

# Biodiesel from lemon and lemon grass oil and its effect on engine performance and exhaust emission

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**Abstract.** In the present scenario many developing countries are depending on oil producing nations for their fuel resources. Due to demand and scarcity of the fuel, there has been a huge increase in fuel prices. The vehicular population is also continuously increasing and becoming a great menace to peoples. This paper aims to provide an alternate solution for petroleum based fuels. It suggests that biodiesel produced from lemon and lemon grass oil can be used as an alternative fuel. This work investigates the thermal performance of four stroke diesel engine using blends of biodiesel and diesel as a fuel. Performance parameters like brake thermal efficiency, mechanical efficiency and specific fuel consumption were measured at different loads for diesel and various combination of biofuel (L10, L20, and L30). The maximum brake thermal efficiency obtained is about 26.12% for L20 which is slightly higher than that of diesel (24.91%). Engine experimental results showed that exhaust emissions including CO<sub>2</sub> and HC were reduced by 6% and 5% for L20 mixture of biodiesel whereas CO emission was as same as diesel. However, there was increase in NO<sub>x</sub> by 26% to the diesel fuel.

## 1. Introduction

Biodiesel is an alternative fuel which is extracted from domestic and renewable resources. Diesel can be combined with any level of biofuel to produce blended biodiesel which contains zero petroleum. It is widely used in a compression – ignition engines. It is nontoxic and free of sulphur and aromatics. Biodiesel is produced from a chemical process of trans-esterification which extracts glycerin from vegetable oil. It is good to the environment because it has lower emission compared to the petroleum. The trans-esterification is done with alcohol products in the presence of a catalyst. The main benefits of biodiesel are reducing global warming gas emissions, hydrocarbons and carbon monoxide. Some vegetable oils such as Palm oil (1), orange oil[2], cotton seed oil[3], soybean oil[4], olive oil[5], nerium oil[6], frying palm oil[7], peanut grown[8], jatropha & karnja [9], Calophyllum oil[10], waste lemon peels[11], sun flower oil[12] and mustard oil[13] has been used in production of biodiesel. It has an important benefit in its properties like lower viscosity, lower flashpoint and higher vapour pressure. Further, getting biodiesel from vegetable oils causes food shortfalls because most of the vegetable oils are consumed by us for daily needs. Kerosene is mainly used for domestic applications like cooking and space heating. Several studies has been done by using kerosene blends with diesel and considerable efficiency was achieved[14]. Animal fats are causing health hazards in human food in many ways. The very low cost animal fats are chicken fat and goat fat from their particular industries. These materials are easily available and can be the suitable feed stocks for conversion to biodiesel to enhance the performance of engine[15]. Sea lemon oil has been chosen to blend with standard diesel and given 7-16% greater efficiency than the diesel[16]. In this study, lemon and lemon grass oil are chosen as a fuel for diesel engine and its blends with standard diesel. The various blends of lemon and lemon grass oil with diesel are prepared with evaluation of its important properties and then subjected to engine performance with exhaust emission compared when with standard diesel.



## 2. Materials and Methods

### 2.1. Preparation of oil

Lemon seeds and lemon grass collected from India are dried in sunlight for a week. From this dried seeds and grass, the oil is extracted by using a mechanical expeller. Adding 10 % of hexane will remove the impurities present in the lemon and lemon grass oil. Then stirring it for 15 min at 85°C and leave an unwanted organic matter to settle for 30 minutes. From this, Hexane gets evaporated due to its low boiling point (68.7°C) and the impurities settled down at the bottom can be removed[16]. Three blends of diesel – lemon and lemon grass oil (with 10%, 20% and 30% mixer of lemon and lemon grass oil blending by volume) were named L10, L20 and L30 respectively, were used in this experiment. Finally exhaust gas emission has been investigated and compared with those of pure diesel.

