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Study on Bio-Diesel as Alternate Fuel Used in I.C. Engines

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Abstract

One of the major incentives for expanding the production and use of bio-fuels worldwide is the potential environmental benefit that can be obtained from replacing petroleum fuels with fuels derived from renewable biomass resources. The use of vegetable oil in diesel engines is one of the available alternatives, but its use in existing vehicles usually requires modification of engine or fuel system components. The increased viscosity, low volatility, and poor cold flow properties of vegetable oils lead to severe engine deposits, injector coking, and piston ring sticking. The paper presents a literature review on vegetable oils as alternative bio-fuel for diesel engines.

Key words: Bio-Fuel: Diesel Engine: Vegetable Oil: Pollutants

Introduction

Renewable and alternative energy sources are becoming more demanding and necessary due to increases in crude oil prices and exhaust gas emissions due to fossil fuels throughout the world. Vegetable oils have their own advantages: first of all, they are available everywhere in the world. Secondly, they are renewable as the vegetables which produce oil seeds can be planted year after year. Thirdly, they are "greener" to the environment, as they seldom contain sulphur element in them. This makes vegetable fuel studies become current among the various popular investigations. So does the evaluation of the performance of diesel engines when fuelled with vegetable oils. A number of investigations have been made, and the test results have proved that vegetable oils are feasible substitutes for diesel fuel. The main problem of using vegetable oils in diesel engines is the high viscosities of such fuels. Chemical and thermal methods are the two techniques to reduce viscosities of vegetable oils. The thermal method uses preheating of fuels, which increases the temperature and reduces viscosity. Chemical methods can be divided into dilution, pyrolysis, trans esterification and micro emulsion. Fuel blending has the advantages of improving the use of vegetable oil fuel with minimal fuel processing and without engine modifications [1-3].

A variety of vegetable oils such as those from soybean, rapeseed, sunflower, jatropha – carcass, palm, and cottonseed etc. have been widely investigated for production of biodiesel. Rapeseed oil and some other vegetable oils when transformed to their methyl esters have many characteristics such as density, viscosity, energy content, and cetane number close to that of diesel. Recently non-edible oil produced from jatropha-curcass seeds has gained interest as this plant can be easily grown on wastelands [4-5].

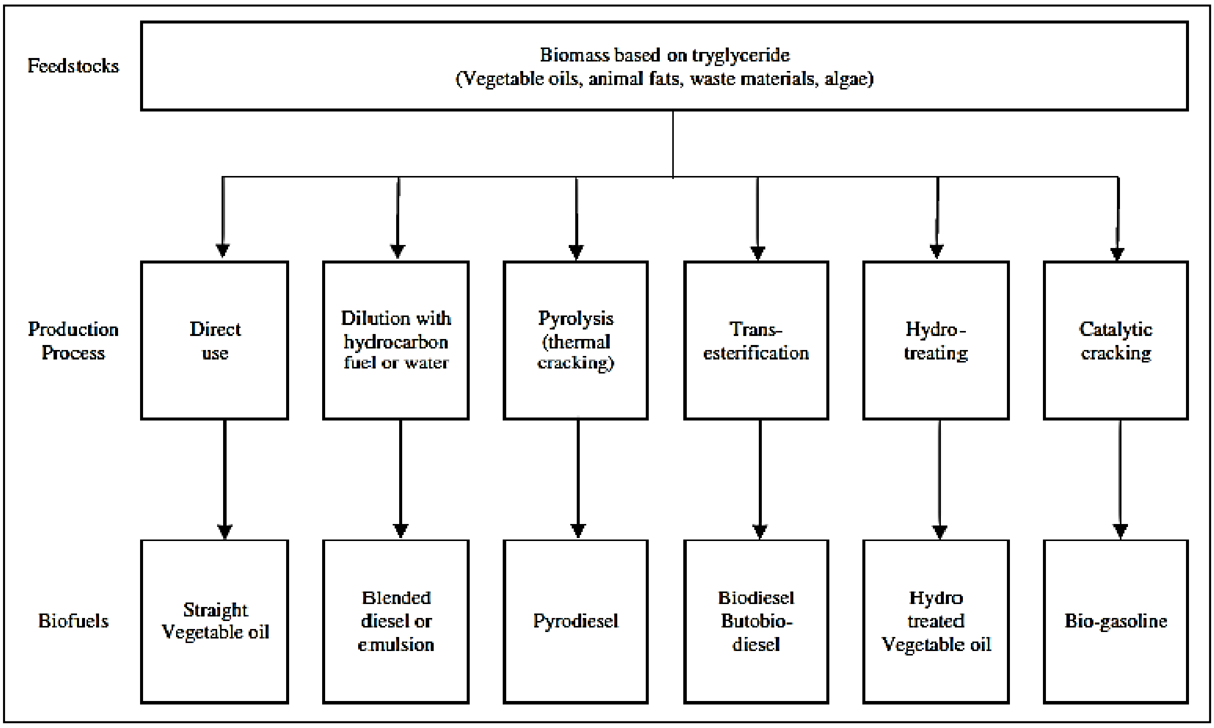
The vegetable oil esters are practically free of sulphur and have a high certain number generally in the range 46 to 60 depending upon the feedstock. The certain number of methyl esters tends to be slightly lower than of ethyl or higher esters. Biodiesel from saturated feed stocks such as animal fat and recycled restaurant cooking fats will generally have a higher certain number than the esters of oils high in poly-unsaturated such as soybean oil. Due to presence of oxygen, biodiesel have a lower calorific value than the diesel fuels [6-7].

