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Chapter

Characteristics Analysis of Performance as Well as Emission of Elaeocarpus Ganitrus Additive Based Pumpkin and Juliflora Mixed Biodiesel Blend in CI Engine

Vinoth Kannan Viswanathan and Pushparaj Thomai

Abstract

Up-to-the-minute researches of different countries have used conformist seed oils such as jatropha oil, coconut oil for the synthesis of biodiesel. In the present investigation, (pumpkin) Cucurbita pepo. L along Prosopis juliflora seed oil was used for the synthesis of mixed biodiesel with 5 ml Elaeocarpus Ganitrus (Rudraksha) as additive. Performance tests were conducted using biodiesel blend in water cooled CI engine and the emissions were analyzed using a five-gas analyzer. Pumpkin and Juliflora biodiesels were blended in equal ratio to form mixed biodiesel denoted by PJB. It was observed that there was 51% amplify in Brake Thermal efficiency and 33% diminution in Brake Specific Fuel consumption at the maximum load when compared to diesel for PJB20 blend with 5 ml additive. It was also noted that emission of CO bargain by 75%, CO₂ bargain by 16.95%, HC compact by 49.2% and NO compact by 34.2% for PJB20 blend with 5 ml Rudraksha additive than that of diesel. The smoke opacity with respect to diesel was also noted to be concentrated by 6% for PJB20 with additive used as fuel in CI engine without any engine modification.

Keywords: Cucurbita pepo. L (pumpkin), Prosopis Juliflora, B20 biodiesel blend, Elaeocarpus Ganitrus, Rudraksha, Emission characteristics, 5-gas analyzer

1. Introduction

Liquid fuels of agricultural origin are being increasingly considered as alternatives to gasoline and gas oil as sources of energy. Specifically, biodiesel has a substantial potential to reduce oil imports and ensure continuity in the energy supply [1]. The main alternative fuels operated so far are oxygenates (alcohol, ether etc.), vegetable oils and their esters, gaseous fuel (hydrogen, liquefied petroleum gas etc.), gas to liquids (GTL) and coal imitatives. Ethanol has attracted attention wide-reaching because of its potential use as an alternative fuel [2]. New cheap oil crops are wanted to produce economical oils appropriate for biodiesel production. One of the possible
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substitute oil crops for the Mediterranean area is pumpkin seed (C. pepo L.). To the authors’ best knowledge, studies on pumpkin seed oil as the feedstock for methyl ester making were never conducted. In the search for substitute oils for biodiesel production, pumpkin seed oil here a promising choice; however, this cannot be regarded as a massive raw material for biodiesel production on a large scale. The percentage increase of biodiesel in the blends increases emissions due to improper combustion process [3]. However, the selecting of oil is an important measure for biodiesel performance. In biodiesel production, it is needed to make the low cost oil crops. Pumpkin oil and juliflora oil are few of the good oil crops for biodiesel production. The pumpkin seed oil contains an oil intensity of 42–54% depending on numerous factors such as plant area, climate and state of ripeness [3]. The biodiesel is extracted from digestible or non-digestible vegetables by using transesterification production method [4, 5]. The biodiesel have most widely used five types of methyl esters like methyl linolenate, methyl stearate, and methyl oleate and methyl palmitate [6]. During the combustion phase of the biodiesel, engine emitted 9% carbon composition which is less than high speed diesel [7]. In any type of biodiesel preparations FFA oil content of less than 3% has been easily converted by using a catalyst [8, 9]. Similarly, the transesterification process of base catalyst cannot access the high amount of FFA content in vegetable oils [10–12]. EG biodiesel can be blended with other biodiesel as additives for improving the performance and reducing the emission at effective cost [13]. Mixture of two biodiesels in equal weight ratio namely C. pepo L (pumpkin) and Tectona grandis (teak) seed oil was used for the synthesis of biodiesel with 5-ml Diethyl ether as additive [14]. Present work investigates the biodiesel obtained from transesterification process of Pumpkin and Maize is used as an alternative fuel to diesel [15]. Present investigation, (pumpkin) C. pepo L and prosopis juliflora seed oil was used for the synthesis of biodiesel [16].

In this experiment, pumpkin seed oil, juliflora seed oil are converted to fatty acid, by adding 15 g potassium hydroxide (KOH) as catalyst for transesterification [17]. Rudraksha was added as additive to the exceeding mixed biodiesel blend and the engine was driven with minimum load to maximum load and at excess load condition. From the results, it was noted that here was an enhancement in BTE and diminish in Specific fuel consumption. The advantage of C. pepo oil along with prosopis juliflora oil over other edible oil stretch out in the oil price. In this regard the proposed research work is aimed to focus on the performance and emission of the pumpkin and juliflora mixed biodiesel blend with Rudraksha additive.

