Bio-diesel as a fuel in I.C. engines – A review

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ABSTRACT
The rapidly increasing consumption of fossil fuel and petroleum products has been a matter of concern for the many countries which imports more crude oil. Because it causes huge foreign exchange out-go on the one hand and increasing exhaust emission on the other. Therefore it is necessary for the development of renewable energy sources. Vegetable oils have become more attractive recently because of their environmental benefits and it is made from renewable resources. Bio-diesel commands crucial advantages such as technical feasibility of blending in any ratio with petroleum diesel fuel, use of existing storage facility and infrastructure, superiority from the environment and emission reduction angle, its capacity to provide energy security to remote and rural areas and employment generation. There are more than 350oil bearing crops identified, among which only sun flower, sunflower, soybean, cottonseed, rapeseed, Jatropha curcas and peanut oils are considered as potential alternative fuels for Diesel engines. So a particular crop which is available in surplus within the country should be used to produce Bio-diesel. This paper reviews the extraction and properties of Bio-diesel, also the outcomes of the research work done in different countries. Also efforts has been made to includes the Bio-diesel scenario in India.

Keywords
Bio-diesel, Jatropha, curcas, renewable energy sources, blending, IC engine.

1 INTRODUCTION
The world energy demand has, for the last two decades, witnessed uncertainties in two dimensions. Firstly, the price of conventional fossil fuel is too high and has added burden on the economy of the importing nations. Secondly, combustion of fossil fuels is the main culprit in increasing the global carbon dioxide (CO2) level, a consequence of global warming. The scarcity and depletion of conventional sources are also cases of concern and have prompted research world-wide into alternative energy sources for internal combustion engines. Biofuels appear to be a potential alternative "greener" energy substitute for fossil fuels [3]. It is renewable and available throughout the world. The idea of using vegetable oils as fuel for diesel engines is not new [8]. Rudolph diesel used peanut oil to fuel one of his engines at the Paris Exposition of 1900. The problem of using neat vegetable oils in diesel engines relates to their high viscosity. The high viscosity will lead to blockage of fuel lines, flters, high nozzle valve opening pressures and poor atomization. One hundred percent vegetable oils cannot be used safely in DI diesel engines. The problems of high fuel viscosity can be overcome by using esters, blending and heating. Vegetable oils exhibit longer combustion duration with moderate rates of pressure rise, unlike petroleum derived fuels.

The use of vegetable oils, such as palm, soya bean, sunflower, peanut, and olive oil, as alternative fuels for diesel is being promoted in many countries [13]. Depending upon the climate and soil conditions, different countries are looking for different types of vegetable oils as substitutes for diesel fuels. For example, soya bean oil in the US, rapeseed and sunflower oils in Europe, palm oil in South-east Asia (mainly Malaysia and Indonesia) and coconut oil in the Philippines are being considered. Besides, some species of plants yielding non-edible oils, e.g. jatropha, karanji and pongamia may play a significant role in providing resources. Both these plants may be grown on a massive scale on agricultural/degraded/waste lands, so that the chief resource may be available to produce biodiesel on 'farm scale'.

This paper gives a review of biodiesel production, experimental investigation on different vegetable oils, characterization, results obtained use of by bio-diesel are briefed.

2 BIO-DIESEL PRODUCTION
Many standardized procedures are available for the production of bio-diesel fuel oil [3]. The commonly used methods for bio-fuel production are elaborated below.

2.1 Blending
Vegetable oil can be directly mixed with diesel fuel and may be used for running an engine. The blending of vegetable oil with diesel fuel in different proportion were experimented success-fully by various researchers. Blend of20% oil and 80% diesel have shown same results as diesel and also properties of the blend is almost close to diesel. The blend with more than 40% has shown appreciable reduction in flash point due to increase in viscosity. Some researchers suggested for heating of the fuel lines to reduce the viscosity.Although short term tests using neat vegetable oil showed promising results, longer tests led to injector coking, more engine deposits, ring sticking and thickening of the engine lubricant[14]. Micro-emulsification, pyrolysis and transesterification are the remedies used to solve the problems encountered due to high fuel viscosity. Although there are many ways and procedures to convert vegetable oil into a Diesel like fuel, the transesterification process was found to be the most viable oil modification process [3].

