Experimental Investigation on Performance, combustion and Emission Characteristics of CI Engine Fuelled with Pumpkin and Maize Biodiesel blends.

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ABSTRACT

The most promising renewable, alternative and environmental friendly liquid fuel is biodiesel. An experimental investigation has been carried out to investigate the performance and emission characteristics of a CI engine without any engine modification fuelled with pumpkin and maize biodiesel with various percentages of blends. The present work investigates the biodiesel obtained from transesterification process of Pumpkin and Maize is used as an alternative fuel to diesel. The performance, combustion and emission test using Pumpkin-Maize (PM) biodiesel and their blends (10%, 20%, 30%, 40% and 50%) with diesel were carried out at variable loads conditions. The research comprises of the performance, combustion characteristics such as brake thermal efficiency, brake specific fuel consumption and emission characteristics such as Carbon monoxide (CO), Carbon dioxide (CO2), Hydro carbon (HC), Nitrogen oxide (NO) and smoke opacity were determined. Also the recent research notifies the engine running with biodiesel exhibit NO emission in higher concentrations. The results concluded that for B30 blend, an increase of 13.75% in brake thermal efficiency of the engine was observed at 80% load respectively. A decrement of brake specific fuel consumption has been observed, especially at higher loads for B30 by 11% respectively. The CO emissions increased by 27.3% and HC emissions increased by 27.2% for B30 blend at maximum loads whereas Smoke opacity decreased by 1.88% and NO emission decreased by 26.9% emissions were observed with respect to diesel fuel. Finally the research highlights the production of PM biodiesel fuel with proper proportion in order to achieve better engine performances and emission characteristics.

Keywords: Pumpkin-Maize biodiesel, Combustion, performance, emission, five gas analyser.
1. INTRODUCTION

