

# An Investigation on the Performance of a Diesel Engine Using Rubber Seed Oil–Diesel Blends

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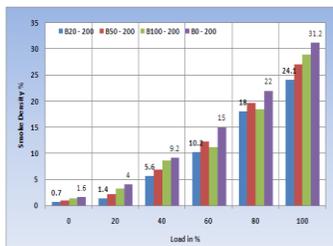
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## Graphical abstract



## Abstract

In this study, the performance and emission characteristics were analyzed by using rubber biodiesel in a single cylinder direct injection diesel engine. The experiments were conducted using different combination of fuels such as 20%, 50% of biodiesel blends by volume (B20 and B50) with pure diesel fuel, pure biodiesel (B100) and pure diesel fuel (B0). The performance parameters were obtained for different load conditions from No load to Full load at rated rpm. Results indicated that the higher brake thermal efficiency, Mechanical efficiency, reduced specific fuel consumption obtained for biodiesel blend of B20, compared to other blends and diesel fuel.

**Keywords:** Diesel engine; rubber seed biodiesel; injection pressure; engine performance; thermal efficiency; emission characteristics

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## 1.0 INTRODUCTION

The usage of fossil fuel is continuously increasing at a more dramatic rate which results in rapid depletion of fossil fuel reserves. In the last two decades, numerous works have been carried out by the various researchers to investigate the usage of bio fuels as an alternative to diesel in an internal combustion engines. Bio fuels which are extracted from vegetable oils are increasing great attention due to their bio degradable and non-toxic characteristics.

From the literature survey [1-6], it is evident that there are various problems associated with vegetable oils being used as fuel in compression ignition engines, mainly caused by the high viscosity. The high viscosity is due to the large molecular mass and chemical structure of vegetable oils which in turn leads to problems in pumping, combustion and atomization in the injector systems of a diesel engine.

Avinash Kumar Agarwal [7] reviewed the performance and emission of compression ignition engine fueled with various biodiesels. Ramadhas [8] reported that vegetable oils pose some problems when subjected to prolonged usage in CI engines because of their high viscosity and low volatility. The common problems are poor atomization, carbon deposits, ring sticking and fuel pump failure. Jindal [9] investigated the effect of

compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester and reported that increase in compression ratio associated with increase in injection pressure improves the performance of the engine in terms of brake specific fuel consumption and brake thermal efficiency. Md. Nurun Nabi *et al.* [10] investigated the combustion and exhaust gas emission characteristics of an engine fuelled with blends of methyl esters of neem oil and diesel. Elango and Senthilkumar [11] investigated the performance and emission characteristics of a diesel engine fuelled with different blends of jatropha oil and diesel. It was reported that among the blends maximum brake thermal efficiency and minimum specific fuel consumption were found for blends up to 20% Jatropha oil. Celik and Simsek [12] investigated to find the optimum blend rate and injection pressure in a four-stroke, single cylinder, direct injection diesel engine using soybean methyl ester. It was reported that the specific fuel consumption and power values of the B25 were found to be nearly the same as those of diesel fuel at 220 bar injection pressure. Rajendra Prasad [13] analyzed the combustion and performance of single cylinder diesel engine using Jatropha biodiesel and its blends. It was reported that the performance characteristics of biodiesel are similar to that of diesel fuel operation and emission levels are lower than the diesel fuel. Venkanna *et al.* [14] investigated the effect of injection pressure on performance,

emission and combustion characteristics of direct injection diesel engine running on blends of pongamia pinnata linn oil (Honge oil) and Diesel Fuel. They reported that the performance, emissions and combustion parameters of 20% honge oil and 80% diesel fuel (volume basis) were found very close to neat diesel fuel where as higher blend ratios were found inferior compared to neat diesel fuel. Ghassam. M. Tashstoush [15] analyzed bio-source-fuels like vegetable oils and waste animal fat were tested at different injector pressures (120, 140, 190, 210 bar) in a direct-injection, naturally aspirated, single-cylinder diesel engine with a design injection pressure of 190 bar. The fuel consumption consistently decreased with an increase in injection pressure for all the fuel including the diesel fuel. The characteristics of the vegetable oils fall within a fairly narrow band and are quite close to those of the diesel oil. Hence it can be used as bio-fuel in compression ignition engines. The rubber seed oil, a non-edible type vegetable oil is a potential source for producing bio-diesel and can be used as fuel in compression ignition engines. Rubber seed kernels (50-60% of seed) contain 40-50% of brown colored oil. At present rubber seed oil does not find any major application. Few studies have been conducted on the performance analysis of compression ignition engine using rubber seed oil based bio diesel [16].