The emission studies show that the use of biodiesel results in reduction of CO, HC and PM, but slight increase in NOx emissions. Reduction in CO emission could probably be attributed to presence of oxygen in the fuel molecule. Decomposition of biodiesel produces a variety of oxygenated hydrocarbons in addition to hydrocarbons. Response of the standard HC measurement technique, the heated flame ionization detector is different for the methyl esters than HC emission and this could be partly responsible for the difference in HC emissions between the normal diesel fuels and biodiesel. The methyl esters have a lower compressibility, which results in advance of dynamic injection timing.

Composition and Properties of Bio-Fuel

Fats and oils (lipids) consist of 95-98% triglycerides. Minor constituents present in oils include free fatty acids, mono- and di-glycerides, phospholipids, tocopherols, sterols, natural coloring agents as well as more or less volatile odorous compounds. Triglycerides are composed of a glycerol molecule esterified with three similar or different fatty acid molecules.

Figure (1): Production process for liquid bio-fuels from biomass feed stocks.



Biodiesel compared to diesel. Change in injection timing and differences in cetane number and combustion characteristics and particulate emissions are observed to be significantly lower with biodiesel compare to diesel fuels. Volumetric fuel consumption with biodiesel is higher than diesel due to its lower heating value. An increase of 10-11% in fuel consumption compared to diesel may be expected when comparing their heating values.

Some twenty fatty acids are found in nature and their numerous possible combinations with the three alcohol functions of the glycerol produce a wide variety of triglycerides and therefore of oils. Generally, biomass-derived feed stocks for the production of liquid bio-fuels can be classified into the following three categories according to the source, i.e. triglyceride-based biomass, starch- and sugar-derived biomass, and cellulosic biomass. A variety of liquid bio-fuels can be produced from triglycerides based biomass such as vegetable oils, animal fats, waste cooking oils and microalgae oils as shown in (Figure. 1) [8-10].

Vegetable oils first developed as fuel for direct use, after more or less deep purification. The oil most frequently produced from rapeseed and sunflower, are composed of fatty acids with carbon chains (18 carbon atoms) including three chains globally longer than those of the hydrocarbons found in diesel. These oils have high molecular weights, about 0.88 kg/mole, density above 910 kg/m3, and low volatility. On heating, they generally crack at temperatures in the region of 300°C. The main characteristics of vegetable oils appear in (Table 1) [11-15]. The usage of vegetable oils as diesel fuel depends on world market prices for mineral products and is therefore of special interest at present only for countries with a large excess of vegetable oil production. It is essential to measure three characteristic parameters to ensure that the fuel used is indeed pure vegetable oil and to confirm the vegetable origin: density, viscosity and carbon residue.

The density specification is suitable for excluding material other than vegetable oil, or for detecting mixtures of vegetable oil with other liquids (petroleum products, glycerol, etc.). The density of vegetable oils is slightly variable between 900 and 960 kg/m3 [16-18].