2.2 Transesterification

Transesterification is the process of using an alcohol (e.g. methanol, ethanol or butanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as a by product. Biodiesel, defined as the mono-alkyl esters of fatty acids derived from vegetable oil or animal fat, in application as an extender for combustion in diesel engines, has demonstrated a number of promising characteristics, including reduction of exhaust emissions [4]. Transesterified, renewable oils have proven to be a viable alternative Diesel engine fuel with characteristics similar to those of Diesel fuel. The transesterification reaction proceeds with catalyst or without catalyst by using primary or secondary monohydric aliphatic alcohols having 1–8 carbon atoms [14] as follows:

Triglycerides + Monohydric alcohol = Glycerine + Mono-alkyl esters

2.3 Micro –emulsification

To solve the problem of high viscosity of vegetable oil, micro emulsions with solvents such as methanol, ethanol and butanol have been used. A micro emulsion is defined as the colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the range of 1–150 nm formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles. These can improve spray characteristics by explosive vaporization of the low boiling constituents in the micelles. All micro emulsions with butanol, hexanol and octanol will meet the maximum viscosity limitation for diesel engines[13,14].

2.4 Cracking

Cracking is the process of conversion of one substance into another by means of heat or with the aid of catalyst. It involves heating in the absence of air or oxygen and cleavage of chemical bonds to yield small molecules[14]. The pyrolyzed material can be vegetable oils, animal fats, natural fatty acids and methyl esters of fatty acids. The pyrolysis of fats has been investigated for more than 100 years, especially in those areas of the world that lack deposits of petroleum. Since World War I, many investigators have studied the pyrolysis of vegetable oil to obtain products suitable for engine fuel application. Tung oil was saponified with lime and then thermally cracked to yield crude oil, which was refined to produce diesel fuel and small amounts of gasoline and kerosene.

3 PROPERTIES OF BIO-DIESEL

The fuel properties of vegetable oils indicate that the kinematics viscosity of vegetable oils varies in the range of 30–40 cSt at 38°C. The high viscosity of these oils is due to their large molecular mass in the range of 600–900, which is about 20 times more higher than that of diesel fuel. The flash point of vegetable oils is very high (above 200 8C). The volumetric heating values are in the range of 39–40 MJ/kg,as compared to diesel fuels (about 45 MJ/kg). The presence of chemically bound oxygen in vegetable oils lower their heating values by about 10%. The cetane numbers are in the range of 32–40.The Biodiesel esters were characterized for their physical and fuel properties, including density, viscosity, iodine value (IV), acid value, cloud point, pour point, gross heat of combustion and volatility. Methyl and ethyl esters prepared from a particular vegetable oil had similar viscosities, cloud points and pour points, whereas methyl, ethyl, 2-propyl and butyl esters derived from a particular vegetable oil had similar gross heating values. However, their densities, which were 2–7% higher than those of Diesel fuels, statistically decreased in the order of methyl similar to 2-propyl > ethyl > butyl esters [14]. The HVs of the Biodiesel fuels, on a mass basis, are 9–13% lower than diesel. The viscosities of Biodiesel fuels are twice that of diesel. The cloud and pour points of diesel are significantly lower than those of the Biodiesel fuels. The Biodiesel fuels produced slightly lower power and torque and higher fuel consumption than diesel.

Biodiesel is clean, efficient, natural energy alternative to petroleum fuels. Among the many advantages of Biodiesel fuel are : safe for use in all conventional Diesel engines, offers the same performance and engine durability as Diesel fuel, non-flammable and non-toxic, reduces exhaust emissions, visible smoke and odors. Biodiesel is better than Diesel fuel in terms of sulphur content (SC), flash point, aromatic content and biodegradability.

4 EXPERIMENTATIONS

A large number of experiments were carried out with vegetable oils as a replacement of I.C. engine fuel by researchers from various parts of the world. A summary of some of these experimental results is given below.