In this study, the performance and emission characteristics of a single cylinder direct injection diesel engine was investigated by using different combination of biodiesel blends B20 (20% rubber seed oil by volume with diesel), B50 (50% rubber seed oil with diesel by volume), pure biodiesel (B100) and pure diesel fuel (B0) at a constant injection pressure of 200 bar. Higher injection pressure was chosen since the higher pressure enhances the combustion process.

## 2.0 EXPERIMENTATION

As the free fatty acid (FFA) content of rubber seed oil is about 22 % and viscosity is 6.82 Cp, it is necessary to reduce the FFA and the viscosity in order to make it suitable for compression ignition engines. Transesterification is generally employed for reducing

the viscosity of vegetable oils. The factors such as type of catalyst (alkaline or acid), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content) and free fatty acid content influence the transesterification. In this process, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acids alkyl esters and glycerol [17].

In the two stage transesterification process, the first stage is to esterify the free fatty acid with methanol by acid catalyst in order to reduce the FFA content less than 1%. In the second stage, the alkali catalyst is added after removing the acid catalyst to complete the transesterification [18-20]. For reducing the FFA less than 2, hydrochloric acid and methanol were used as reagents. Oil was heated at 65°C and Methanol and HCl were added. The oil was stirred for 90 minutes and settled for one day. Pre treated oil was collected from the lower layer and washed with deionized water to remove excess acid. Then water was removed and dried over sodium sulphate. For 13.8 kg of rubber seed oil 9.62 litres of methanol and 1.75 litres of HCl were used. Initial FFA content of 22 is reduced to less than 1 by this process.

In the second stage, Methanol (MeOH) and Potassium hydroxide (KOH) were used as the reagents. Oil was heated at 65°C and the required amount of MeOH and KOH were added. Stirring was done for 1 hour and allowed to settle for 12 hours. The biodiesel layer was washed thoroughly 5 to 6 times with hot ionized water. Then water removed and dried over sodium sulphate. For 13 kg of rubber seed oil, 6.67 litres of MeOH and 119.6 gm of KOH were used. After the process 11.5 litres of rubber biodiesel was obtained.

The study was carried out on a direct injection single cylinder four stroke 18 HP diesel engine (Bore: 99 mm, Stroke: 98 mm, CC: 900 cc, compression ratio 18:1). The rated rpm of the engine is 2000 rpm. The diesel engine is connected to an alternator. A 3 phase 15 KVa alternator was used for this study. The experimental set up is shown in Figure 1. The properties of diesel and rubber seed oil are presented in Table 1.



Figure 1 Experimental set up

**Table 1** Properties of diesel and rubber seed oil

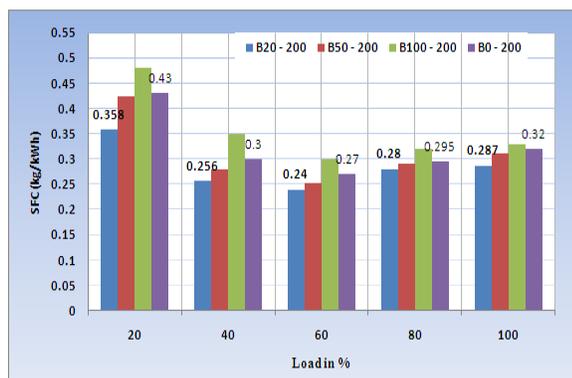
Properties	Diesel	Rubber seed oil
Dynamic viscosity in $C_p$	4.14	6.82
Flash point in $^{\circ}C$	65	72
Density in g / cc	0.82	0.86
Calorific Value in kJ/kg	44500	36500

Initially the engine was run on No load condition and its speed was adjusted at rated rpm. The engine was then tested at No load and 20%, 40%, 60%, 80% and 100% loads at rated rpm. The engine was tested on both fuels (Rubber biodiesel and Diesel) and its combinations (B20, B50 and B100) for each load condition and the engine was run for at least 10 minutes after which data were collected. The injection pressure can be varied by changing the spring tension of injector needle with setting screw. Exhaust gas temperature was recorded by using a thermocouple, which is fitted in the exhaust pipe. The performance of the engine at different loads was evaluated in terms of Brake Specific Fuel Consumption (BSFC), Brake Thermal Efficiency (BTHE), Brake Power (BP), Mechanical efficiency, Smoke density and Exhaust gas temperature.