5 ml Rudraksha biodiesel as additive was added to mixed biodiesel blend Pumpkin+Juliflora biodiesel called PJB were then blended with diesel. Take 900 ml of diesel in 1000 ml measuring jar first and add 100 ml PJB biodiesel and add 5 ml Rudraksha additive named PJB10 biodiesel. Take 800 ml of diesel in 1000 ml measuring jar first and add 200 ml PJB biodiesel and add 5 ml Rudraksha additive named PJB20 biodiesel. Take 700 ml of diesel in 1000 ml measuring jar first and add 300 ml PJB biodiesel and add 5 ml Rudraksha additive named PJB30 biodiesel. Take 600 ml of diesel in 1000 ml measuring jar first and add 400 ml PJB biodiesel and add 5 ml Rudraksha additive named PJB40 biodiesel. Take 500 ml of diesel in 1000 ml measuring jar first and add 500 ml PJB biodiesel and add 5 ml Rudraksha additive named PJB50 biodiesel. In India Rudraksha is available in abundance from the Gangetic plane in foothills of the Himalayas and hilly regions, which can be converted into biodiesel. Rudraksha trees can be cultivated in larger scale which may cause severe impact on expenditure of EG biodiesel production. The EG biodiesel as additive are blended in minimal quantity of 5 ml with diesel fuel consumption which led to better performance and clean environment.
Make manual mixing of both fuels, and then take this blend into a mechanical agitator and mixing thoroughly for 15–25 min. The blend is under observation for assuring that there was no separation and settling. This blend was poured to diesel tank in the experiment engine and run the experiments. The volume of addition of Rudraksha biodiesel is very little amount and there is no need to remove the same amount from the blended mixed biodiesel. Rudraksha biodiesel is used as additive to other biodiesel blends. The optimum Rudraksha biodiesel as additive with mixed biodiesel blends were also used to conduct the performance and emission tests at varying loads and compared diesel. Tests were carried out for analyzing various parameters such as brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature. Besides these, the other tests were carried out to measure the emissions of CO, CO$_2$, HC, NO and smoke in the exhaust [18].

2. Methodology and raw materials

2.1 Pumpkin seed and Juliflora seed oil

Both the oils are not gladly accessible in the marketplace as there is no more viable making. The seeds of pumpkin and juliflora were procured and the oil drawing out was prepared in a laboratory.

Figure 1a and b represents the seeds of *Cucurbita pepo* and *Prosopis Juliflora*. The preparation of biodiesel from the pumpkin oil and juliflora oil were done unconnectedly using catalytic transesterification process. 15 g of KOH (6,1 ratio) [19] was added to pumpkin and juliflora oil followed by 200 ml of methanol. The mixture was maintained at 65–70°C for 1 h and then residues were allowed to settle down for 2 h in a titration setup [20]. After few hours the glycerin were separated from the biodiesel by

![Seeds of Raw materials (a) Cucurbita pepo seed (b) Prosopis Juliflora seed.](image-url)
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Titration. The two different biodiesel namely pumpkin biodiesel and juliflora biodiesel, half a liter both were assorted to variety the mixed biodiesel. It was followed by stimulated well using magnetic stirrer at the range of 60–80°C temperature. Both the biodiesel are mixed in alike ratio of 50:50 vol. each, for the point of matching the calorific value of mixed biodiesel by way of diesel and also to meet up the average flash point of the diesel fuel. Pumpkin biodiesel has privileged flash point which guides to delayed firing of fuel during ignition, while juliflora biodiesel has minor flash point nearer to diesel and increase the possibility of easy and fast ignition of air fuel mixture. 50:50 combination of pumpkin and juliflora biodiesel blend is identified as PJ biodiesel. 5 ml Rudraksha bio additive was added to each sample to facilitate the combustion process as well as to reduce the emissions from the burnt fuel. It was denoted by R5. The, following blends with additives were prepared with the diesel fuel and mixed biodiesel fuels. 900 ml diesel and 100 ml PJ-biodiesel with 5 ml additive labeled PJB10 + R5, 800 ml diesel and 200 ml PJ-biodiesel with 5 ml additive labeled PJB20 + R5, 700 ml diesel and 300 ml PJ-biodiesel with 5 ml additive labeled PJB30 + R5, 600 ml diesel and 400 ml PJ-biodiesel with 5 ml additive labeled PJB40 + R5 and 500 ml PJ-biodiesel with 5 ml additive labeled PJB50 + R5. Table 1 represents the physical properties of diesel, PJ biodiesel and B20 blend with Rudraksha additive.