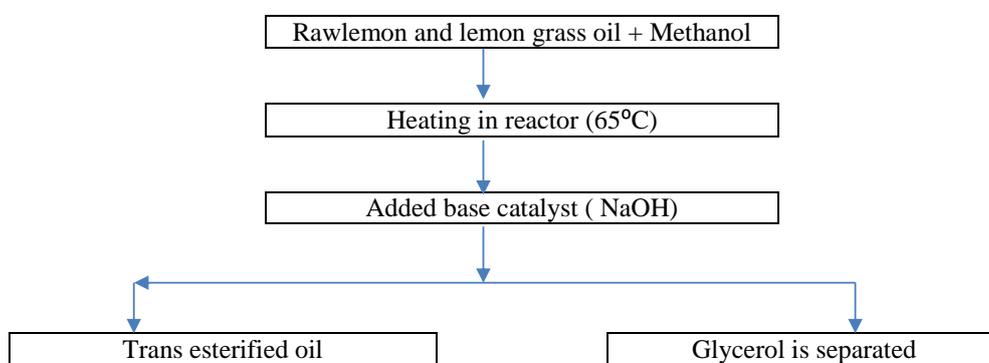
### 2.2. Trans-esterification:

Trans-esterification is a process of chemical reaction which involves alcohol and triglycerides in the presence of a catalyst [17]. This process has three reversible reactions, they are the conversion of triglycerides to di glycerides followed by the conversion of di glycerides to mono glycerides[18]. Finally, by giving one ester in each step, glycerides are converted into glycerol. Higher concentration of NaOH will increase the reaction rate of bio fuel[19].

The overall trans-esterification reaction is given by three consecutive and reversible equations as shown below:

1. Triglyceride (TG) + ROH  $\leftrightarrow$  Di glyceride (DG) + RCOOR1
2. Di glyceride (DG) + ROH  $\leftrightarrow$  Mono glyceride (MG) + RCOOR2
3. Mono glyceride (MG) + ROH  $\leftrightarrow$  Glycerol + RCOOR

The products of the reaction are the biodiesel itself and glycerol[13]. The Flow chart of trans-esterification process of lemon and lemon grass oil is shown in Fig.1



**Figure. 1** Trans-esterification process of lemon and lemon grass oil

### 2.3. Property analysis:

The important physio-chemical properties of lemon and lemon oil were determined. The determination of density, calorific value, viscosity, flash point and fire point are carried out using a hydrometer, a Redwood viscometer, a bomb calorimeter and Pensky–Martin’s closed cup apparatus respectively.

It is observed that properties like density, viscosity, flash point and fire point of lemon and lemon grass oil is higher whereas the calorific value is lower when compared with diesel. Table 1 shows the physico-chemical properties of sea lemon oil and diesel and the comparison of density, viscosity and calorific value of blends with diesel are shown in Table 2.

**Table 1.**Physio-chemical properties of diesel and biodiesel (lemon and lemon grass oil)

Fuel properties	Diesel	Lemon & Lemon grass oil
Kinematic viscosity, cSt at 40 <sup>0</sup> C	3.9	52.4
Specific gravity at 15 <sup>0</sup> C	0.84	0.94
Flash point, <sup>0</sup> C	56	94
Fire point, <sup>0</sup> C	64	100
Calorific value kJ/kg	44500	41400
Density, kg/m <sup>3</sup>	0.83	0.89

**Table 2.**Comparison of properties of oil blends with diesel.

Fuel blends (by vol%)	Density, kg/m <sup>3</sup>	Viscosity, cSt	Calorific value kJ/kg
100 % diesel	0.84	3.9	44500
10% lemon & lemon grass oil + 90% of diesel	0.88	7.2	41270
20% lemon & lemon grass oil + 80% of diesel	0.89	12.3	40800
30% lemon & lemon grass oil + 70% of diesel	0.91	25.4	40200

### 3. Experimental and test procedure

The experimental study was conducted on four stroke single cylinder VCR water cooled diesel engine. The general specifications of the test engine are shown in the Table 3.

A kirloskar sv-1 type standard engine test bed was used which consists of an electrical dynamometer. Torque will be measured by using electrical dynamometer (Direct current apparatus rated for 3.5kW). A magnetic pickup sensor is used to measure the speed of the engine.

**Table 3.**Engine specification

Parameter & parts	Size & type
Make	Kirloskar sv-1
Type	Vertical cylinder, diesel engine
Number of cylinder	1
Bore diameter	87.5
Stroke length	110mm
Compression ratio	17.5
Cycle	Diesel cycle
Speed	1500 rpm
Rated brake power	3.5kw
Cooling system	Water
Fuel	Diesel
Fuel injection pressure	185 bar
Fuel ignition timing	0 to 25 degbtdc
Specific fuel consumption	25kg/kw-hr

To attain the steady state condition, the engine was run for 15-20 minutes without any load. The probe was inserted in the exhaust port of the engine after attaining the steady state condition. Engine was warmed up with diesel before beginning each step and temperature of engine oil was maintained around 85°C.

