ENVIROMENTAL BENEFITS THROUGH REDUCTION IN EXHAUST EMISSIONS OF C.I. ENGINE USING CLEAN BURNING FUEL: AN EXPERIMENTAL STUDY

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ABSTRACT

Transport vehicles greatly pollute the environment through emissions such as CO, CO₂, NOₓ, SOₓ, unburnt or partially burnt HC and particulate emissions. Fossil fuels are the chief contributors to urban air pollution and major source of green house gases and considered the prime cause behind the global climate change. With the increasing fuel prices, the auto industry forced to make their engines to breathe cleanly and fuel efficiently. This paper discusses about the utilization and advantages of using karanja oil, as the bio fuels. The experiments conducted on single cylinder direct injection diesel engine for the various blends (B20, B40, B60, B80 and B100) of karanja biodiesel with diesel and compared with the diesel fuel. The results indicate that Blends of karanja oil gives good performance of the engine in addition to the lower engine emissions. It has been observed from the results that by using Karanja biodiesel there is decrease in brake thermal efficiency and increase in specific fuel consumption, the reason for this the combined effects of the relative density, viscosity and heating value of the blends and poor combustion characteristics of Karanja biodiesel due to higher viscosity and poor volatility. The gaseous emissions of oxide of nitrogen from all blends are higher than mineral diesel at all engine loads. Significant improvements observed in the performance parameters of the engine as well as exhaust emissions, when blends of Karanja oil used. Karanja oil blends with diesel can replace diesel for operating the C.I. engines giving lower HC, CO, Smoke emissions and improved engine performance.

Key Words: C.I. Engine, Kinematic viscosity, Calorific value, Engine efficiency, Exhaust emissions

INTRODUCTION

High among the major challenges facing the industrialized nations today are, the economical use of existing fossil fuels and the development of suitable alternative and renewable fuels or blends, while considering their environmental impact. Reduction of emissions, largely, without sacrificing fuel economy will be an enormous challenge.

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The demand for petroleum-based energy around the world is continuously increasing. Petroleum is the largest single source of energy which has been consuming by the world's population, exceeding the other energy resources such as natural gas, coal, nuclear and renewable. According to International Energy Outlook 2007 published by the Energy Information Administration, the world consumption for petroleum and other liquid fuel will grow from 83 million barrels/day in 2004 to 97 million barrels/day in 2015 and just over 118 million barrels/day in 2025. Under these growth assumptions, approximately half of the world's total resources would be exhausted by 2025. Also, many studies estimating that the world oil production would peak sometime between 2007 and 2025. Therefore, the future energy availability is a serious problem for us. Another major global concern is environmental concern or climate change such as global warming. Global warming is related with the greenhouse gases which are mostly emitted from the combustion of petroleum fuels. In order to control the emissions of greenhouse gases, Kyoto Protocol negotiated in Kyoto City, Japan in 1997 and came to effect since February, 2005. Now, Kyoto Protocol covers more than 160 countries globally and targeting to reduce the greenhouse gas emission by a collective average of 5% below 1990 level of respective countries. The Intergovernmental Panel on Climate Change (IPCC) concludes in the Climate Change 2007 that, because of global warming effect the global surface temperatures are likely to increase 1.1°C to 6.4°C between 1990 and 210012.

**Indoor Air Pollution**

Pollution is perhaps most harmful at an often unrecognized site inside the homes and buildings where we spend most of our time. Indoor pollutants include tobacco smoke; radon, an invisible radioactive gas that enters homes from the ground in some regions; and chemicals released from synthetic carpets and furniture, pesticides, and household cleaners. When disturbed, asbestos, a nonflammable material once commonly used in insulation, sheds airborne fibers that can produce a lung disease called asbestosis. Pollutants may accumulate to reach much higher levels than they do outside, where natural air currents disperse them. Indoor air levels of many pollutants may be 2 to 5 times, and occasionally more than 100 times, higher than outdoor levels. These levels of indoor air pollutants are especially harmful because people spend as much as 90 percent of their time living, working, and playing indoors. Inefficient or improperly vented heaters are particularly dangerous.