The various blends of rubber seed oil and diesel were prepared and its important properties such as viscosity, calorific value, flash point, fire point, etc. were evaluated and compared with that of diesel [1]. The blends were then subjected to engine performance and emission tests and compared with that for diesel. It was found that 50–80% of rubber seed oil blends gave the best performance. Long run tests were conducted using optimized blend and diesel. It was found that blend fueled engine has higher carbon deposits inside combustion chamber than diesel-fueled engine. Utilization of blends requires frequent cleaning of fuel filter, pump and the combustion chamber.Hence, it is recommended that rubber seed oil–diesel blend fuel is more suitable for rural power generation

Nwafor [2] conducted test with rapeseed oil with advancing injection timings on Petter model single cylinder, energy cell diesel engine. It is an air-cooled, high speed, indirect injection, four-stroke engine.The test results showed that plant oil fuels exhibited longer ignition delay with slower burning rates. The test results also showed that each alternative fuel requires injection advance appropriate to its delay period. The delay period was noted to be influenced by the engine load, speed and the system temperature. At the engine speed of 2400 rpm, there seems to be a significant increase in brake thermal efficiency when running on rapeseed oil fuel with standard injection timing. Mechanical efficiency was observed to be reduced with advanced timing compared to the standard timing test results at 2400 rpm. The engine ran smoothly with advance of 3.58° as compared to the standard timing. A further 1.58° advance tended to produce erratic behaviour of the engine. There seems to be a significant reduction in CO and CO2 emissions with advanced timing for the speeds tested. A moderate injection advance is recommended for operations at low engine speeds. The overall results indicate that vegetable oils exhibit longer combustion duration with moderate rates of pressure rise, unlike petroleum derived fuels.

Nwafor [3] investigated the effect of elevated fuel inlet temperature on the emission characteristics of diesel engine running on pure vegetable oil. Test runs were conducted on Petter model single cylinder energy cell diesel engine. It is an air-cooled, high speed, indirect injection four-stroke engine. The test results showed that the fuel consumption of heated and unheated oil operations at high loads was similar and higher than diesel fuel operation. The results indicate increases in exhaust temperature with heated oil over the other fuels. The heated fuel showed a comparative reduction in delay period over the unheated. The unheated oil and diesel fuel operations showed an increase in CO production as the load was increased. The plant fuels showed marginal increase in CO2 emissions over diesel fuel operation. The concentrations of HC in the exhaust were higher when running on diesel fuel. The heated fuel showed a marginal increase in HC emissions over the unheated plant fuel.

An experimental evaluation of using jojoba oil as an alternate Diesel engine fuel is conducted by *Huzayyin et al.[4]*.The tests were conducted on an air cooled, single cylinder, four stroke, direct injection Diesel engine has 100 mm bore, 105 mm stroke, compression ratio of 17 and a rated brake power of 5.775 kW at 1500 rpm without any modifications. At present jojoba desert shrub are grown in the USA, Latin America, South Africa and many other countries. In recent years, jojoba oil has become one of the most genuinely Egyptian products. Its chemical and physical properties have indicated a good potential of using jojoba oil as an alternative Diesel engine fuel. Blending of jojoba oil with gas oil has been shown to be an effective method to reduce engine problems associated with the high viscosity of jojoba oil. Reasonable viscosity values have been obtained using blend ratios as high as 60%J–40%D oil.

Gvidonas Labeckas et al. [5] conducted tests with blends of shale oil with diesel on naturally aspirated, four stroke, four cylinders, water cooled, direct injection Diesel engine. Shale oil is produced in Estonia from local oil shale. Test results show that when fuelling a fully loaded engine with shale oil, the brake specific fuel consumption at the maximum torque and rated power is correspondingly higher by 12.3% and 20.4%. However, the brake thermal efficiencies do not differ widely and their maximum values remain equal to 0.36–0.37 for Diesel fuel and 0.32–0.33 for shale oil. The total nitrogen oxide emissions from the shale oil at engine partial loads remain considerably lower although when running at the maximum torque and rated power, the NOx emissions become correspondingly higher by 21.8% and 27.6%.

Karaosmanoglu et al. [6] conducted long term tests using sunflower oil on single-cylinder direct injection, air cooled diesel engine, having a bore/stroke ratio of 108:110 mm.Engine tests were conducted at a speed of 1600 rpm under part load condition for 50 hour. An overall evaluation of results indicates that the sunflower oil can be proposed as a possible candidate for diesel fuel.During the test, the engine experienced no significant differences in drop or increase in power and fuel consumption. For studying changes in lubricating oil employed at the test, samples were taken and their characteristics analyzed. Lubricating oil characteristics exhibited no remarkable change. Changes that will take place at fuel injectors during the test were observed on quantitative bases. The nozzle of the injector emerged clean, without any formation of a cloggage. No significant problems were met during the engine tests of the sunflower oil

Silvio et al. [7] conducted tests using 100% palm oil on direct injection four-stroke 70 kW diesel-generator. The results proved that a diesel-generator set can be adapted to run with palm oil. Increasing the palm oil temperature the performance and endurance of the diesel generator increases compared to operation in ambient conditions. The deposits on the cylinder head presented high levels when the engine operated with palm oil heated at 50°C and acceptable levels when heated at 100°8C (almost similar to the operation with diesel oil).However, other engine modifications are required to improve lubricating oil degradation, performance, emissions and reach a more efficient combustion.