Speed of the engine was maintained as 1500 rpm (constant speed) at different load conditions. Then, the diesel was replaced with biodiesel L10, L20 and L30 and the performance of the engine was measured using

an Electronic Data Acquisition System at varying load conditions. The schematic view of the test equipment is shown in Figure.2.

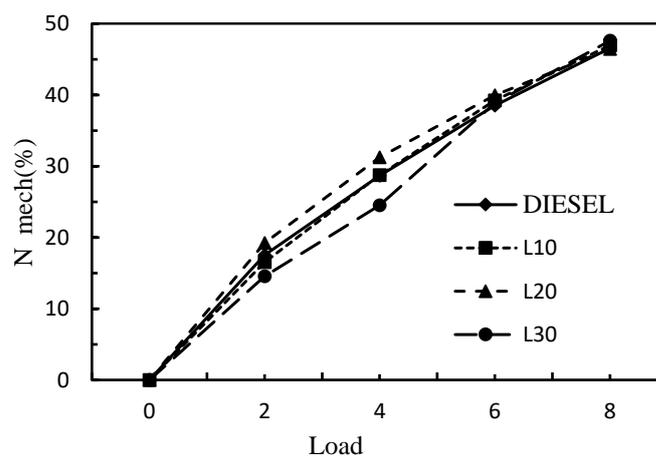


**Figure. 2** Experimental setup

#### 4. Results and discussion:

##### 4.1. Performance parameters:

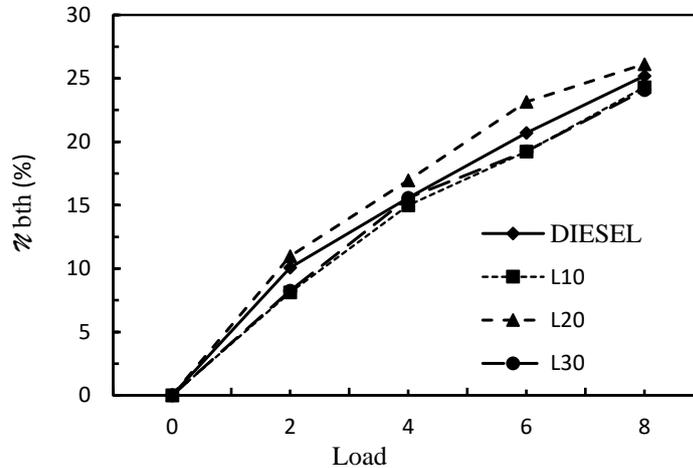
The evaluation of performance of engine was done. The variations of brake thermal efficiency, specific fuel consumption and mechanical efficiency with load for diesel fuel and lemon and lemon grass oil (biodiesel) are plotted in graph. Figure. 3 shows the effect of bio-diesel blend on mechanical efficiency ( $\eta_{\text{mech}}$ ) at different loads with engine run at 1500 rpm. It has been seen that the mechanical efficiency first increases as load increases and falls with increase in load after some time. Indicated power increased due to high amount of heat released during the process. This is the main reason for increase in mechanical efficiency. L20 (20 % of lemon and lemon grass oil blends with diesel) has maximum mechanical efficiency of 47.59 % compared to diesel and other blends for different loads.



**Figure. 3** Effect of bio-diesel blend on mechanical efficiency

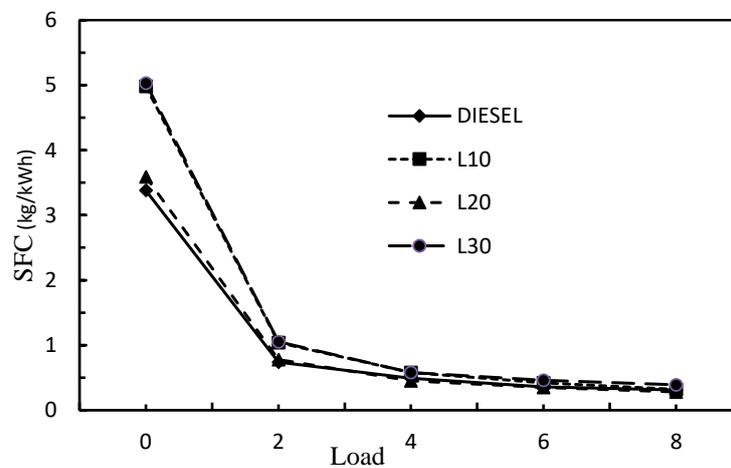
Figure. 4 shows the effect of bio-diesel blend on brake thermal efficiency ( $\eta_{\text{bth}}$ ) at different loads with engine run at 1500 rpm. It is evident that the brake thermal efficiency first increases as load increases and falls with increase in load after reaching maximum value. The reason for increase in the brake thermal efficiency might

be better vaporisation and mixing rate of biodiesel[2]. L20 (20 % of lemon and lemon grass oil blends with diesel) has good brake thermal efficiency (26.12%) than the diesel (24.91%) for different loads.