The energy crisis has provoked the whole world due to the depletion of fossil fuels in rapid condition and environmental destruction. Fuel is an essential in day today life, and also it creates the atmospheric pollution substantially [1]. The potentiality of the biodiesel as an alternative fuel was carried out in boilers and diesel engines. The work emphasis fuel consumption, emission and environmental related issues to study the net energy requirement related to land availability and conservation [2]. Most of the studies report the fuel consumption and thermal efficiency; many authors derived their results in increasing fuel consumption in particular proportion to the loss of heating value. The particle emission is concentrated much and found to be very fewer people were studied the parameter [3]. The diesel ethanol blends with cetane number used to study the engine combustion and emission characteristics, reveals that whenever the ethanol fraction increases the ignition delay increases to decrease the cetane number of the blend also the diesel equivalent brake-specific fuel consumption decreases [4]. The preheated Karanja oil and its blends improve the engine efficiency. The blends of lower proportion of karanja oil improve the brake specific energy consumption and brake specific fuel consumption, were found to be comparable [5]. The production of bio-oil using the non-edible jatropha, karanja and polanga oil based methyl esters blended with conventional diesel in a water-cooled three cylinder engine. The research reveals that 50% of the jatropha bio-oil increases the power was observed provided that reduction in smoke during full throttle performance [6]. The diesel engine fuelled with diesel with dimethoxymethane blends for dimethoxymethane volume fractions (0-50%) and the influence of the dimethoxymethane and oxygen fractions on engine performance, combustion and emission parameters over a varying range of DMM fractions. Due to increase in oxygen fraction the engine thermal efficiency increases and the brake specific fuel consumption decreases was observed [7]. The CI engine performance in evaluating the properties of bio-diesel ethanol blends and comparison with the classical diesel fuel represents the inference of performance, emission at different loading conditions. The conclusions have resulted that CO emission decreases significantly due to increase in CO₂ emission, NOx emission increases especially at medium and high loads and with maximum proportion of ethanol and bio-oil blends increases the HC, CO emissions as well as NOx emission [8,9]. The investigation and effects of water injection on the engine performance and emission running with bio-oil and its blends were studied and results that water injection at intake does not show any significance change in BSFC and thermal efficiency at higher loads also the NOx emission up to 50% and 40% of CO emission increases [10]. The performance of dual fuel diesel engine with non-edible jatropha bio-oil was investigated to measure the parameters like brake thermal efficiency, brake specific fuel consumption and power output. The results shows that a good substitute to diesel fuel in diesel engine in the near future as far as decentralized energy production was concerned [11]. The bio-oil corn stalk produced through a fast pyrolysis process contains water and oxygenated organics. The suitable and stable emulsions of bio-oils by mass fractions were prepared using ultrasonic emulsification to determine the optimum hydrophilic and lipophilic balance value. The results yield the reliable operation and no
trace of corrosion [12]. The waste cooking oil (WCO) used as a fuel in a diesel engine to investigate the performance based on the parameters like energy consumption, smoke, carbon monoxide, unburned hydrocarbons and NOx emission were evaluated. WCO emulsion showed increased cylinder peak pressure and ignition delay in the normal engine [13]. The investigation on diesel-ethanol-bio-oil blends were extended to the greatest possible degree. The increase in ethanol percentage in pilot fuel showed remarkable change and hence the percentage improvement shows a further improvement. The outcomes of the work reports that the pilot operation of the D45E15B40 and D30E20B50 blends is found to be beneficial in improving engine performance as it improves the brake thermal efficiency [14]. The effect of fuel properties of acid treated JME-WPO emulsion prepared using mixed surfactants are found more stable. The brake thermal efficiencies of emulsions are higher, BSHC are reduced [15]. In emulsion preparation, fuel property, combustion and emissions the contribution of water concentration plays a vital role. The emulsified fuel has lower calorific value; the ignition delay and heat sink effect have major drawbacks. The brake power and torque are reduced in case of emulsified fuel [16]. The study of thermal and oxidative behaviour of glycerol diesel hybrid fuel system on both kinetic analyses of pyrolysis and combustion reactions shows that micro emulsification may be more preferable for glycerol [17]. The bio-oil derived from transesterification of Jatropha seed and Fish wastes used for the investigation of performance, combustion and emission test on stationary single cylinder diesel engines. The outcome suggests that the brake thermal efficiency slightly lowered than the conventional diesel, the efficiency compared to FOME the JOME is better at all loads provided that HC, CO and PM emissions were lowered [18]. A study examines the utilizing cerium oxide nano particle mixed with an emulsion of nerium oleander bio-fuel on a compression ignition direct injection diesel engine. The deliverables from the study recommends the brake thermal efficiency and brake specific fuel consumption were found to be enhanced and a reduced NOx emission and smoke opacity emission [19]. The goal of the experimentation is to analyse the regular characteristics of performance and emission enriched with hydroxyl gas with varying EGR rates on comparison with neat diesel was done. The results reveal the BTE is increased at no load condition and further more improvement in full load condition [20]. The investigation on CI engine for different concentrations of Calophyllum Inophyllum and diethyl ether in diesel was monitored and the conclusion depicts that the fuel have lower BTE compare to pure diesel, a moderate hike in BSFC and BSEC and with emission in a reduced rate [21, 22]. The corn feed stock bio-oil preparation results a comparable performance and emission characteristics when compared with diesel was investigated and produce a promising outcomes for the bio-diesel [23]. Investigation on a common rail diesel injection engine was conducted using tallow bio-diesel. The deliverables form the investigation clearly denotes that the engine performance improved with the increase in fuel injection also emission found increased at the higher injection pressures [24, 25]. Diethyl-ether as additive added to the pumpkin and juliflora seed biodiesel to produce alternative fuel and with different concentrations of blends were investigated. The results show that, the BTE as in increasing pattern and BSFC in decreasing pattern, the B20 blend exhibit the good results with the emission parameters [26].
In this present work, experiments were carried out to study the combustion performance and emission characteristics of a CI engine test with PM Biodiesel blends and compared with diesel. The experimental results showed that the PM Biodiesel blend can be used as a partial replacement for diesel to reduce dependence on petroleum-based diesel fuel.

2. EXPERIMENTAL SETUP & TEST PROCEDURE

In this study the performance and emission characteristics of a CI engine, running with biodiesel, without additive have been investigated using a single cylinder, 4 strokes, water cooled and constant speed CI engine running at 1500rpm. The compression ratio of the engine is 17.5:1 with a maximum power output of 5.2kW. The load cell connected with an eddy current dynamometer supplies the load to run the motor. A data acquisition system used to monitor the engine performance. The brake specific fuel consumption is measured using a solenoid controller. The steady air flow through the intake manifold system was confirmed by employing a surge tank to measure pulsation impact from the engine. The fly wheel speed was measured using a non-contact sensor mounted on the engine. The combustion characteristics such as pressure, heat transfer rate and ignition delay are monitored by using data prediction software. The schematic representation of engine setup was shown in Figure 1. The specification of exhaust emission measuring equipment was represented in table 1. The detailed specifications of the engine were represented in Table 2.

