Biodiesel from Goat and Sheep Fats and Its Effect on Engine Performance and Exhaust Emissions

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ABSTRACT
In the present day scenario the cost of fuel has become a great menace to Indians. In Indian cities automobile pollution has become a pressing issue. The vehicular population is continuously increasing and pollution is increasing rapidly. The percentage of carbon dioxide in the atmosphere increases the temperature. This paper aims to provide an alternate solution to petroleum based fuels. It suggests that biodiesel produced from inedible animal fat (goat & sheep) to be used as an alternate fuel. In this study biodiesel is produced from fats of sheep and goat obtained from meat stalls in and around Hosur Taluk, Krishnagiri District, Tamilnadu and South India. The objective of the present study is to investigate the effects of petro diesel and biodiesel blends on the performance and emission characteristics on a four stroke single cylinder diesel engine. The engine was operated at constant speed. The readings of the important parameters were noted at different loads. Detailed analysis was done on the performance and emission parameters of biodiesel blends and diesel. At maximum load condition, the specific fuel consumption of 50% biodiesel is 0.36 kg/kW-hr is more than that of diesel 0.35 kg/kW-hr. It was observed that the thermal efficiency of biodiesel fuel was less than that of petro diesel. The maximum brake thermal efficiency obtained is about 26% for B10 which is slightly higher than that of diesel (23%). For various percentages of biodiesel blends, there is an increase in brake thermal efficiency and indicated thermal efficiency. The engine experimental results showed that exhaust emissions including carbon monoxide (CO), carbon dioxide (CO₂), hydro carbons (HC) and smoke emissions were reduced for all biodiesel mixtures. The emissions of the engine running on B10 were reduced by 2%, 8%, 13% and 22% for smoke density, HC, CO and CO₂ respectively as compared to petro diesel at various loading conditions. However, an increase in oxides of nitrogen (NOₓ) emission was experienced for biodiesel mixtures. B10 has NOₓ emission of 8.6% at maximum load.

KEYWORDS: Automobile pollution, Biodiesel, Animal Fats, Emission test

INTRODUCTION
Many developing countries like India depend on the oil producing nations for their fuel resources. Due to the increase in import of fuel and scarcity of fuel, there has been a drastic increase in fuel prices. Diesel engines are widely used for their low cost and better efficiency. This ever increasing fuel bills have prompted developing countries to search for a suitable environment friendly alternative diesel fuel. This paper discusses the process and advantages of using biodiesel produced from animal fats, and suggests that this biodiesel can be a suitable fuel resource. The raw material used in the biodiesel processes is animal fat.

Some vegetable oils such as sun flower[1], tall oil [2],[12], waste vegetable oil [3], olive oil [9], pomace oil [7], soya bean oil [18], cotton oil [13], Mahua oil [25], rape seed oil [27], palm oil [4], cooking oil [29] etc. have been used in biodiesel production. Although vegetable oil esters have certain advantages such as lower viscosity, lower flash point, higher vapor pressure and easier processing relative to animal fatty acid esters, they are non economic and non feasible due to their high cost. Further, many varieties of vegetable oil used in the production of biodiesel are consumed by humans and hence are valuable. The use of edible vegetable oils for biodiesel production causes food shortfalls.

On the other side, animal fats in human food cause health hazards. Chicken fat, lard and tallow are relatively inexpensive by products of their respective industries. Only tallow is used significantly in non food applications. These materials are readily available and can be the suitable feed stocks for conversion to biodiesel. Petro diesel emission contributes to the development of cancer ,cardiovascular and respiratory health effects ,pollution of air water and soil ,reductions in visibility and global climate change [15]. Important operating disadvantages of biodiesel in comparison with petrodiesel are cold start problems, lower energy content, higher copper strip corrosion and fuel pumping difficulty from higher viscosity [5]. There are several techniques proposed to reduce the viscosity of animal fat and vegetable oil such as blending, pyrolysis, micro emulsion and transesterification [8].

One of the promising approaches for a heavy reduction of the in-cylinder carbon formation involves the addition of oxygen to the conventional diesel fuel by means of adding an oxygen rich compound to diesel fuel or using oxygenated hydrocarbon as the main fuel. Previous literature shows that the weight percent of oxygen content in the fuel is the most important factor for particulate matter reduction, and it is more significant than other properties such as chemical structure or volatility [28].

