



Feasibility study of using used edible oil with diesel in diesel engine

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Abstract

The paper address a recent changes in political relations between net fossil oil producing countries and net fossil oil consuming countries, instability in oil producing regions as well as the depletion of many existing oil fields make fuel supply is anything but insecure. Development of vegetable oil fuels could lead to greatly reduced dependence on fossil oils. Keeping this in mind possibility of the use of vegetable oils in a diesel engine is experimentally evaluated in the present research. A series of tests are conducted and repeated for each of the test fuels. The engine works at a constant speed of 1500 rpm, but at different loads & blends of used cooking oil. The performance and the behavior of the fuel in diesel engine are analyzed and compared. As vegetable are costly & require large land area for production the used oil of food industry is the best alternative to be used as biofuel regarding cost.

Keywords: diesel engine, edible oil, fossil oil

Introduction

Edible oil blends

Rudolf Diesel invented the compression ignition engine in year 1893 that could operate at higher compression ratio and was 30% more efficient than a petrol engine. Rudolf Diesel could run this engine with vegetable oil.

The vegetable oil molecule is composed of three long carbon chains on a glycerol 'backbone' and its properties are determined by the individual fatty acid chains. Vegetable oil is an alternative fuel for diesel engine, however the viscosity of the vegetable oil must be lowered to allow for proper atomization of the fuel, otherwise incomplete combustion and carbon build up will ultimately damage the engine.

Blends: Blends are the mixture of biofuel and conventional hydrocarbon-based diesel. "B" factor is used to state the amount of blending. For example B20 refers 20% biofuel, while pure biofuel is referred as B100.

Biofuels: Biofuels are the liquid fuels derived from plant materials. These are entering in the market due to oil price hikes and need for energy security. The biofuels offer the following characteristics:

1. Biofuel can be used in the existing engine without any modifications.
2. Biofuel is made entirely from vegetable sources. It does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
3. Biofuel is an oxygenated fuel. Emissions of carbon monoxide and soot tend to reduce.
4. Biofuel is produced from renewable vegetable oils. We can use vegetable oil both in its neat form and modified form. It is to be noted that the usage of vegetable oils in neat form is possible but not preferable. The high viscosity of vegetable oils and the low volatility affects the atomization and spray pattern of fuel, leading to incomplete combustion and severe carbon deposits,

injector choking and piston ring sticking.

5. The methods used to reduce the viscosity are
 - a. Blending with diesel
 - b. Emulsification
 - c. Pyrolysis
 - d. Transesterification

Advantages of natural vegetable oil

Vegetable oils have high calorific value and energy density. Ease of handling due to existence liquid form. Minimized soot emission. High energy efficiency while burned. It is neither harmful nor toxic to human beings, animals, soil or water. It is neither flammable nor explosive, and does not release toxic gases. It does not cause damage if accidentally spilled. Its handling does not require special care to be taken. It is produced directly by nature therefore it does not have to be transformed. It is a recyclable form of energy. It does not have adverse ecological effects. It does not contain sulfur therefore avoid effects like acid rains. When burned it is neutral in CO₂ therefore no contribution to the greenhouse effect.

Literature Review

J Patterson: J Patterson in their paper concluded that Methyl esters derived from vegetable oils by the process of transesterification (commonly referred as 'biodiesel'), can be used as an alternative fuel in compression ignition engines. In this study, three different vegetable oils (rape, soy and waste oil) were used to produce biodiesel fuels that were then tested in a four cylinder direct injection engine. Engine performance and emissions were recorded at five load conditions and at two different speeds. Engine performance and emissions for all of the 5% biodiesel blends were indistinguishable from mineral diesel. However, at higher blends, the rape fuel exhibited better emission and performance characteristics than either the soy or waste fuels. Furthermore while emissions

trends varied for each blend and fuel, emissions of smoke were significantly reduced at all speed and load conditions, and NO_x was reduced by up to 50% at low loads. It was also shown that while engine performance was not significantly deteriorated by biodiesel, there was evidence of increased ignition delay with higher blends, and a possible two stage ignition process where mineral diesel ignited earlier than the biodiesel.

In another research alternative fuel investigations were carried out on a single cylinder, direct injection, water cooled diesel engine operating on diesel, straight vegetable oils (Thumba oil and Neem) and 20% biodiesel blend of Thumba oil. The experiment covered a range of loads. Results show that Thumba oil can be used as an alternative fuel with better performance and lower emissions compared to Neem oil. The most significant conclusion is that 20% biodiesel blend of Thumba oil shows maximum brake power, reduced BSFC, emissions, smoke opacity and NO_x than straight vegetable oils.