**Table 1: Typical Constituents along Roadways**

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>CNS, heart impairment; affects heart patients at 10 ppm</td>
</tr>
<tr>
<td>Pb</td>
<td>CNS / Brain damage; cognitive impairment at 2 ug/m³</td>
</tr>
<tr>
<td>PM</td>
<td>Lung constriction; affects asthmatics at low concentrations</td>
</tr>
<tr>
<td>NOx</td>
<td>Emphysema-like symptoms; affects lung function at 100 ppb</td>
</tr>
<tr>
<td>SOx</td>
<td>Irritates respiratory system; lung/throat irritation at 6 ppm</td>
</tr>
</tbody>
</table>
Table 2: Air Toxics

<table>
<thead>
<tr>
<th>Toxics</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>Leukemia, plus non cancer effects</td>
</tr>
<tr>
<td>Toluene</td>
<td>Liver lesions, reduced kidney weight; RfC at 400 ug/m³</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>Lymphoma, leukemia, plus non-cancer effects</td>
</tr>
<tr>
<td>Xylene</td>
<td>Impaired motor coordination at 100 ug/m³.</td>
</tr>
</tbody>
</table>

Pollution Cleanup and Prevention

In India, the serious effort against local and regional air pollution began with the Clean Air Act. The law requires that the air contain no more than specified levels of particulate matter, lead, carbon monoxide, sulfur dioxide, nitrogen oxides, volatile organic compounds, ozone, and various toxic substances. To avoid merely shifting pollution from dirty areas to clean ones, stricter standards apply where the air is comparatively clean. In national parks, for instance, the air is supposed to remain as clean as it was when the law passed. The act sets deadlines by which standards must be met. The Environmental Protection Agency (EPA) is in charge of refining and enforcing these standards, but the day-to-day work of fighting pollution falls to the state governments and to local air pollution control districts. In an effort to enforce pollution standards, pollution control authorities measure both the amounts of pollutants present in the atmosphere and the amounts entering it from certain sources. The usual approach is to sample the open, or ambient, air and test it for the presence of specified pollutants. The amount of each pollutant is counted in parts per million or, in some cases, milligrams or micrograms per cubic meter. Pollution, controlled in two ways: with end-of-the-pipe, devices that capture pollutants already created and by limiting the quantity of pollutants produced in the first place. End-of-the-pipe devices include catalytic converters in automobiles and various kinds of filters and scrubbers in industrial plants. In a catalytic converter, exhaust gases pass over small beads coated with metals that promote reactions changing harmful substances into less harmful ones. When end-of-the-pipe devices first began to use, they dramatically reduced pollution at a relatively low cost. As air pollution standards become stricter, it becomes more and more expensive to clean the air. In order to lower pollution, overall, industrial polluters sometimes allowed to cooperate deals. For instance, a power company may fulfill its pollution control requirements by investing in pollution control at another plant or factory, where more effective pollution control accomplished at lower cost. End-of-the-pipe controls, however sophisticated, can only do so much. As pollution efforts evolve, keeping the air clean will depend much more on preventing pollution than on curing it. Gasoline, for instance, reformulated several times to achieve cleaner burning. Various manufacturing processes redesigned so that less waste produced. Car manufacturers are experimenting with automobiles that run on electricity or on cleaner-burning fuels. Buildings designed to take advantage of sun in winter, shade, and breezes in summer to reduce the need for artificial heating and cooling, which usually powered by the burning of fossil fuels choices people make...
in their daily lives can have a significant impact on the state of the air. Using public transportation instead of driving, for instance, reduces pollution by limiting the number of pollution-emitting automobiles on the road\textsuperscript{3,4}.