![Schematic layout of the experimental setup](image)

**Table 1 Specification of Exhaust Emission Measuring Equipment**

<table>
<thead>
<tr>
<th>Equipment Name</th>
<th>Model</th>
<th>Measurement Range</th>
</tr>
</thead>
</table>
| Exhaust gas analyzer    | AVL 444 di-gas analyzer | CO,HC,NO,CO$_2$  
                          |                     | CO : 0-10 (% Volume), HC : (0-20000 ppm),  
                          |                     | CO$_2$ : 0-10 (% Volume), NO : (0-5000 ppm) |
| Smoke meter             | AVL 437C smoke meter | Smoke density  
                          |                     | 0-100 (Opacity in %) |
Table 2. Specification of the engine

<table>
<thead>
<tr>
<th>Engine</th>
<th>Kirloskar TV1, single cylinder, four stroke, water cooled, constant speed diesel engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Power</td>
<td>5.2 kW</td>
</tr>
<tr>
<td>Speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Bore</td>
<td>87.5 mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>110 mm</td>
</tr>
<tr>
<td>Dynamometer Arm Length</td>
<td>185 mm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>17.5:1</td>
</tr>
<tr>
<td>Cylinder Volume</td>
<td>0.661 litre</td>
</tr>
<tr>
<td>Intake valve opens</td>
<td>4.5° BTDC</td>
</tr>
<tr>
<td>Intake valve closes</td>
<td>35.5° ABDC</td>
</tr>
<tr>
<td>Exhaust valve opens</td>
<td>35.5° BBDC</td>
</tr>
<tr>
<td>Exhaust valve closes</td>
<td>4.5° ATDC</td>
</tr>
<tr>
<td>Original fuel injection</td>
<td>18° BTDC</td>
</tr>
</tbody>
</table>

3. RESULT & DISCUSSION

3.1 Performance parameter

3.1.1 Brake Thermal Efficiency

It is evident from Figure 2 that the relation between brake thermal efficiency (BTE) and load was graphed to depict the overall blends of BTE characteristics of PM Biodiesel blends, and diesel are almost similar in nature. From Figure 2, it was observed that the BTE was increased with the increase in load for all fuel samples. Due to low heat losses at higher loads, the brake thermal efficiency got increased with respect to load. The overall entire load range, the BTE was decreased with the increase in blend ratio. At maximum load (100%) the BTE was observed to be 28.87% for diesel, and increased by 30.16%, 29.2%, 30.4, 30.65% and 32.22% for B10, B20, B30, B40 and B50 respectively.

Figure 2, BTE vs. Load Variations to the Biodiesel Blend
This higher BTE of PM Biodiesel operation is due to the combined effect of slightly higher viscosity, higher density and nearly equal calorific value of the prepared biodiesel. At low loads, the rate of increase in BTE was low when compared with that at higher load ranges, this was due to the reduction in in-cylinder temperature and quenching effect by latent heat of the bio-diesel at higher load ranges.

### 3.1.2 Brake Specific Fuel consumption

![Graph showing Brake specific fuel consumption vs Load](image)

**Figure 3, Brake specific fuel consumption vs Load**

The relation between brake specific fuel consumption and load variation were represented in Figure 3. The inference from the Figure 3 denotes that for all fuels, the BSFC was getting decreased with respect to load variation. The percentage increase in biodiesel slightly decreases the BSFC. At maximum load (100%) the BSFC was observed to be 0.297 kg/kW-hr for diesel, 0.286 kg/kW-hr for B10, 0.297 kg/kW-hr for B20, 0.287 kg/kW-hr for B30, 0.286 kg/kW-hr for B40 and 0.274 kg/kW-hr for B50 respectively. The change in viscosity and decrease in volatility due to the addition of PM Biodiesel with diesel resulted in the poor spray pattern and non-homogeneous fuel distribution which in turn caused the improper combustion.