The straight vegetable oils (SVO) viscosity is much higher than that of diesel fuel: it increases with the carbon chain lengths. SVO high viscosity causes:

(i) Decrease in injection rate due to head losses in fuel injection pumps, filters and injectors,

(ii) Poor fuel atomisation and vaporisation by the injectors, which leads to incomplete combustion inside the combustion chamber. This results in lower thermodynamic efficiency and an increase in soot emissions and particle matters.

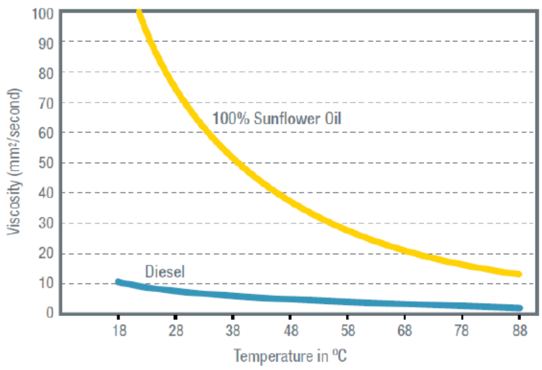
Table (1): Properties of bio-fuel.

Vegetable oil	Viscosity at 40°C (mm^2/s)	Carbon residue (% w)	Cetane number	GCV (kJ/kg)	Ash content (% w)	Sulphur content (% w)
Cotton	33.7	0.25	33.7	39.4	0.02	0.01
Poppy	42.4	0.25	36.7	39.6	0.02	0.01
Rapessed	37.3	0.31	37.5	39.7	0.006	0.01
Sunflower	34.4	0.28	36.7	39.6	0.01	0.01
Sesame	36	0.25	40.4	39.4	0.002	0.01
Flax	28	0.24	27.6	39.3	0.01	0.01
Palm	63.6 (30°C)		42			
Jatropha	49.9 (38°C)		40-45			
Castor	29.7	0.21	42.3	37.4	0.01	0.01
Soya	33.1	0.24	38.1	39.6	0.006	0.01
Peanut	40	0.22	34.6	39.5	0.02	0.01
Hazelnut	24	0.21	52.9	39.8	0.01	0.02
Walnut	36.8	0.24	33.6	39.6	0.02	0.02
Almond	34.2	0.22	34.5	39.8	0.01	0.01
Olive	29.4	0.23	49.3	39.7	0.008	0.02
Wheat	32.6	0.23	35.2	39.3	0.02	0.02
Corn	35.1	0.22	37.5	39.6	0.01	0.01
Diesel	2-4.5		47			

Viscosity is a rapid indicator of fuel quality before use, especially if the nature of the feedstock is not well known, or if the oil could have been deteriorated or polymerized during storage.

As (Figure 2) [19-20] indicates, the viscosity of pure SVO is much higher than that of diesel fuel at normal operating temperatures. This can cause premature wear of fuel pumps and injectors and can also dramatically alter the structure of the fuel spray coming out of the injectors to increase droplet size, decrease spray angle, and increase spray penetration.

Figure (2): Effect of temperature on viscosity of Sunflower oil as comparison to diesel.



Effect of Bio-Fuel on Combustion

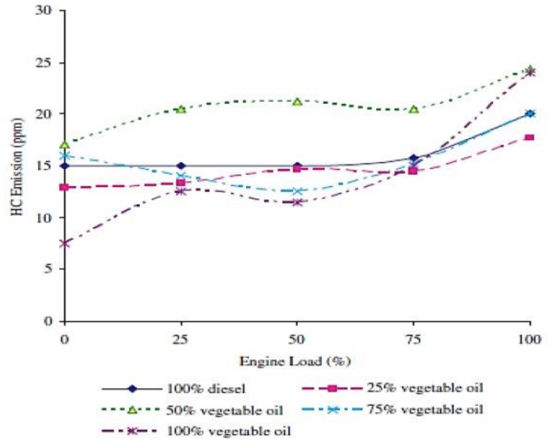
As biodiesel is produced from vegetable oils or animal fats, its use has been promoted as a means for reducing greenhouse gas CO2 emissions that would otherwise be produced from the combustion of Petroleum-based fuels. The total impact that biodiesel

could have on global warming would be a function not just of its combustion products but also of the emissions associated with the full biodiesel production and consumption lifecycle. On an average the carbon content on mass basis of plant-based biodiesel is 77.8% and of animal fat based biodiesel is 76.1% compared to 86.7% for the Petroleum based diesel [21].