To solve both the energy concern and environmental concern, the renewable energies with lower environmental pollution impact should be necessary. Nowadays several new and renewable energies emphasized and biomass energy is one of the renewable energies among them. Biomass energy includes liquid biofuels derived from biomass and which are promising as alternative fuels with low environmental pollution impact, to replace petroleum based fuels. Some of the well known liquid biofuels are ethanol for gasoline engines and biodiesel for compression ignition engines or diesel engines. Biodiesel is a renewable and environmental friendly alternative diesel fuel for diesel engine. It can be produced from food grade vegetable oils or edible oils, nonfood grade vegetable oils or inedible oil, animal fats and waste or used vegetable oils, by the transesterification process. Transesterification is a chemical reaction in which vegetable oils and animal fats are reacted with alcohol in the presence of a catalyst. The products of reaction are fatty acid alkyl ester and glycerin, and where the fatty acid alkyl ester is known as biodiesel. Biodiesel is an oxygenated fuel and which containing 10\% to 15\% oxygen by weight. Using biodiesel can help to reduce the world's dependence on fossil fuels and which also has significant environmental benefits. The reasons for these environmental benefits are: using biodiesel instead of the conventional diesel fuel reduces exhaust emissions such as the overall life circle of carbon dioxide (CO\textsubscript{2}), particulate matter (PM), carbon monoxide (CO), sulfur oxides (SOx), volatile organic compounds (VOCs), and unburned hydrocarbons (HC) significantly. On the other hand, most of the researchers have reported that 100\% biodiesel emits lower tail pipe exhaust emissions compared to the diesel fuel; nearly 50\% less in PM emission, nearly 50\% less in CO emission and about 68\% less in HC emission. Furthermore, since biodiesel can be said a sulfur-free fuel, it has 99\% less SOx emission than the diesel fuel. However, most of the biodiesel produce 10\% to 15\% higher oxides of nitrogen (NOx) when fueling with 100\% biodiesel\textsuperscript{4-6}.

**Vegetable Oil Properties**

There is a need to search and find ways of using alternative fuels, which are preferably renewable and emit low levels of gaseous and particulate pollutants in internal combustion engines, in the case of agricultural application, fuels that produced in rural areas in a decentralized manner, near the consumption points will be favored. The permissible emission levels can also be different in rural areas because of the large differences in the number density of engines. Fuels like vegetable oils, biodiesel alcohols, natural gas, biogas, hydrogen, and researchers for engine applications are investigating liquefied petroleum gas (LPG) etc.

Vegetable oils are easily available in rural areas, are renewable, have a reasonably high cetane number used in C.I. engines with simple modifications and easily blended with diesel in the neat and esterified forms. Jatropha oil, Karanja oil, coconut oil,
sunflower oil, rapeseed oil and neem oil are some of the vegetable oils that tried as fuels in internal combustion engines; observed that the heat release rate is very similar to diesel with vegetable oils. Also CO and HC emissions are higher than diesel. Bio diesels from several feedstocks have also been investigated extensively. Brake thermal efficiency with the bio diesel of vegetable oils is comparable with diesel where as in case of straight vegetable oil it is less than diesel. Further, with esters HC emissions lower compared to the raw oil. To improve the performance of vegetable oil fuelled engines several methods like conversion to biodiesel, addition of oxygenates, duel fuelling with gaseous fuel, use of cetane number improving additives and preheating to lower the viscosity tried. Addition of oxygenates and duel fuelling lead to high brake thermal efficiency and also reduction in HC and CO emissions in some cases further stated the spray of a fuel with a high density penetration is deeper the spray will not also diverse as it comes out of the nozzle. Since the viscosity of Jatropha, oil is higher than diesel this can lead to poor atomization and mixture formation with air. This will lead to slower combustion, lower thermal efficiency, higher emissions of smoke and HC etc.