### 3.2 Combustion parameters

#### 3.2.1 Heat Release Rate (HRR)

The heat release rate (HRR) for diesel and for biodiesel bends, at 50% load on the engine, between the crank angle variation of $-30^\circ$ and $90^\circ$. A premixed combustion phase followed by a diffusion combustion phase has a comparable shape for heat release characteristics. The lower HRR caused due to air-fuel mixture preparation, which interns increases ignition delay period. Increase in viscosity and decrease in volatility predominantly affect the reduction in cetane number at higher blend ratios. The latent heat and low cetane number of the investigated biodiesel results the quenching effect in engine, the quenching affect cylinder temperature and results in delayed HRR. Figure 4 (a) & (b) represents the HRR vs Crank angle for 50% load and 100% load.
3.2.2 Ignition Delay (ID)

The length in between the beginning of the fuel spray injection and combustion as far as degree crank angle is meant to be ignition delay. The factors influences the delay period were cylinder pressure and cetane index was consider as fundamental factors. The variety of ignition delay with brake mean effective pressure for all fuel samples was monitored. Ignition delay of diesel sprays is a strong function of ambient temperature and pressure. Figure 5 represent the ignition delay vs load.

3.2.3 Pressure vs Crank angle

The variation in cylinder pressure with crank angle for the diesel and pumpkin-maize biodiesel were shown in fig. From these figures, it can be noticed that at higher engine loads, pressure trends are almost similar for all the fuels. 20% biodiesel blend shows delayed pressure rise with respect to diesel at lower loads. Ignition delay for all fuels decreases as the engine load increases because the gas temperature inside the cylinder is higher at high
engine loads, thus it reduces the physical ignition delay. The inference shows that the maximum cylinder pressure at different loads for different blends depicts that the amount of energy supplied increases with pressure. Figure 6 (a) & (b) represents the Pressure vs Crank angle for 50% load and 100% load.

3.3 Performance parameter

3.3.1 Carbon monoxide emission

Figure 7 represents the relation between CO emission and load. The inference of the graph denotes that, the CO emission normally takes place during the partial burning of the fuel in the cylinder. The PM Biodiesel blends and diesel were investigated for CO emission as 0.08, 0.09, 0.1, 0.11, 0.15 and 0.16 for diesel, B-10 and other concentrations of blends were represented, up to maximum of 100% load. Higher CO emissions in the exhaust gas of the engine may be attributed to the polymerization that takes place at the core of the spray; this also caused concentration of the spray core and decreased the penetration rate [13].
It was also observed that above medium load, the CO emission for all blended fuels was greater than that of diesel. This was due to the reduction in cylinder temperature by the high latent heat of vaporization and low cetane number of corn oil biodiesel [23]. Increase in burning chamber will produce the lower emission of CO using PM Biodiesel blends. This was due to the reduction in cylinder temperature by the high latent heat of vaporization and low cetane number of PM Biodiesel blends. This was also because of the fact that the reduced combustion at higher blend ratio by the high latent heat, high viscosity and low cetane number of PM Biodiesel [17].

3.3.2 Carbon dioxide Emission

The CO$_2$ emission for the neat diesel is lower than the emission of bio-oil blends. More oxygen supply in the biodiesel blends ensures complete combustion that increase in carbon dioxide emission. In general, during combustion, incomplete fuel burning leads to CO emissions. If sufficient oxygen exists, CO will oxidize to CO$_2$. Figure 8 represents the emission of CO$_2$ for varying brake power. The graph denotes that, the emission ranges from 4.4 to 4% in volume for B20 and B40 at maximum. The increase of CO$_2$ emission levels may be due to the CO decrease, which continues the oxidation process because of the high oxygen level of the studied fuels, ensuring a more complete combustion [13].

![Figure 8 CO$_2$ emission vs Load](image)

3.3.3 NO Emission

The NO emission generally rises due to the usage of biodiesel. From figure 9, it was evident that NO emission increased with brake power for all of the fuels tested. But the decrease in NO emissions with increase in the proportion of PM Biodiesel may be due to the improved combustion. Also the higher oxygen content of biodiesels leads to more complete combustion resulting in greater combustion temperature peaks which caused NO emissions reduction. It is observed that NO emissions are obtained with the diesel, B10, B20, B30, B40 & B50 respectively about 1212, 982, 920, 886, 810 and 792 ppm which shows decrement at full load compared to that of diesel.
3.2.3 HC Emission