The properties of pumpkin biodiesel, juliflora biodiesel and the blends such as viscosity, density, calorific value, flash point and fire point were measured in the laboratory scale. The hydrometer was used to determine the density of the fuel samples. Viscosity was measured with red wood viscometer; bomb calorimeter was used to measure the calorific value of sample fuels and flash point, fire point apparatus was used to find the flash point and fire point for the sample fuels.

### Table 1. Physical properties of fuels and its blend.

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Density (kg m⁻³)</th>
<th>Calorific value (kJ/kg)</th>
<th>Kinematic viscosity (poise)</th>
<th>Fire point (°C)</th>
<th>Flash point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>825</td>
<td>42,000</td>
<td>2.870</td>
<td>0.78</td>
<td>0.65</td>
</tr>
<tr>
<td>PJ Biodiesel</td>
<td>766</td>
<td>39,846</td>
<td>4.960</td>
<td>1.06</td>
<td>0.98</td>
</tr>
<tr>
<td>B20 blend with Rudraksha additive</td>
<td>828</td>
<td>42,400</td>
<td>2.950</td>
<td>0.82</td>
<td>0.68</td>
</tr>
</tbody>
</table>

2.2 Experimental setup and experimental uncertainty analysis

A single cylinder, 4-strokes, constant speed (1500 rpm) and water cooled CI engine whose compression ratio 17.5:1 with utmost power output of 5.2 kW was used to examine the performance and emission characteristics of mixed biodiesel. An eddy current dynamometer associates the load to the motor.

Table 2 shows the test engine specifications in detail. The specific fuel consumption was determined using solenoid controller. The flywheel speed was measured using a non-contact type of sensor mounted up on the engine. The cooling water transmits the heat to the surrounding that was generated during the engine operation. The engine load were applied at different percentage such as 20%, 40%, 60%, 80%, 100% (maximum load) and 120% (over load) by eddy current dynamometer. Table 3 shows the specification of exhaust gas analyzer and smoke meter. Figure 2 shows the schematic arrangement of KIRLOSKAR TV-1 test engine.
Error and uncertainties occurs in the experimentation can come up from gadget selection, state, calibration, examination, environment, reading as well as test planning. Errors will crawl into all experimentations regardless of the care which is put forward. Uncertainty analysis is wanted to prove the accuracy of the untried results. Uncertainty analysis is conceded out using the procedure given by Holman (1994) and Moffat (1988). The uncertainty in brake power is 0.21% brake specific fuel consumption is 2.22% and brake thermal efficiency is 2.56%. The instruments used in the investigational study and their accuracy and uncertainty proportions are given in Table 4. The uncertainty of the entity measurements has been taken from the manufacturer’s data sheet. Since the equipment is within the calibration validity period, it is predictable that the uncertainties of entity measurements are in agreement with the manufacturer’s claim.

### Table 2.
**Specifications of the engine.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine power</td>
<td>5.2 kW (7 hp)</td>
</tr>
<tr>
<td>No. of cylinder</td>
<td>1</td>
</tr>
<tr>
<td>No. of strokes</td>
<td>4</td>
</tr>
<tr>
<td>Fuel</td>
<td>H.S Diesel</td>
</tr>
<tr>
<td>Cylinder bore</td>
<td>0.0875 m</td>
</tr>
<tr>
<td>Stroke length</td>
<td>0.11 m</td>
</tr>
<tr>
<td>Engine speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>17.5:1</td>
</tr>
<tr>
<td>Orifice dia.</td>
<td>0.02 m</td>
</tr>
<tr>
<td>Loading</td>
<td>Eddy current dynamometer</td>
</tr>
<tr>
<td>Dynamometer arm length</td>
<td>0.195 m</td>
</tr>
<tr>
<td>Inlet valve open</td>
<td>5° before TDC</td>
</tr>
<tr>
<td>Inlet valve close</td>
<td>36° after BDC</td>
</tr>
<tr>
<td>Exhaust valve open</td>
<td>36° before BDC</td>
</tr>
<tr>
<td>Exhaust valve close</td>
<td>5° after TDC</td>
</tr>
<tr>
<td>Fuel injection</td>
<td>23° before TDC</td>
</tr>
<tr>
<td>Injection pressure</td>
<td>220 bar</td>
</tr>
</tbody>
</table>