The specific gravity of karanja 1.091 times more than the diesel. The viscosity at normal temperature is 14.04 times more for karanja oil. Considerable reduction in viscosity reported with the increase in temperature around 80 to 90°C. The calorific value of karanja and Mahua oil is 84.72% and 88.26% of diesel respectively and considered plus point when compared with ethanol and methanol. He also reported pour point of karanja oil is slightly more than diesel but Mahua oil has considerable higher pour point thereby indicating problems in the fuel flow at low atmospheric temperature. The flash point of both fuels is too above that of diesel fuel indicating its in-volatile nature. The carbon residue is also higher for both the oils, which creates problems of carbon deposition on injector, valve faces, piston head and the water content in the oil is negligible. In addition, reported viscosity of Jatropha, Mahua oil reduces with increase in temperature, and drastic reduction obtained at 80 to 90°C. Also reported flash point of karanja oil found to be greater than 100°C, which is safe for storage and handling and reported viscosity of karanja oil 10 times greater than diesel oil.

**Engine performance with vegetable oil esters as fuel**

The important compositional difference between biodiesel and the diesel fuel is concerned with oxygen content. Biodiesel contains 10–12% oxygen in weight basis and this lowers the energy content. The lower energy content causes reductions in engine torque and power. Biodiesel containing oxygen reduces exhaust emissions such as HC, smoke and CO mainly due to the effect of complete combustion. Since biodiesel contains little or no sulphur compared to the diesel fuel, a significant reduction in SO2 emission was obtained. There are four possible reasons for reduction in particulate emissions. First is the presence of oxygen in fuel rich regions of the combustion fuel spray. Second is the modification of radical pool, which inhibits key soot formation reactions and provides OH radicals for oxidation of soot precursors. Third, is the removing carbon from soot formation process via C–O bonding within molecule
due to oxygen, thereby sequestering carbon from the soot formation process. Fourth is the low level of sulphur content of biodiesel. NOx emissions mainly depend on the engine fuelling system, engine type and engine loading. Two different observations can be seen in the literature. First, higher NOx emissions may be due to higher temperatures of combustion chamber using biodiesel. This is also evident from higher exhaust gas temperatures from biodiesel-fuelled engines. However, some studies showed lower NOx emissions. This is because higher cetane numbers of biodiesel shortens the ignition delay. The amount of premixed fuel and peak burning temperature reduced, leading to the reduction in NOx emissions.10,11

There was a decrease in brake thermal efficiency and increase in specific fuel consumption when Jatropha oil-diesel blends used as fuel. The reason claimed for increased specific fuel consumption was combined effects of the relative density, viscosity and heating value of the blends and for decreased thermal efficiency were poor combustion characteristics of Jatropha oil due to higher viscosity and poor volatility. Author claimed in paper that blends containing 30:70 and 40:60 J/D have specific fuel consumption very close to that of diesel. However, the actual values reported by him are 7 and 15 % higher respectively. He also claimed that higher exhaust temperature with blends was indicative of lower thermal efficiencies of the engine which is obvious, however, the higher exhaust gas temperature also point to the late burning of fuel and hence inefficient combustion process.12,13

The energy content of tobacco seed oil was 39.4 MJ/kg. Tobacco seed oil was less viscous (27.7 cSt) compared to the other vegetable oil. The calculated cetane number of tobacco seed oil was 38.7, which was within the typical cetane number range of all vegetable oils. Compared to the other vegetable oils, tobacco seed Oil has the lowest flash point of 220 °C. All vegetable oils have relatively high flash points, so they considered safe fuels under normal. It has the lowest cloud point of -7.8 °C. Moreover, its pour point was -14 °C; also reported the disadvantage of the commonly used seed oils is the inadequate cold flow performance during winter compared to the other vegetable oils14,15.