G Laxmi Narayan Rao: According to G. Laxmi Narayan Rao Transesterified vegetable oils (biodiesel) are promising alternative fuel for diesel engines. Used vegetable oils are disposed from restaurants in large quantities. But higher viscosity restricts their direct use in diesel engines. In this study, used cooking oil was dehydrated and then transesterified using an alkaline catalyst. The combustion, performance and emission characteristics of Used Cooking oil Methyl Ester (UCME) and its blends with diesel oil were analyzed in a direct injection C.I. engine. The fuel properties and the combustion characteristics of UCME were found to be similar to those of diesel. A minor decrease in thermal efficiency with significant improvement in reduction of particulates, carbon monoxide and unburnt hydrocarbons was observed compared to diesel. They concluded that the use of transesterified used cooking oil and its blends as fuel for diesel engines will reduce dependence on fossil fuels and also decrease considerably the environmental pollution.

Sergio C. Capareda: In their research on engine performance and exhaust emissions of cottonseed oil biodiesel shown that when using cottonseed oil biodiesel blends, CO, total hydrocarbon (THC), NO_x, and SO₂ emissions decreased as compared to petroleum diesel. Carbon dioxide emissions had no definitive trend in relation to cottonseed oil biodiesel blends. Carbon monoxide emissions increased by an average 15% using B5 and by an average of 19% using B100. Hydrocarbon emissions decreased by 14% using B5 and by 26% using B100. Nitrogen oxide emissions decreased by four percent with B5, five percent with B20, and 14% with B100. Sulfur dioxide emissions decreased by an average of 86% using B100, and by 94% using B50 blended with ultra-low sulfur diesel. The difference between peak output power when using biodiesel and when using diesel was insignificant in blends less than B40. Peak brake power when using B100 was about five percent lower than for diesel fuel. Pure cottonseed oil biodiesel achieved and maintained a peak corrected brake power of 13.1 kW at speeds of 2990, 2875, and 2800 rpm at loads of 41.3, 42.7, and 43.8 N-m. Using B5 produced a peak power of 13.6 kW at 2990 rpm and 43.9 N-m and at 2800 rpm and 46.7 N-m, while using B20 produced a peak power of 13.4 kW at 2990 rpm and 43.7 N-m. Brake-specific fuel

consumption at peak load and torque when using B100 was 1238 g/kW-h. Brake-specific fuel consumption at peak power and loads using B5 and B20 were 1276 and 1155 g/kW-h.

The idea of using vegetable oils as fuel for diesel engines is not new. With the advent of cheap petroleum, appropriate crude oil fractions were refined to serve as fuel and diesel fuels and diesel engines evolved together. In the 1930s and 1940s vegetable oils were used as diesel fuels from time to time, but usually only in emergency situations.

Recently, because of increases in crude oil prices, limited resources of fossil oil and environmental concerns there has been a renewed focus on vegetable oils and animal fats to make biodiesel fuels.

Prof. Gao Zonying, Jiangsu University Zhenjiang, where Elsbett engines were tested in the eighties, addressed the concept of using plant "food" for fuel, indicating that petroleum should be the "alternative" fuel rather than vegetable oil and alcohol being the alternatives and some form of renewable energy must begin to take the place of the non-renewable resources.

Availability & feasibility of used cooking oil in diesel engine

The use of waste cooking oil (WCO) as an alternative to diesel in engines has clear benefits from economic and environmental point of view.

Used cooking oil has been considered as prospective fuel because it is less expensive than fossil fuels and vegetable oils. The used cooking oil is collected from various sources and can be easily used as fuel by simple refining process. Although used cooking oil has protein residues and impurities but the simplicity of refining process is making the used cooking oil more suitable.

Sources of used cooking oil

Oil Distributors: Large oil distributors, who have waste vegetable oil which has not met the specification for food purpose, may supply large quantity of such oil at low price. Although this will need additional heating but still can be kept cost competitive.

Snack Food Companies

Snack food companies are large producer of the used cooking oil. The oil has been used in cooking so this is much cleaner and of better quality.

Restaurants

Restaurants are the most common source of waste vegetable oil. The quantity and quality of this oil is largely dependent on what they fry and how often they change their oil. The longer oil is used before it is replaced, the thicker and dirtier it can become.

Sweet Shops

We can easily collect a large amount of used cooking oil from sweet shops which make snacks.