### 3.0 RESULTS AND DISCUSSION

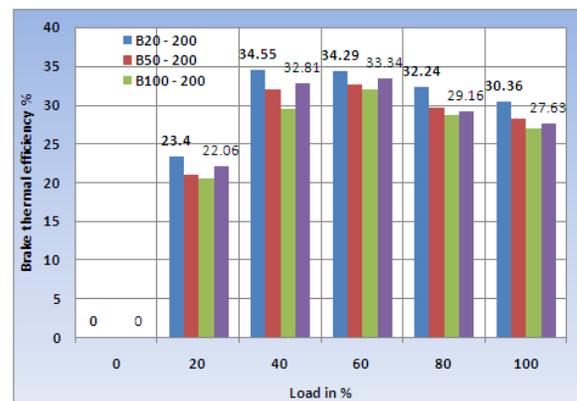
#### 3.1 Brake Specific Fuel Consumption

It can be observed from the Figure 2 that the brake specific fuel consumption (ratio of the rate of fuel consumption, kg/h and the brake power, kW) for the blend B20 is lower than that of other blends and standard diesel at all load levels. Average BSFC for the blend B20 was found to be lower than diesel by 10% at full load. However, if the concentration of bio diesel in the blend increases more than 20% the specific fuel consumption was found to have increased at all loads. This is because of the lower calorific value of biodiesel. Higher BSFC was observed when the engine was running with B100. Average BSFC for the blend B100 was 5% higher than that of diesel when the engine was tested at full load. It was observed that the specific fuel consumption decreased with increasing load upto 60% for all the fuels. When the load on the engine is increased more than 60%, the specific fuel consumption tends to increase. It may be due to the availability of oxygen is relatively low at higher loads.

**Figure 2** Load vs brake specific fuel consumption

#### 3.2 Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to load for different fuel combinations is plotted in Figure 3. It can be observed that the brake thermal efficiency increased with increasing load upto 40% and started decreasing gradually irrespective of fuels tested. The brake thermal efficiency of blend B20 was found to have maximum compared to diesel fuel at all engine loads.

**Figure 3** Load vs brake thermal efficiency

This can be attributed to the fact that the biodiesel contains some amount of oxygen which improves the combustion characteristics. However, when the concentration of rubber seed oil in the blend is more than 20%, thermal efficiency tends to decrease. The brake thermal efficiency obtained for B100 was found to be lower compared to other blends and diesel fuel. The reason may be due to the reduction in calorific value and higher viscosity of rubber seed oil. It can be concluded that atomization is more predominant than the oxygen availability in the blend during the combustion.

#### 3.3 Brake Power

The variation of brake power for diesel fuel and biodiesel blends is shown in Figure 4. Results showed that the brake power increases with load irrespective of fuels tested. The brake power increased with the addition of biodiesel up to 20% and reached a maximum value, then decreased with further increase of the biodiesel content and reached minimum value for B100.

Fuel B20 gives maximum brake power which is 10.6 KW followed by B50 at full load condition. It was found that brake power of B20 is 8.16% higher than B50. However, the brake power of biodiesel blend B100 was lower than that of the diesel fuel. It can be attributed to the fact that the higher viscosity of bio diesel results in the power losses due to poor atomization of fuel during the injection.

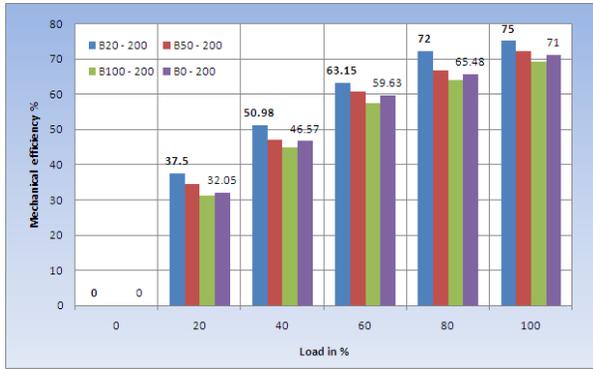


Figure 4 Load vs brake power

### 3.4 Mechanical Efficiency

The variation of mechanical efficiency with load for diesel fuel and different biodiesel blends is shown in Figure 5. It can be inferred that the mechanical efficiency of the engine increases as load increases irrespective of fuels tested. However, mechanical efficiency of the blends B20 and B50 were higher than that of the diesel fuel. This can be possibly due to better lubricating property of the bio diesel which reduces frictional losses. Moreover, mechanical efficiency of the engine when fueled with B100 is slightly lower than that of diesel. Because of higher viscosity B100 fuel significantly affects the atomization and spray characteristics, which result in the power losses.