### Table 3.
**Specification of exhaust emission measuring equipment.**

<table>
<thead>
<tr>
<th>Equipment name</th>
<th>Model</th>
<th>Measurement range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust gas analyzer</td>
<td>Make Model and AVL 444 di-gas</td>
<td>CO, HC, NO, CO₂, CO: 0–10 (% Volume), HC: 0–20,000 ppm, CO₂: 0–10 (% Volume), NO: (0–5000 ppm)</td>
</tr>
<tr>
<td>Smoke meter</td>
<td>AVL 437C smoke meter</td>
<td>smoke density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0–100 (Opacity in %)</td>
</tr>
</tbody>
</table>

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3. Result and discussions

The trial engine was examined for the performance and emission individuality using PJ biodiesel blend with additive and the same was judged against the diesel. 5 ml Rudraksha bio additive was put in to the PJ biodiesel blends for civilizing the performance individuality of biodiesel. The emissions of blended biodiesel such as CO, CO₂, HC, and NO was hardnosed using five-gas analyzer. The smoke opacity proportion was studied with AVL 437C Free accelerometer Smoke meter. The performance of the engine was also investigated for brake specific fuel consumption and brake thermal efficiency.
3.1 Performance characteristics

Figure 3 shows the comparison of Brake Thermal Efficiency (BTE) for mixed biodiesel used in the test engine. At maximum load (100%) the BTE was observed to be 27.83% for diesel, 42.02% for PJB20 + R5 blend that shows, PJ biodiesel with Rudraksha additive results in higher BTE and good thermal performance with B20 blend compared to other blends. The BTE improvement of about 51% for PJB20 blend with Rudraksha additive compared to diesel was noted. When the load exceeds the maximum limit, the efficiency tends to decrease for both diesel as well as biodiesel blends.

Figure 4 shows the comparison of Specific Fuel Consumption (SFC) for mixed biodiesel used in the test engine. At maximum load (100%) the SFC was observed to be 0.307 kg/kW-h for diesel, 0.206 kg/kW-h for PJB20 + R5 blend that shows, PJ biodiesel with Rudraksha additive results in lower SFC with B20 blend compared to other...
blends. The SFC decrement of about 33% for PJB20 blend with Rudraksha additive compared to diesel was noted. When the load exceeds the maximum limit, the fuel consumption was observed to increase for both diesel as well as biodiesel blends.

Figure 5 shows the comparison of Exhaust Gas Temperature (EGT) for mixed biodiesel used in the test engine. Lower engine temperature was observed when PJ biodiesel is used with Rudraksha and this improves the combustion process due to excess amount of oxygen present in additive. At maximum load (100%) the EGT was observed to be 322°C for diesel, 291°C for PJB20 + R5 blend that shows, PJ biodiesel with Rudraksha additive results in lower EGT with B20 blend compared to other blends. The EGT decrement of about 9.63% for PJB20 blend with Rudraksha additive compared to diesel was noted. When the load exceeds the maximum limit, the exhaust gas temperature was observed to increase for both diesel as well as biodiesel blends.

3.2 Emission characteristics

Figure 6 shows the emission of carbon monoxide (CO) at different loads from the test engine by using diesel, PJ biodiesel blend with Rudraksha additive. The features affecting CO emission were air–fuel mix and oxygen. CO emission was because of the inadequate burning of fuel, where the oxidation has not occurred properly [21]. This is due to inadequate air quantity and inability of carbon conversion to CO$_2$ at exhaust manifold. At maximum load the CO emission was observed to be 0.32% by volume for diesel, 0.08% by volume for PJB20 blend with Rudraksha additive. The CO emission was observed to be reduced by 75% for PJB20 + R5 blend. It was observed that the blended biodiesel with additive has comparatively lower emission. This decrease in CO output was because of increase in burning chamber temperature and nearness of more oxygen in additive based biodiesel.

Figure 7 shows the emission of Carbon dioxide (CO$_2$) at different loads as of the test engine by means of diesel and PJ biodiesel blend with additive. This CO$_2$ emission shows absolute combustion process due to the quantity of oxygen there in the biodiesel. At maximum load the CO$_2$ release was observed to be 5.9% by vol. for diesel, 4.9% by vol. for PJB20 blend with additive. CO$_2$ emission was observed to be reduced by 16.95% for B20 blend with additive compared to diesel was noted.
Figure 6. Load vs. emission characteristics of CO for PJB + R5 blended biodiesel.

Figure 7. Load vs. emission characteristics of CO for PJB + R5 blended biodiesel.