Narayana Reddy et al. [9] conducted tests with neat Jetropa oil on a single cylinder, constant speed, direct injection diesel engine by changing the engine operating parameters. Tests shown that advancing the injection timing from the base diesel value and increasing the injector opening pressure increase the brake thermal efficiency and reduce HC and smoke emissions significantly. Enhancing the swirl has only a small effect on emissions. The ignition delay with Jatropha oil is always higher than that of diesel under similar conditions. Improved premixed heat release rates were observed with Jatropha oil when the injector opening pressure is enhanced. When the injection timing is retarded with enhanced injection rate, a significant improvement in performance and emissions was noticed. Governoment of India is encouraging for the use of Jetropa oil as a Bio fuel in India.

China is rich in cottonseed and research on using cottonseed oil as diesel engine fuel has been intensively and widely studied there. From a technological point of view, the fuel property of cottonseed oil seems to meet the fundamental requirements of diesel engine.*Y.He et al. [10]* conducted tests with blend of 30% cottonseed oil and 70% diesel on diesel engine. The experimental results obtained showed that a mixing ratio of 30% cottonseed oil and 70% diesel oil was practically optimal in ensuring relatively high thermal efficiency of engine, as well as homogeneity and stability of the oil mixture. For this purpose, a modification of diesel engine structure is unnecessary, as has been confirmed by the literature. High viscosity of cottonseed oil is one of the key problems preventing its widespread application.

In India, karanji oil was experimented for analyzing its performance characteristics by *Srinivasa Rao [15]*. Karanjia oil was found to give a better performance compared to that of diesel. *Senthil Kumar et al. [16]* conducted experiments by blending Jatropha oil with diesel. It has been reported that exhaust gas temperature, smoke, HC and CO are higher compared to diesel. *Deshpande [17]* used blends of linseed oil and diesel to run the CI engine. Minimum smoke and maximum brake thermal efficiency were reported in this study.

Barsic et al. [18] conducted experiments using 100% sunflower oil, 100% peanut oil, 50% of sunflower oil with diesel and 50% of peanut oil with diesel. A comparison of the engine performance was presented. The results showed that there was an increase in power and emissions. In another study, *Rosa et al. [19]* used sunflower oil to run the engine and it was reported that it performed well. Blends of sunflower oil with diesel and safflower oil with diesel were used by *Zeiejerdki et al. [20]* for his experimentation. He demonstrated the least square regression procedure to analyze the long-term effect of alternative fuel and I.C. engine performance.

Indian Railway, the largest transport corporation in India, is experimenting with Jatropha oil ester to run passenger trains. If biodiesel is used as per plans, to the extent of10% mixture with the conventional diesel, the railways would be able to save on its rising fuel bill and also to control the atmospheric pollution levels (sulphur and lead emissions). The Railways' annual fuel (diesel) bill of Rs. 3400 crores could be reduced by nearly Rs. 300 crores to 400 crores per annum by using biodiesel [21].

5 ADVANTAGES AND DISADVANTAGES

The advantages of vegetable oils as Diesel fuel are:

• Liquid nature-portability,

• Ready availability,

• Renewability,

• Higher heat content (about 88% of D2 fuel),

• Lower SC,

• Lower aromatic content,

• Biodegradability.

The disadvantages of vegetable oils as Diesel fuel are:

• Higher viscosity,

• Lower volatility,

• **The reactivity of unsaturated hydrocarbon chains.**

6 CONCLUSION

In this review, it is concluded that

- Compared to diesel fuel, a little amount of power loss happened with vegetable oil fuel operations.
- Particulate emissions of vegetable oil fuels were higher than that of diesel fuel, but on the other hand, NO2 emissions were less.
- Vegetable oil methyl esters gave performance and emission characteristics closer to the diesel fuel. So, they seem to be more acceptable substitutes for diesel fuel.
- Raw vegetable oils can be used as fuel in diesel engines with some modifications.
- Before starting wide application, there are some improvements that should be done, such as
- Fuel systems should be optimized for vegetable oil operation.