<table>
<thead>
<tr>
<th>Make</th>
<th>Kirloskar</th>
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<tbody>
<tr>
<td>No of cylinders</td>
<td>Single</td>
</tr>
<tr>
<td>Cooling</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel</td>
<td>Diesel</td>
</tr>
<tr>
<td>Speed</td>
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</tr>
<tr>
<td>HP</td>
<td>5HP</td>
</tr>
<tr>
<td>Starting</td>
<td>Crank</td>
</tr>
<tr>
<td>Lubrication</td>
<td>Forced</td>
</tr>
<tr>
<td>Bore(mm)</td>
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</tr>
<tr>
<td>Stroke(mm)</td>
<td>110</td>
</tr>
<tr>
<td>Compression ratio</td>
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</table>

Dynamometer

<table>
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<th>Type</th>
<th>Powermag</th>
</tr>
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<tbody>
<tr>
<td>Cooling</td>
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</tr>
<tr>
<td>Load measurement method</td>
<td>Strain gauge</td>
</tr>
<tr>
<td>Max speed</td>
<td>3000rpm</td>
</tr>
<tr>
<td>HP</td>
<td>5HP</td>
</tr>
<tr>
<td>Coupling Type</td>
<td>Direct</td>
</tr>
<tr>
<td>Loading</td>
<td>Auto loading system.</td>
</tr>
</tbody>
</table>

Many investigations have shown that using biodiesel in diesel engines can reduce hydrocarbon
(HC), carbon monoxide (CO) and particulate matter (PM) emissions, but oxides of nitrogen (NOx) emission may increase [6], [17] and [26]. The oxygen content of biodiesel is an important factor in the NOx formation, because it increases combustion temperature to maximum level due to excess hydrocarbon oxidation and increase NOx formation [10] and [21]. This experiment evaluates the effect of biodiesel on engine performance and emission characteristics. Through analysis and discussions about the effects of biodiesel on the engine performance and emissions proper petro diesel–biodiesel blend can be selected and valuable conclusions extracted from this experimental study.

METHODS

Waste animal (goat & sheep) fat was obtained from meat shops in and around Hosur Taluk, Krishnagiri District, Tamilnadu, and South India. It was cooked in a vessel to remove the water vapour. The temperature was gradually increased to 80°C to extract the oil from the fat. The hot oil was strained in a white cloth to remove the residue.

PREPARATION OF BIODIESEL

Two methods to obtain biodiesel were: Acid transesterification with H2SO4 as catalyst and pre-esterification with acid as catalyst followed by basic transesterification with KOH as catalyst. Acid transesterification was carried out in a 1 L glass reactor, immersed in a temperature controlling bath, equipped with a thermostat, mechanical stirring, sampling outlet, and condensation system. Pre-esterification and basic transesterification reactions were carried out in a 500 mL spherical glass reactor, provided with a thermostat, magnetic stirring, sampling outlet and condensation system. Before reactions all material was completely dry. In acid transesterification reaction, 500 g of animal fats were heated in the reactor, when fats reached 60°C, methanol and catalyst (H2SO4) were added, in established amounts for each experiment, and the stirring system was connected, taking this moment as zero time. The mixture was stirred vigorously at reflux of methanol for 48 h, samples of 20 cm³ were taken out at 10 h spaced intervals. Samples and reaction final mixture were placed in decantation funnels and allowed to stand overnight to ensure the complete phase separation (methyl esters and glycerol). The glycerol phase (bottom phase) was removed and the biodiesel phase (upper phase) was heated at 85 °C to remove methanol. The biodiesel was neutralized with KOH (20% needed KOH to neutralize the added H2SO4 as catalyst) and it was washed with deionized water to reach neutral pH. In pre-esterification, 250 g of animal fats were heated in the reactor at the reaction temperature, in this moment methanol and acid catalyst were added and stirring of the mixture started (zero time). At evenly spaced intervals, samples of 1 cm³ were taken out from the reaction mixture and its acid value was measured. After the established reaction time under vigorous stirring, the mixture was placed in a decantation funnel and allowed to stand overnight. Two phases could be identified, the upper phase consisted of methanol, catalyst, H2O and impurities and the bottom phase mainly consisted of fats and the esterified fatty acids. The phases were separated and the esterified product was then transesterified by basic catalysis, using same system as pre-esterification and similar procedure. The esterified product was weighed and the suitable amount of methanol and catalyst (KOH) were added. After reaction time, the mixture was placed in a decantation funnel, glycerol phase was separated, methanol was eliminated and biodiesel phase was washed with deionized water to remove catalyst. It was identified that viscosity and density of the biodiesel meets specifications required by ASTM D6751 and EN14214. It required two kilograms of animal fat to obtain one liter of biodiesel.

TABLE 2. PROPERTIES OF PETRO DIESEL AND BIODIESEL FROM (GOAT AND SHEEP) FATS

<table>
<thead>
<tr>
<th>Property</th>
<th>Biodiesel from goat and sheep fats</th>
<th>Petro diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>0.87</td>
<td>0.835</td>
</tr>
<tr>
<td>Calorific value(MJ/kg)</td>
<td>39.85</td>
<td>42.5</td>
</tr>
<tr>
<td>Viscosity(mm²/sec)</td>
<td>4.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Flash point(°C)</td>
<td>83</td>
<td>45</td>
</tr>
</tbody>
</table>

The experimental study was conducted on a single cylinder, four stroke diesel engine. The general specifications of the test engine are shown in the Table 1. A Kirloskar type standard engine test bed which consists of an electrical dynamometer was used. The electrical dynamometer is a swinging field direct current (DC) apparatus rated for 3.75kW.