Figure 8 show the emission of hydro carbon (HC) at different loads from the test engine by using diesel and PJ biodiesel blend with additive. HC emission was observed with unburned fuels due to inadequate temperature formation at near the cylindrical walls in the engine [12, 22]. The lesser HC release occurs due to lower heat rejection by high in-cylinder temperature. At maximum load the HC emission was observed to be 118 ppm for diesel and 60 ppm for B20 blend with additive, which is decreased by 49.2% for PJB20 + R5 blend compared to diesel, was noted. It was observed that the blended biodiesel with additive has lower emission than that of diesel. It shows the oxygen content in additive increases the possibility of complete fuel burning [23]. At minor loads, HC emission was noted to be lesser but when blend ratio enlarges, HC emission also elevates compared to diesel. Yet, at greater loads the cutback in HC emission was typically inclined by rising wall temperature in the cylinder towards the exhaust manifold [7]. The researchers found an analogous reduction
in HC emission by using Rudraksha additive with biodiesel processed with uncoated engines that shows the possibility for further reduction of HC with coated engine.

**Figure 9** shows the emissions of nitrogen oxide (NO) from the exhaust system while using different biodiesel blends with additive. Yilmaz N found reduction in NO, by using di-tertiary-butyl peroxide (DTBP) in coated engine while using biodiesel [24]. NO emission happens due to combustion process at privileged temperature and poorer oxygen attention. While using biodiesel blends, the oxygen intensity were higher and this results in minor NO emission. At maximum load, NO emission was viewed to be 1212 ppm for diesel and 798 ppm for PJB20 blend with additive Rudraksha. The NO emission was observed to be decreased by 34.2% for B20 blend with Rudraksha additive compared to diesel was noted. In case of biodiesel with additive, an optimized concert was achieved at B50 blend of biodiesel due to sufficient heat generation and better oxygen concentration.
Figure 10 shows the smoke opacity for diesel as well as biodiesel blends. The enhancement of oxygen plays a key role in smoke emission from the engine at different loading conditions. At maximum load, the smoke opacity was observed to be 67.8% for diesel and 63.8% for PJB20 blend with additive. The smoke emission was observed to be decreased by 6% for PJB20 blend with additive against to diesel was noted. Use of biodiesel generates higher smoke levels when match up with the diesel due to the rate of adjourned oxidation process. In this stare use of PJ biodiesel with Rudraksha additive diminish the smoke level in the engine.

The incidence of additive has abridged the smoke opacity than that of diesel and all biodiesel blends. For PJB20 blend with additive the smoke opacity was almost identical to the diesel. It shows sign of the presence of sufficient oxygen substance and non-defective combustion progression. As the result, it was incidental that the exhaust temperature is essential for characterizing the smoke actions. Also, the smoke density was pragmatic to increase with percentage of lift in biodiesel blends with growing loads.

4. Conclusion

The experimental work Pumpkin-Juliflora biodiesel with Rudraksha additive was conducted on a single cylinder, four-stroke direct infusion water cooled diesel engine with an eddy current dynamometer. Performance and emission characteristics of PJ biodiesel with additive were observed as follows:

- The diesel and PJ biodiesel blend with additive demonstrated a reduction pattern for BSFC and increasing pattern of BTE. PJB20 + R5 blend shows decreased BSFC by 33% at ceiling load evaluated with the diesel.

- PJB20 + R5 merge with additive shows 51% augmented BTE at maximum load compared with diesel.
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- PJBJ20 merge with Rudraksha additive demonstrated a diminution in CO₂ emission by 16.95% at ceiling load in contrast to diesel.

- Alike results were established in the PJBJ20 merge with additive for the CO release that was abridged by 75% at ceiling load owing the ignition process as of the company of surplus oxygen and superior temperature of the arrangement.

- The HC discharge for PJBJ20 merge with additive shows a decrease of 49.2% compared to diesel.

- The NO emission for PJBJ20 merge with additive demonstrates a reduction of 34.2% by volume at maximum load compared with diesel. NO output decreases with increasing biodiesel blends with additive.

- Smoke opacity for PJBJ20 + R5 merge was 6% lower than that of diesel. Smoke will be generally higher for biodiesel when compared with diesel. Whereas in this research the smoke was observed to be decreased due to Rudraksha additive mixed with biodiesel.

- From the results, it is evident that PJBJ20 mixed biodiesel merge with Rudraksha additive exhibits better performance and decreased emission characteristics and therefore could be considered as an alternative fuel to diesel without any engine modifications.

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