Vegetable oils are mainly consumed on the food market. Therefore, it has some unfavorable properties as fuel, such as high density, drying with time and gumming, lower cetane number.

7 REFERENCES

[1] A.S.Ramadhas*,S.Jayaraj, C.Muraleedharan.Characterization and effect of using rubber seed as fuel in the compression ignition engines, Renewable Energy, 30 (2005) 795–803.

[2] Nwafor, G. Rice, A.I. Ogbonna. Effect of advanced injection timing on the performance of rapeseed oil in diesel engines, elsvier,Renewable Energy, 21 (2000) 433-444

[3] Nwafor. Emission characteristics of diesel engine running on vegetable oil with elevated fuel inlet temperature,Biomass and Bioenergy journal, 27 (2004) 507 – 511

[4] A.S. Huzayyin a, A.H. Bawady b, M.A. Rady a, A. Dawood. Experimental evaluation of Diesel engine performance and emission using blends of jojoba oil and Diesel fuel, Energy Conversion and Management journal, 45 (2004) 2093–2112

[5] Gvidonas Labeckas , Stasys Slavinskas.Performance and exhaust emission characteristics of direct-injection Diesel engine when operating on shale oil,Energy Conversion and Management 46 (2005) 139–150.

[6] F. Karaosmanoglu, G. Kurta, T. OÈ zaktas.Long term CI engine test of sunflower oil, elsvier, Renewable Energy 19 (2000) 219±221.

[7] Silvio C.A. de Almeidaa, Carlos Rodrigues Belchiora, Marcos V.G. Nascimentob,Leonardo dos S.R. Vieirab, Guilherme Fleuryb, Performance of a diesel generator fuelled with palm oil, elsvier, 81 (2002) 2097–2102

[8] Recep Alton, Selim etinkaya b, H useyin Serdar Y. The potential of using vegetable oil fuels as fuel for diesel engines, elsvier, Energy Conversion and Management 42 (2001) 529±538

[9] J. Narayana Reddy, A. Ramesh. Parametric studies for improving the performance of a Jatropha oil-fuelled compression ignition engine, elsvier, Renewable Energy.

[10] Y. He, Y.D. Bao. Study on cottonseed oil as a partial substitute for diesel oil in fuel for single-cylinder diesel engine, Renewable Energy, 30 (2005) 805–813

[11] N. Usta, E. Ozturk b, O. Can, E.S. Conkur, S. Nas, A.H. Con,A.C. Can, M. Topcu.Combustion of biodiesel fuel produced from hazelnut soapstock/waste sunflower oil mixture in a Diesel engine Energy Conversion and Management,elsvier, 46 (2005) 741–755

[12] N.Usta, Use of tobacco seed oil methyl ester in a turbocharged indirect injection diesel engine, Biomass and Bioenergy journal, 28 (2005) 77–86

[13] B.K. Barnwal, M.P. Sharma.Prospects of biodiesel production from vegetable oils in India,elsvier, Renewable and Sustainable Energy Reviews, 9 (2005) 363–378

[14] Ayhan Demirbas. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey elsvier, Energy Conversion and Management 44 (2003) 2093–2109

[15] www.goodnewsindia.com

[16] Senthil Kumar M, Ramesh A, Nagalingam B. Experimental investigation on Jatropha oil-Methonal dual fuel engines, SAE 2001-01-0153, 2001.

[17] Deshpande NV. Bio-diesel: An alternative fuel for compression ignition engines, Proceedings on Recent trends in alternative fuels, Nagpur, India, 2002.

[18] Barsic NJ, Humke H. Performance and emission characteristics of a naturally aspirated diesel engine with vegetable oil, SAE 810262, 1981.

[19] Rosa Radu. The use of sunflower oil in diesel engines, SAE 972979, 1997.Tavel, P. 2007 Modeling and Simulation Design. AK Peters Ltd.

[20] Zeiejerdki K, Pratt K. Comparative analysis ofthe long term performance of a diesel engine on vegetable oil, SAE 860301, 1986.

[21] The Hindu, Daily Newspaper dated 4.1.2003.