil has low emission characteristics except NOx than that of neat diesel. It is also endorsing that JCOME can be used as biodiesel as a partially/fully substitute of diesel and can be avoided the usage of edible oils such as sunflower oil, palm oil and other edible oils in biodiesel production in order to avoid food security. JCOME biodiesel has lower CO emission, lower smoke density, lower particulate matter and higher NOx emission characteristics when compared to neat diesel.

Biodiesel that are made with methyl esters are oxygenated fuel and it promotes the better combustion that causes less CO emission and reduction in particulate matter. The formation of smoke is primarily resulted from the incomplete burning of the hydrocarbon fuel and partially reacted carbon content in the liquid fuel. The smoke density of JCOME biodiesel is less because of improved combustion characteristics of biodiesel. Methyl esters with their lower stoichiometric air-fuel ratio relative to diesel can burn with less air requirement for combustion. This causes rise in NOx emission and increases with increase in percentage of methyl esters in the JCOME blends.

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