MATERIAL AND METHODS
The experiment of performance and emission characteristics were conducted on a typical four-stroke, single cylinder, constant-speed, water-cooled, direct-injection diesel engine. The engine coupled with an eddy current dynamometer. The dynamometer used for loading the engine. Tests conducted at no-load, 20, 40, 50, 60, 80, and 100% of rated load for all fuels. Engine speed maintained at 1500 rpm (rated speed) during all experiment. Fuel consumption, inlet air-flow rate and exhaust temperatures also measured. The smoke opacity of the exhaust gases measured by smoke opacimeter (Make AVL Austria; Model: 437). Exhaust gas composition was measured using NDIR based exhaust gas analyzer (Make AVL Austria; Model: 444 Digas). This analyzer measures CO₂, CO, HC, NO and O₂ in the exhaust gas. The specification of engine and exhaust gas analyzer shown in Table 3 and Table 4.
Table 3: Technical specification of the engine and the dynamometer

<table>
<thead>
<tr>
<th>Engine specification</th>
<th>Kirloskar Oil Engine Ltd. India</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Kirloskar Oil Engine Ltd. India</td>
</tr>
<tr>
<td>Model</td>
<td>TV-1</td>
</tr>
<tr>
<td>Engine</td>
<td>4-stroke, single cylinder, Constant speed, Direct Injection, Compression Ignition</td>
</tr>
<tr>
<td>Rated power</td>
<td>4.2 kW at 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>Compression Ratio</td>
<td>17.5</td>
</tr>
<tr>
<td>Nozzle opening pressure</td>
<td>200-220 bar</td>
</tr>
<tr>
<td>Displacement Volume</td>
<td>661 cc</td>
</tr>
<tr>
<td>Connecting Rod Length</td>
<td>234 mm</td>
</tr>
<tr>
<td>Fuel flow measurement</td>
<td>Fuel measuring unit with DPT</td>
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<tr>
<td>Air flow Measurement</td>
<td>Orifice meter with manometer and DPT</td>
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</table>

<table>
<thead>
<tr>
<th>Dynamometer Specification</th>
<th>Eddy Current</th>
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</thead>
<tbody>
<tr>
<td>Type</td>
<td>Eddy Current</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>SAJ India</td>
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<tr>
<td>Model</td>
<td>AG10</td>
</tr>
<tr>
<td>Load Measurement</td>
<td>By load cell</td>
</tr>
</tbody>
</table>

Fig. 1: Experimental Set-up
RESULTS AND DISCUSSION
Specific gravity of diesel, karanja methyl ester and their blends

Fig. 1 shows Specific gravity of diesel, karanja oil ester and their blends B80, B60, B40, B20 at 20 °C are 0.848, 0.895, 0.884, 0.872, 0.860, 0.859 gm/cc respectively. Specific gravity of diesel is lower as compared to other blends with KBD and Specific gravity of KBD highest at this temperature. Specific gravity of diesel, karanja oil ester and their blends B80, B60, B40, B20 at 80 °C are 0.820, 0.855, 0.850, 0.830, 0.821, 0.815 gm/cc respectively. Continuous reduction in Specific gravity for diesel and all the blends observed, at this temperature.

![Image of a graph showing the effect of temperature on specific gravity](image)

**Fig.1:** Effect of temperature on Sp. Gravity

Viscosities of diesel, karanja oil methyl ester and their blends at different temperatures.

Fig. 2 shows The Kinematic viscosity of diesel karanja oil ester and their blends B80, B60, B40, B20. At 20 °C are 4.63, 13.3, 11.7, 10.7, 9.4, 8.01 cSt respectively. Whereas for the temperature at 80°C the Kinematic viscosity for crude karanja oil was found to be 2.05, 3.8, 3.5, 3.3, 2.95, 2.05Cst respectively. Similar pattern of Kinematic viscosity was reported by Senthil, et al,
Suryawanshi, et al and. It was found that with the increase in temperature, viscosity of Karanja methyl ester decreased. It was observed that at 80 °C B20 blend has same viscosity as compared to diesel. Reduction in viscosity is mainly due the removal of glycerol molecules present in the vegetable oil by transesterification process.