**Figure. 4** Effect on bio-diesel blend on brake thermal efficiency

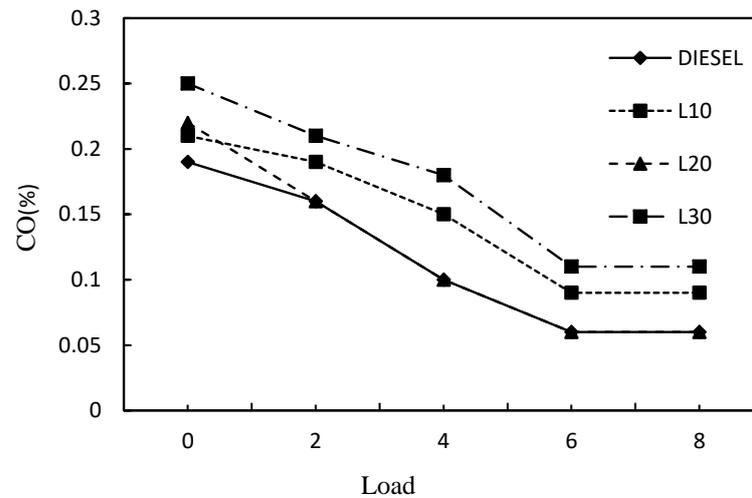
Figure. 5 shows the variations of specific fuel consumption (SFC) for various lemon and lemon grass oil-diesel blends. It decreases with increase in engine load. High calorific value of lemon and lemon grass oil was the main reason to this reduction in the specific fuel consumption [16]. The difference in density also was one of the reason for this reduction.



**Figure. 5** Effect of bio-diesel blend on specific fuel consumption

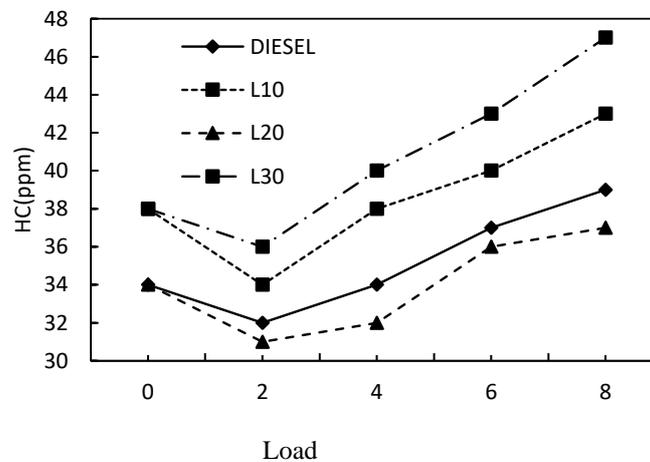
#### 4.2. Emission parameters

The hydrocarbon, NO<sub>x</sub>, carbon monoxide and carbon dioxide were investigated as emission parameters. The effect of bio-diesel blend on those parameters was investigated and plotted in the graph. The effect of bio-diesel blend on carbon monoxide emission with blend ratio is shown in the figure 6. Due to higher supply of oxygen, diesel engine will produce lower CO. In lemon and lemon grass oil it was same as diesel. It shows that there is no gradual increase of incomplete combustion by using lemon and lemon grass oil and CO emission is purely based on incomplete combustion.