Since biodiesel is free from sulfur hence less sulfate emissions and particulate reduction is reported in the exhaust. Due to near absence of sulfur in biodiesel, it helps reduce the problem of acid rain due to transportation fuels.

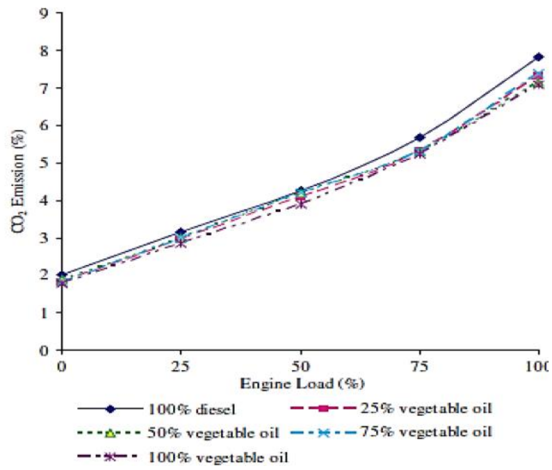
Higher thermal efficiency, lower BSFC and higher exhaust temperatures are reported for all blends of biodiesel compared to mineral diesel Biodiesel is oxygenated fuel (hence more complete combustion) and causes lesser particulate formation and emission. This is also due to oxygenated nature of biodiesel where more oxygen is available for burning and reducing hydrocarbon emissions exhaust as shown in the (Figure 3) [22].

Figure (3): Effect of bio-fuel blend on HC emission.



The biodiesel have a slightly higher carbon content per unit energy (2.068 kg/100MJ) than the conventional diesel (2.042 kg/100MJ) and thus may be expected to give higher CO2 emissions on combustion. The measured data however, suggest that the combustion generated CO2 from biodiesel and conventional diesel are substantially similar as shown in (Figure 4) [23].

Figure (4): Effect of bio-fuel blend on CO2 emission.



The cost of producing methyl or ethyl esters from edible oils is currently much more expensive than hydrocarbon based diesel fuel. Due to the relatively high costs of vegetable oils (about 1.5 to 2 times the cost of diesel), methyl esters produced from it cannot compete economically with hydrocarbon-based diesel fuels unless granted protection from considerable tax levies applied to the latter. In absence of tax relief, there is a need to explore alternate feedstock for production of biodiesel [24].

The cost of bio-diesel can be reduced further if we consider non-edible oils and used frying oils instead of edible oils. Non-edible oils such as mahua, karanja, babassu, jatropha, neem etc., are easily available in many parts of the world, and are cheaper compared to edible oils. Most of these non-edible oils are not used to their potential and in fact produced in surplus quantities. Several countries including Netherlands, Germany, Belgium, Austria, USA, Japan and India discard used frying oils. With the mushrooming of fast food centers and restaurants in the world, it is expected that considerable amounts of used-frying oils will be discarded. This oil can be used for making biodiesel, thus helping to reduce the cost of water treatment in the sewerage system and in the recycling of resources [25].

Conclusions

Vegetable oils are usually available everywhere in the world and are renewable as the vegetables which produce oil seeds can be planted year after year. Also, they are "greener" to the environment, as they seldom contain sulphur element in them. The main problem of using vegetable oils in diesel engines is the high viscosities of such fuels. Due to the need to adapt the combustion time, use of vegetable oils in diesel engines generally leads to higher CO, HC and PM. In contrast, due to their slower combustion and lower temperatures in the combustion chamber, vegetable oils reduce NOx emissions. While vegetable oils represent an alternative fuel, they will continue to present risks related to their intrinsic characteristics, which neither car nor agricultural tractor and machinery manufactures are willing to assume. The results from some experiments prove that vegetable oil and its blends are potentially good substitute fuels for diesel engines in the near future when petroleum deposits become scarcer.

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