Cost Analysis

In developed countries used cooking oil is available at very low or at zero price. In India we can acquire used cooking oil at reasonable prices. A sample study was performed in Kota

city Rajasthan and findings are as follows:

Table 1

Study	Result
The fresh oil cost	Rs 70-80
The number of snacks shops in kota	100
Total quantity of waste oil	1/5 th per liter
The cost of waste oil	Rs 20/liter

“Major consumption of vegetable oil in Kota city is for kachory and samosa”. The following data are available:

Table 2

Study	Result
The Total No of shops in Kota	App.100
No of Big shops makes Kachori & samosa	50 shops, Rs. 2000/day
No of small shop	50, 1000/day
Luggage Rikshaw	200, 500/day
Total No of kachory & samosa	2.5 lakhs

Table 3

Study	Result
One can of vegetable oil	15 liter oil
Total No of kachory & samosa makes by one can	1500
Total No of consumption of oil	2500 liter
Waste oil	500 liter
Approximate waste oil other snacks (Namkeen)	100 liter
Total waste oil from kota city	600 liter/day

Use of waste vegetable oil as a fuel competes with some other uses of the commodity, which has effects on its price as a fuel and increases its cost as an input to the other uses as well.

Availability of used cooking oil in India and abroad

In U.K. processors get free used cooking oil from local restaurants. In USA fast food giants like McDonald's, Wendy's, Burger King and others supply tons of their used cooking oil almost free.

India is the largest consumer of edible oils, but availability of used cooking oil is very less here. It is because oil is reused till the end. Govt. should take some action to ensure the availability of used cooking oil at reasonable price and also takes some action to stop the reuse of used cooking oil so that the quality of food is maintained.



Fig 1: Single cylinder water cooled 4 stroke diesel engine

Engine Specification

Type: Single cylinder Water Cooled 4 Stroke Diesel Engine
 Bore =80mm
 Stroke = 110 mm
 Power 5 hp @ 1500 rpm
 Orifice dia = 25 mm
 Coefficient of discharge = 0.64
 CV of diesel = 42000kJ/kg
 Brake Drum Radius = 13.43 cm
 Max Load = 17.75 kg

Brake Horsepower

Shaft Power = $2\pi N T/60$ Watt
 N=rpm.

Torque $T = W*(R+t/2)$

Radius of drum $R=13.43$ cm

t = belt thickness = 6 mm

Net Load $W = T_1 - T_2$

Friction power we measure by Williams line Method

Indicated Horsepower

Indicated power $IP = F.P + B.P$

Indicated thermal efficiency

Indicated thermal efficiency is the ratio of energy in the indicated power to the input fuel energy.

$HITH = IP / \text{energy in the fuel per second}$

$HITH = IP / m.CV$

Brake thermal efficiency

Brake thermal efficiency is the ratio of energy in the indicated power to the input fuel energy.

$HBTH = BP / \text{energy in the fuel per second}$

$HBTH = BP / m.CV$

Mechanical Efficiency

Mechanical Efficiency is the ratio of brake power to the indicated power.

$H_m = BP/IP = BP/BP + FP$

Specific Fuel Consumption (SFC)

SFC = Fuel consumption per unit time /Power

ISFC = indicated Specific fuel consumption = m/IP

BSFC = brake Specific fuel consumption = m/BP

Break mean effective pressure

$IP = P_{im} \cdot L \cdot A \cdot n \cdot K / 60000$; where IP = indicated power (kW)

P_{im} = indicated mean effective pressure (N/m²)

L = Length of stroke (m)

A = Area of piston (m²)

N = No of power stroke = $N/2$ for 4-stroke engine

K = No. of cylinder

N = speed in rpm

Major Findings

The experimental results shown here in the form of table for “Mustard + Diesel” and “sesame + Diesel” Blends.

In Table the observations are being reported and calculated for “Mustard + Diesel” as B1 “sesame + Diesel” as B2 Blends between load Vs fuel consumption.

Table 4

Load (kgf)	PD	B ₁ (10)	B ₁ (20)	B ₁ (30)	B ₁ (50)	B ₁ (80)	B ₁ (90)
0	0.125	0.117	0.117	0.105	0.117	0.125	0.125
4	0.16	0.153	0.142	0.153	0.143	0.142	0.14
8	0.18	0.2	0.21	0.16	0.188	0.2	0.2
12	0.25	0.25	0.22	0.22	0.238	0.22	0.22
15	0.28	0.28	0.285	0.285	0.263	0.25	0.25