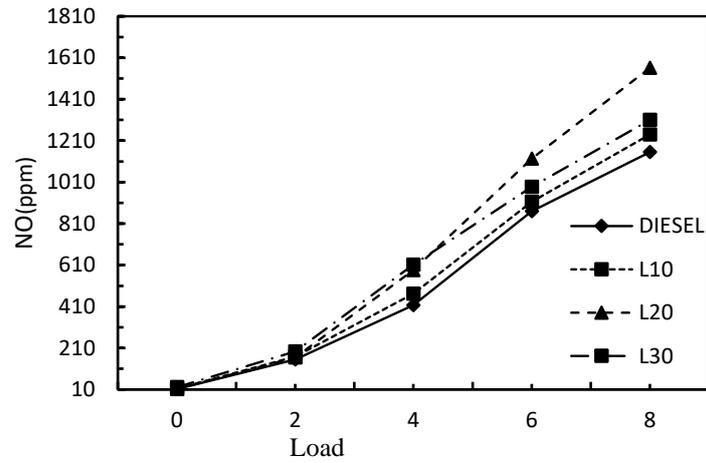
**Figure. 6** Variation in CO emission with blend ratio

HC emission is reduced by 5% when lemon and lemon grass oil blends 20% with pure diesel. Among all lemon oil blends, it shows the lowest HC emission of full load operation, compared to other lemon oil blends [16]. This is also due to complete combustion which reflects in higher brake thermal efficiency. A proportion mixture may become leaner than the combustion unit due to a reduction in the fuel cetane number. The effect of HC emission with blend ratio is shown in figure 7.



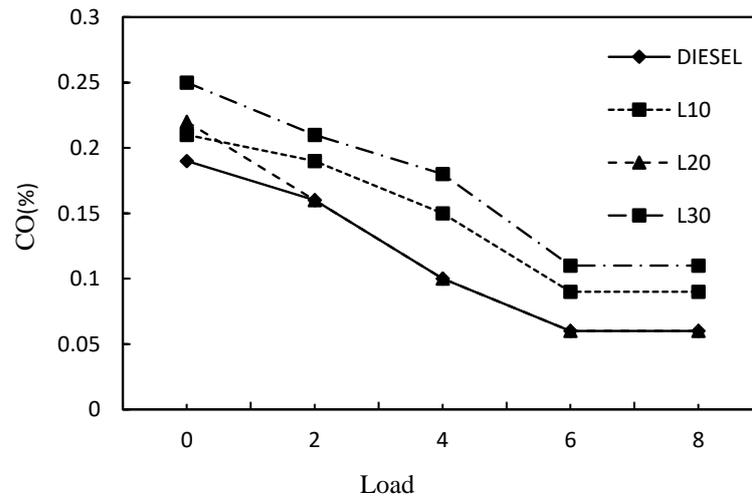
**Figure. 7** Variation in HC emission with blend ratio

The emission of  $\text{NO}_x$  is mainly influenced by the availability of oxygen and in-cylinder gas temperature. Due to enhancement of oxygen level, higher intensity of heat was released and lower cetane number of biodiesel were the reason to increase the  $\text{NO}_x$  emission around 26%. Because the lower cetane number will increase the ignition delay which causes higher  $\text{NO}_x$  emission [12]. Effect of  $\text{NO}_x$  with blend ratio is shown in figure 8.



**Figure. 8** Variation in NO<sub>x</sub> emission with blend ratio

The effect of carbon dioxide with blend ratio is shown in the figure 9. Due to higher supply of oxygen, there was reduction on CO<sub>2</sub> around 6% for L20. It showed that there was complete combustion occurring which reduced and maintained the CO level. Because CO is converted as CO<sub>2</sub> when the complete combustion occurs.



**Figure. 9** Variation in CO<sub>2</sub> emission with blend ratio

## 5. Conclusion

The performances of single cylinder four stroke diesel engine has been operated with different fuel blends at rated rpm and rated load conditions have been experimentally investigated in the present study and the following results were obtained.

- Brake thermal efficiency ( $\eta_{\text{bth}}$ ) and Mechanical efficiency ( $\eta_{\text{mech}}$ ) slightly increases with 20% concentration of lemon and lemon grass oil-diesel blends as compared with pure diesel fuel. This is only because of the fuel properties such as lower density, lower viscosity and higher calorific value of blend L20.
- The Specific fuel consumption decreases with increase in percentage concentration of lemon and lemon grass-diesel blends as compared with pure diesel fuel. Decrease in specific fuel consumption of the blended fuels was mainly due to evaporation and faster combustion of the blend particles as compared with diesel fuel.
- HC (5%) and CO<sub>2</sub> (6%) emissions were reduced in the 20% concentration of lemon and lemon grass with diesel. CO emission was as same as the emission of diesel. It showed that, there was very less chance for incomplete combustion than diesel fuel.
- NO<sub>x</sub> emission was increased by 26% for lemon and lemon grass oil when compared to the pure diesel.

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