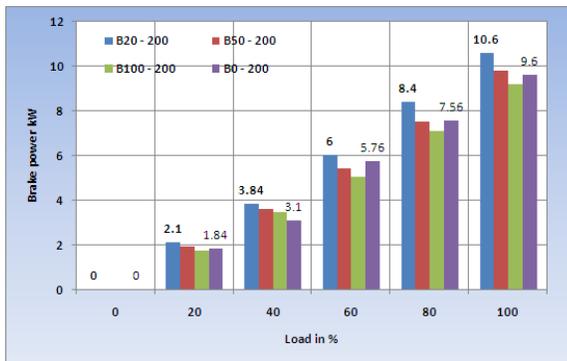


Figure 5 Load vs mechanical efficiency

### 3.5 Exhaust Gas Temperature

The variation of exhaust gas temperature with respect to load for diesel and blended fuels is depicted in the Figure 6. The exhaust gas temperature increases with increasing load for all the tested fuels. The figure also demonstrates that the exhaust gas temperature increased linearly with increasing the concentration of bio diesel in the diesel. It was observed that the exhaust gas temperature is lower for B20 compared to other blends and diesel at all loads. Biodiesel contains some amount of oxygen molecules in the ester form which enhances the combustion process. When B100 fuel was used, higher exhaust temperature attained which indicates more energy loss. That is biodiesel fueled engines has the potential to emit more NOx as compared to that of diesel fueled engines.

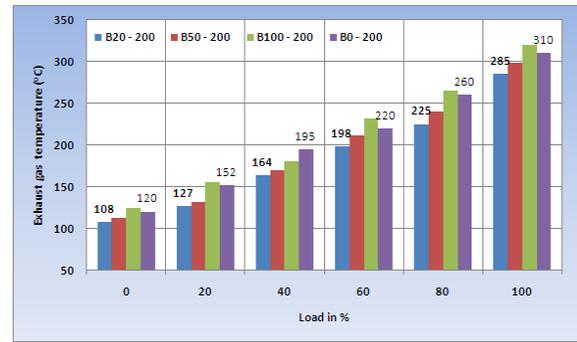


Figure 6 Load vs exhaust gas temperature

### 3.6 Smoke Density

The observed values of smoke density with respect to load for different combination of fuels is illustrated in Figure 7. Smoke density for biodiesel blend is noticed to be generally lower than that of the diesel fuel. It infers that lesser amount of unburnt hydrocarbons present in the engine exhaust emission. So lower smoke density values are achieved with biodiesel blends as compared to that of the diesel. The reduction in smoke density is mainly due to the fact that biodiesel has about 10 to 12% oxygen contents which help in better combustion.

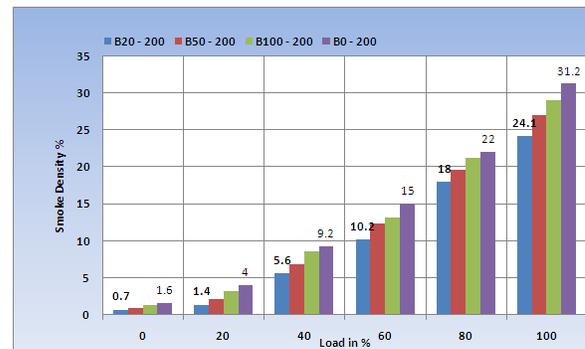


Figure 7 Load vs smoke density

## 4.0 CONCLUSION

The combustion and emission characteristics of single cylinder compression ignition engine fuelled with rubber seed biodiesel and its blends were analyzed and compared to the standard diesel fuel at constant 200 bar injection pressure. Based on the experimental results, the following conclusions were obtained. It was found that B20 (20% rubber seed biodiesel + 80% diesel), combination provides the best engine performance. The brake thermal efficiency and brake power of the engine increased by 9.88 % and 10.41% respectively when fueled with B20 compared with pure diesel at full load.

Mechanical efficiency of the blends B20 and B50 were higher than that of the diesel fuel at all load conditions. Moreover, the specific fuel consumption and smoke density are decreased by 10.3% and 29.5% respectively when engine fueled with B20 compared to diesel at full load condition. Exhaust gas temperature is lowered by 8 % for B20. It was also observed that when biodiesel content was increased in the diesel, the exhaust gas temperature increased.

Experimental investigations show that blending of rubber seed esters up to 20% with diesel can be used in an unmodified compression ignition engine.

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