Table 5

Load (kgf)	PD	B ₂ (10)	B ₂ (20)	B ₂ (30)	B ₂ (50)	B ₂ (80)	B ₂ (90)
0	0.125	0.105	0.11	0.125	0.115	0.125	0.125
4	0.16	0.153	0.153	0.16	0.153	0.142	0.133
8	0.18	0.18	0.18	0.2	0.196	0.2	0.2
12	0.25	0.22	0.21	0.25	0.25	0.23	0.26
15	0.28	0.25	0.25	0.28	0.28	0.285	0.285

Table 6

Load	PD	B ₁ (10)	B ₁ (20)
0	0.125	0.117	0.117
4	0.16	0.153	0.142
8	0.18	0.2	0.21
12	0.25	0.25	0.22
15	0.28	0.28	0.285

(Load Vs. Fuel Consumption)

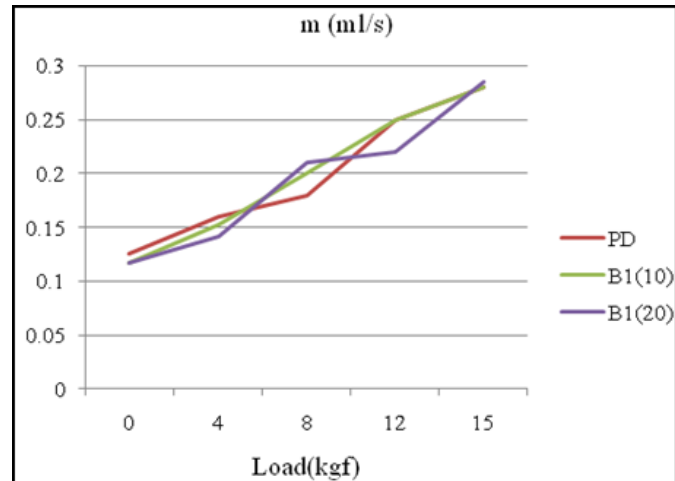


Fig 2: Showing the variation of fuel consumption with load with PD, B1 (10) and B1 (20).

Table 7

Load	PD	B ₁ (30)	B ₁ (50)
0	0.125	0.105	0.117
4	0.16	0.153	0.143
8	0.18	0.16	0.188
12	0.25	0.22	0.238
15	0.28	0.285	0.263

(Load Vs. Fuel Consumption)

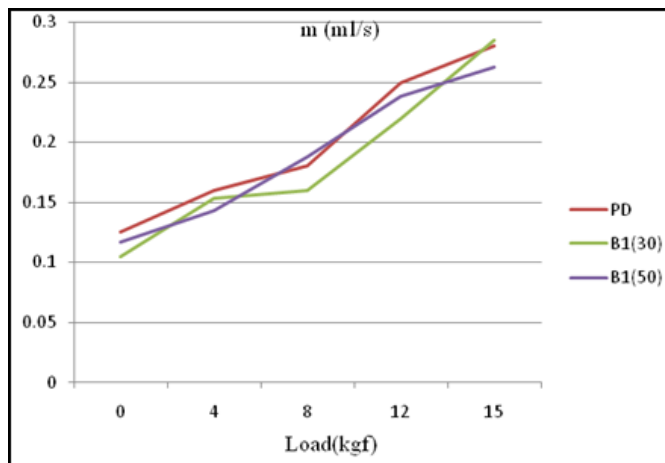


Fig 3: Showing the variation of fuel consumption with load with PD, B1 (30) and B1 (50).

Conclusion

The basic engine performance i.e. power output, fuel consumption, specific fuel consumption with edible oil blends are almost similar to that of pure diesel.

The thermal efficiency is increased with load but it is irrelevant regarding the performance of engine.

It is very important that bio fuel is greener and hence less polluting. Bio fuels have the great advantage over fossil fuels of being potentially carbon neutral. Carbon dioxide produced through their combustion is absorbed by the next oil crop grown, offering a sustainable carbon cycle. Other edible oils like coconut oil, Ground nut canola oil, corn oil, palm oil and peanut oil, used cooking oil which have the physical & chemical properties similar to the sesame oil can also be used as fuels.

Developing country like India is major consumer of vegetable oil for food preparation, results in a higher possibility of used cooking oil availability. The used cooking oil can easily be used as a replacement to diesel by simple filtration process. Multiple times reuse of cooking oil in food preparation restricts the availability of used cooking oil but right food preparation policy in place can cope with such limitations. Educating masses in the country regarding use of vegetable oil as major fuel will generate jobs in fuel development, collection and storage logistics along with engine and equipment design. This will also make developing countries like India independent in terms of meeting fuel requirements.

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