EXPERIMENTAL

The engine speed was measured with a magnetic pickup sensor. The schematic view of the test equipments is shown in (Fig 1). Diesel fuel flow was measured with a high precision electronic balance. Exhaust gas temperature and lubricating oil temperatures were measured with a multipoint electronic temperature indicator. The thermocouples used were NiCr-Ni type which can measure upto 1200°C. An AVL DI GAS 444 Gas Analyser was used to determine the percentage of carbon monoxide, hydrocarbon, carbon dioxide, oxygen and oxides of nitrogen. The engine was allowed to run for several minutes to attain the steady state conditions. After attaining steady state conditions the probe is inserted into the exhaust pipe of the engine. The exhaust gas flows over the reactor in the gas analyzer. The analyzer attained the steady state condition and the different values of five gases are displayed. An AVL 437 smoke meter was employed to determine the smoke intensity. The readings are displayed on the monitor of the smoke meter.

Blends of animal fat (goat & sheep) based biodiesel fuel (B10 – blended in volume at the ratio of 10% with diesel fuel), B20, B30, B40, B50 and petro diesel fuel were used in this experiments.
Experiments were conducted at different load conditions at constant speed (1500 rpm). Before each test, the engine was warmed up with diesel fuel. Engine oil temperatures were kept stable around 80°C. The parameters like time taken for 10cc consumption of fuel, speed, exhaust gas temperature, CO, CO2, NOx, HC and smoke intensity were noted at different load conditions (20%, 40%, 60%, 80% & 100%) for each sample.

RESULTS
The evaluation of performance and exhaust emissions were done. The variations of brake thermal efficiency indicated thermal efficiency and mechanical efficiency with load for diesel fuel and animal fat based biodiesel are shown. It is observed that both diesel fuel and B10 have similar trends in engine performance. Maximum indicated thermal efficiency occurred at 60% load with both types of fuel. Slight differences were observed for indicated thermal efficiency and mechanical efficiency with the addition of biodiesel fuel at higher loads as shown in (Fig. 2 and Fig. 11) respectively.

However, specific fuel consumption (SFC) was decreased at all engine loads compared to the diesel fuel as shown in Fig. 2. In general, power loss can be seen with the addition of biodiesel fuel because of its oxygen content and lower heating value when compared with diesel fuel [25]. Therefore, an increase of mass based flow rate in the same fuel volume occurred due to the higher density of biodiesel [19], [4], [20], [23] and [11].

Using lower percentage of biodiesel in biodiesel – petro diesel blends, the brake specific fuel consumption of the engine is lower than that of petro diesel for all loads. At maximum load condition, the specific fuel consumption of 50% biodiesel is 0.36 kg/kW-hr which is more than that of diesel 0.35 kg/kW-hr. (Fig. 1 and Fig. 3) indicate decrease in thermal efficiency of biodiesel fuel. They also indicate that engine thermal efficiency is affected inversely with specific fuel consumption and heating value of the fuel. They show the lower thermal efficiency occurred with B50 fuel due to the lower heating value of the fuel. Similar results are also observed in the past experiments [24], [19] and [16].

The variation of brake specific fuel consumption with load for different fuels considered for the present analysis is presented in Fig. 2. In all the cases, it is found that brake thermal efficiency increases with the increase in applied load. This is due to the reduction in heat loss and increase in power developed with increase in load. The maximum brake thermal efficiency obtained is about 26% for B10, which is slightly higher than that of diesel 23%. The maximum brake thermal efficiency obtained while using B10, B20, B30, B40 and B50 are 26%, 24%, 24%, 24% and 23% respectively. The mixing of biodiesel in diesel oil yields good thermal efficiency curves in (Fig. 3). Initially, the thermal efficiency of the engine is improved with increasing concentration of the biodiesel in the blend. The possible reason for this is the additional lubrication provided by the biodiesel. The molecule of biodiesel (methyl esters of the oil) contains some amount of oxygen, which take part in the combustion process. (Fig. 2 and Fig. 3), indicate decrease in thermal efficiency of biodiesel fuel. They also indicate that engine thermal efficiency is affected inversely with specific fuel consumption and heating value of the fuel. They show the lower thermal efficiency occurred with B50 fuel due to the lower heating value of the fuel. Similar results are also observed in the past experiments [24], [19] and [16].