Figure 10 represents the relation between HC emission and load. Partial burning of fuel with air, higher carbon to oxygen content and quenching of the oxidation process were the main causes for HC emissions in diesel engine [23]. The observation from the graph was the HC emission increased with the increase in load for all fuels; this was due to the presence of fuel-rich mixtures and lower oxygen for combustion at higher loads. The HC emission is 38, 46, 53, 61, 67 ppm for diesel, B-10, B-20, B-30, B-40 and B-50, respectively, at 100% load. Lower HC emissions in the exhaust gas of the engine may be attributed to the efficient combustion of PM Biodiesel blends due to the presence of fuel bound oxygen and warmed-up conditions at higher loads. Due to the high latent heat of vaporization of PM Biodiesel blends, inferences that the increase in percentage of biodiesel blends with diesel increase the HC emission.
3.2.4 Smoke Opacity

Figure 11 shows variation of smoke opacity for diesel, PM Biodiesel, and blends, respectively, at various loads. From the figure it follows that smoke opacity increases with increase in load. It is observed that smoke emissions are higher for prepared biodiesel and blends compared to diesel oil other than B10 and B30 blends. This may be due to heavier molecular structure, double bonds in vegetable oil chemical structure, and higher viscosity of PM Biodiesel and their blends. These factors are responsible for higher smoke emissions resulting in incomplete and sluggish combustion. The number of double bonds present in the fatty acid is strongly related to emissions. The smoke opacity is 64%, 62.4%, 66.7%, 62.8%, 78.6% and 86.9% for diesel, B-10, B-20, B-30, B-40 and B-50, respectively, at 100% load.

![Figure 11 Smoke opacity vs Load](image)

CONCLUSION

The combustion, performance and emission characteristics of a single cylinder four stroke, water cooled, constant speed Kirloskar TV-1 engine using Pumpkin-Maize Biodiesel and its blends as fuel were investigated. The following conclusion were made based on the test results as follows

1. Pure diesel and PM Biodiesel explains an increasing pattern in BTE as for maximum load (100%) the BTE was observed to be 28.87% for diesel, and increased by 30.16%, 29.2%, 30.4, 30.65% and 32.22% for B10, B20, B30, B40 and B50 respectively.
2. At maximum load (100%) the BSFC was observed to be 0.297 kg/kW-hr for diesel, 0.286 kg/kW-hr for B10, 0.297 kg/kW-hr for B20, 0.287 kg/kW-hr for B30, 0.286 kg/kW-hr for B40 and 0.274 kg/kW-hr for B50 respectively. The BSFC decreases with increase in load and compression ratio. B20 blend have the BSFC almost equal to diesel while other blends have lower BSFC than the standard diesel. This is due to high density and high viscosity properties of the biodiesel.
3. The PM Biodiesel blends and diesel were investigated for CO emission as 0.08, 0.09, 0.10, 0.11, 0.15 and 0.16 for diesel. B-10 and other concentrations of blends were represented, up to maximum of 100% load. It was observed that CO emission increased by 27.3% for B-30 blend with respect to diesel. The carbon monoxide (CO) emission of engine was increased with increase in amount of biodiesel blends.

4. Emission of CO₂ for varying brake power in graph denotes that, the increasing emission ranges from 4.4 to 4% in volume for B20 and B40 at maximum load. Emission of CO₂ for B30 blend was lower than diesel at lower loads and at maximum load CO₂ emission was almost equal to diesel fuel emission as 5.4% by volume.

5. The NO emissions are lower for Pumpkin-Maize biodiesel and blends when compared to diesel at almost all loads. NO emission is 1212ppm for diesel, 982 ppm for B-10, 920 for B-20, 886 ppm for B-30, 810 ppm for B-40 and 792 ppm for B-50 blends respectively, at 100% load. It was observed that NO emission decreased by 26.9% for B-30 blend with respect to diesel.

6. The observation from the graph was the HC emission increased with the increase in load for all fuels. The HC emission is 67ppm for diesel, 86 ppm for B-10 and B-20 blends, 92, 102, 106 ppm for, B-30, B-40 and B-50 blends respectively, at 100% load.

7. The smoke opacity is 64%, 62.4%, 66.7%, 62.8%, 78.6% and 86.9% for diesel, B-10, B-20, B-30, B-40 and B-50, respectively, at 100% load. It is observed that smoke emissions are more for higher blends compared to diesel oil other than B10 and B30 blends. Hence B30 blends shows reduced smoke opacity by 1.88%.

8. On the whole it was concluded that the blends of Pumpkin-Maize Biodiesel were safe to use as an alternative fuel in a CI Engine in which the B30 blend shows a promising performance and optimum characteristics for an alternative of alternative fuels.

REFERENCES