![Fig. 2: Effect of temperature on viscosity](image)

**Effect of load percentage on brake specific fuel consumption**

The variation in brake specific fuel Consumption with Brake power for different fuels shown in Fig. 3. The mean brake specific fuel Consumption for the blends were higher than that of diesel for every 20% additional blending of biodiesel in diesel. As the brake specific fuel Consumption was calculated on weight basis, obviously higher densities resulted in higher values for brake specific fuel Consumption. As the density of karanja biodiesel was higher than that of high-speed diesel, this means the same fuel Consumption on volume basis resulted in higher biodiesel blends caused higher mass injection. The heat content of pure karanja biodiesel was lower than diesel by about 12%. Due to these reasons, the brake specific fuel Consumption for other blends, namely B40, B60, B80 and karanja biodiesel were higher than that of high-speed diesel. As shown in figure Fig. 3 at rated load BSFC for diesel and all the blends higher, i.e. for diesel 0.23 kg/ kWh and For B100, B80, B60, B40, B20 were 0.291, 0.271, 0.257, 0.246, 0.238 kg/ kWh respectively.

![Fig. 3: Effect of load percentage on specific fuel consumption](image)
Effect of load percentage on brake thermal efficiency

The brake thermal efficiency obtained for different fuels is shown in Fig. 4, as a function of load for compression ratios of 15:1. It can be seen from this figure that the brake thermal efficiency in general reduced with the increasing concentration of karanja biodiesel in the blends. The variations in brake thermal efficiency between various blends at full load conditions was less than those at part loads, due to the increased temperatures inside the cylinder, as more amount of fuel burnt at higher loads. The brake thermal efficiency of the engine is one of the most important criteria for evaluating the performance of the engine. It indicates the combustion behavior of the engine to a greater extent. Brake Thermal Efficiency for B100 lower as compared to all the fuel blends at all conditions. at rated load Brake Thermal Efficiency for diesel and all the blends lower and it is noticed that Brake Thermal Efficiency increased with increasing fuel blend it is higher for diesel, i.e. for diesel 28.9 % and For B100, B80, B60, B40, B20 were 27, 27.2, 27.5, 27.8, 28.3 % respectively.

Effect of load percentage on NOx emissions

It is obvious from the fig.05 that the increase of NOx emissions at all the load and fuel blends. Increase in NOx emissions due to larger delay period of karanja biodiesel.
Effect of load percentage on HC emissions

From the Fig. 6 it can be seen that HC emission reduces due to the increase in fuel blends. Reductions in HC emissions due to karanja biodiesel contain 10-12% Oxygen in the fuel itself which promotes complete combustion.

![Fig. 6: Effect of load % on HC emission](image)

Effect of load percentage on CO emissions

From the Fig. 7, it has been observed that there is reduction in CO emission at all load and fuel blends. This reduction shows the better combustion phenomena of the karanja biodiesel blends. This reduction is good signal for environmental protection through global warming.

![Fig. 7: Effect of load percentage on CO emission](image)

Effect of load percentage on smoke emission

From Fig. 8 it is observed that smoke opacity increases with engine load higher blend concentration lower smoke at even lower load. Lower Smoke opacity may be due to 11% oxygen contain in Karanja oil itself.
CONCLUSION

Initially the engine was run on pure diesel and base line data generated. Then the engine was run on biodiesel and there blends at different load conditions. The performance and emission characteristics were measured for no load, 20%, 40%, 60%, 80%, and 100%. The respective graphs plotted and trends were analysed.the analysis gave an insight on the behavior of the engine at different loads with fuel blends. Based on the results of this study; the following specific conclusions were drawn:

The results obtained from the study conclude that

1. All the Bio diesel blends show reduced sp. Gravity with rise in temperature.
2. The Bio diesel blends have comparable viscosity with diesel between 50\(^\circ\)-80\(^\circ\) C. B20 had almost the same value as that of diesel fuel.
3. Fuel properties of diesel, karanja oil and blends are comparable.
4. The maximum brake thermal efficiency was observed for diesel and with blends for B20 blends.
5. Bsfc is the inverse brake thermal efficiency hence best value of Bsfc were just similar to the brake thermal efficiency trends.
6. The most suitable blend from emission point of view was found to be 100 per cent karanja lower emission compared to diesel.

REFERENCES


Environment is
GOD’S GIFT
preserve it