The variation of brake specific fuel consumption with load for different fuels is presented in (Fig 2). For all fuels tested, brake specific fuel consumption is found decreased when there is an increase in the load. This is due to the higher percentage increase in brake power with load as compared to the increase in fuel consumption. Using lower percentage of biodiesel in biodiesel – petro diesel blends, the brake specific fuel consumption of the engine is lower than that of petro diesel for all loads. At maximum load condition, the specific fuel consumption of 50% biodiesel is 0.36 kg/kW-hr which is more than that of diesel 0.35 kg/kW-hr. It is also noted that the calorific value of biodiesel is lower than that of diesel. With increase in biodiesel percentage in the blends, the calorific value of fuel decreases. Hence, the specific fuel consumption of the higher percentage of biodiesel in blends increases as compared to that of diesel.

The emission characteristics of biodiesel are of special interest with regard to meeting the environmental norms. (Fig. 5) shows the plots of CO.
emissions of the various blends of biodiesel from animal fats at various load conditions. The fuels produce low amount of carbon monoxide emission at higher load conditions.

There is an increase in the carbon monoxide emissions with increase in load. This is typical with all the internal combustion engines, since the air fuel ratio decreases with increase in load. The engines also emit more CO using petro diesel as compared to that of biodiesel blends under all loading conditions. With increasing biodiesel percentage, CO emission decreases. Biodiesel itself has about 12% of oxygen content in it [30] and [31]. This helps for a complete combustion. Hence, CO emission level decreases with increasing biodiesel percentage in the fuel. (Fig. 6) compares the CO emissions of various fuels used in the diesel engine. The CO emissions increase with increase in load. The lower percentage of biodiesel blends emits very low amount of CO in comparison with diesel. B10 emits very low level of CO emissions. Using higher concentration of biodiesel blends as the fuel, CO emission is found increased. But, its emission level is lower than that of diesel. The presence of more amount of CO in exhaust emissions indicates the complete combustion of the fuel. This supports the higher value of exhaust gas temperature. The CO produced are readily absorbed by plants. Hence the CO produced is being removed continuously.

Fig. 6. Variation of Carbon Dioxide of biodiesel and diesel with Load

Fig. 7. Variation of Hydro Carbon of biodiesel and diesel with Load

Fig. 8. Variation of Smoke Density of biodiesel and diesel with Load

Fig. 9. Variation of Exhaust Gas Temperature of biodiesel and diesel with Load

Fig. 10. Variation of Oxides of Nitrogen of biodiesel and diesel with Load

Fig. 11. Mechanical Efficiency vs Load

So, lower smoke density values are achieved with biodiesel blends, when compared to that of diesel. B20 gave smoke density of 66% as compared to 72% in the case of petro diesel.

With increase in the value of exhaust gas temperature, Oxides of nitrogen emission also increases. Biodiesel fuelled engines has the potential to emit more NOx as compared to that of diesel fuelled engines.
CONCLUSIONS
In this study, methyl ester was produced from inedible animal fat (goat & sheep). By considering methyl ester as a kind of biodiesel fuel, an experimental study was carried out to investigate the performance and emission characteristics of methyl ester blends (10%, 20%, 30%, 40%, 50%, 50%) by volume with a petroleum diesel fuel (B10, B20, B30, B40, B50) in a diesel engine. The results were compared.

The following conclusions are drawn from the experimental study:
1. Viscosity and density of methyl ester meets ASTM D6751 and EN14214 specifications. Viscosity and density of methyl ester are very close to the viscosity and density of petro diesel. The calorific value of biodiesel is less than the calorific value of petro diesel (Table 2).
2. Biodiesel cannot be used as a fuel in cold weather conditions due to the relatively low pour point. Preheating and lowering freezing point is required to eliminate the problems related to cold weather conditions.
3. Biodiesel and its blends can be used without any engine alterations in a direct injection diesel engine.

The addition of biodiesel to the diesel fuel decreases the thermal efficiency of the engine and increases the specific fuel consumption. This is due to the lower heating value of biodiesel compared to neat diesel fuel.
4. HC and CO emissions are higher at low engine loads and lower at high engine loads, while NOx increases with engine loads. The CO2 emission increases with the increase in load. The lower percentage of biodiesel blends emit very low amount of CO2 in comparison with diesel. Biodiesel reduces HC and CO emissions due to better combustion with oxygen presence of the fuel. There is an increase in NOx emissions due to the higher burning temperature and the greater oxygen level in the combustible mixtures.

Thus Biodiesel from animal fat is a good alternate fuel. Firstly it can be used without modification of the engine. Secondly because, animal fat is not edible as well as it causes dreadful diseases to human beings. Thirdly, it helps to create an eco-friendly atmosphere, because it will increase fuel availability and provide solution to future fuel scarcity.

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REFERENCE


