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Emission Characteristics of Pongamia Pinnata Biodiesel and Its Blending up to 100% in a Diesel Engine

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Abstract:

Import dependence for oil in India which is about 70 per cent is likely to increase further. The study is initiated to investigate the potential of Karanja oil as a source of biodiesel. Biodiesel is an alternative fuel made from renewable biological resources such as vegetable oil and animal fat. It is completely biodegradable and non-toxic. Main objectives of the study are feasibility of Karanja oil for the production of biodiesel optimization of different parameters for high yield /conversion of Karanja oil to biodiesel. This survey presents the suitability of Pongamia Pinnata (karanja) as a source of renewable fuel substituting petrodiesel in CI engine. The fuel properties of esterified karanja oil and its blend with diesel fuel at different proportions are studied including engine tests. The straight karanja oil blend upto 25% with the petrodiesel meets the standard specification. However blending of this oil with petrodiesel upto 20% (by volume) can be used safely in a conventional CI engine without any engine modification that could help in controlling air pollution.

Keywords:

Biodiesel, Karanja oil, alternate fuel, fuel.

Introduction:

During last decade India has maintained a high growth rate in accepting the improved technological challenges in global scenario. India ranks sixth in the world in terms of energy demand accounting for 3.5% of world commercial energy demand in 2001.

The energy demand is expected to grow at 4.8%. The demand of diesel is projected to grow from 39.81 million metric tons in 2001 – 02 to 52.32 million metric tons in 2006 – 07 @ 5.5% per annum. Also due to gradual depletion of the world petroleum reserve, rising petroleum prices, increasing threat to the environment from exhaust emission and global warming have generated an intense international interest in developing alternative non petroleum fuels. The majority of energy used today is obtained from fossil fuels. The environmental concern of the global warming and climate changes has greatly increased the interests of the application study of renewable fuels to internal combustion engines. The investigations have concentrated on decreasing fuel consumption and on lowering the concentration of toxic components in combustion product by using non-petroleum, renewable, sustainable and non-polluting fuels. So what is the need of hour to switch over to non-conventional energy sources such as wind, solar energy, biodiesel, tidal energy etc. which are easily available[1]. Further sources of conventional fuels (like petroleum and coals) will be available only for next 50 years. So we should think over the issue alternative fuels. Also the sharply rising petroleum price on markets worldwide has also boosted the studies and applications of renewable fuels in the area. A lot of research and studies on different kinds of renewable fuels such as raw vegetable oil, waste cooking oil, biodiesel, methanol and ethanol are being done. The first three are able to be applied to diesel engines and the last two are mostly applied to petrol engines[2].

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Further, increasing prices of conventional fuels is one of the major reasons to search for alternative fuels. Conventional like diesel, gasoline have limited stock, they may last only for next 50 to 70 years, so we should concentrate on this issue Alternative fuels. Pollution created by present fuels is a major issue which forces us to think for alternative fuels. Disturb in natural cycles due to pollution can't be tolerated so we have a need of alternative fuels[3]. Types of alternative fuels: i. Liquefied Petroleum Gas (LPG, commonly known as propane), ii. Compressed Natural Gas (CNG), iii. Liquefied Natural Gas (LNG), iv. Methanol (M85), v. Ethanol (E85), vi. Biodiesel (B20), vii. Electricity, viii. Hydrogen.

Biodiesel:

Biodiesel is a liquid fuel made up of fatty acid alkyl esters, fatty acid methyl esters (FAME), or long-chain mono alkyl esters. It is produced from renewable sources such as new, used vegetable oils animal fats and is a cleaner-burning replacement for petroleum-based diesel fuel. It is nontoxic and biodegradable. Biodiesel has physical properties similar to those of petroleum diesel. In simple terms, biodiesel is a renewable fuel manufactured from methanol and vegetable oil, animal fats, and recycled cooking fats (U.S. Department of Energy, 2006).The term "biodiesel" itself is often misrepresented and misused. Biodiesel only refers to 100% pure fuel (B100) that meets the definition above and specific standards given by the American Society of Testing and Materials (ASTM) International (D 6751)[4]. However, it is often used to describe blends of biodiesel with petroleum diesel. Such blends are generally referred to as "B2," "B5," "B20,"[5] etc., where the number indicates the percent of biodiesel used. The chemical conversion of the oil to its corresponding fatty ester (biodiesel) is called transesterification. Transesterification refers to a reaction between an ester (triglyceride) of one alcohol (glycerine) and a second alcohol (methanol) to form an ester of the second alcohol (methyl ester).

High viscosity is the main problem while using biofuel in engine, which is solved by means of transesterification[6-8]. Many researches have used Methyl esters of Pongamia pinnata , mahua oil, rapeseed oil, linseed oil, soybean, jatropha, cottonseed and palm oil reported the performance and emission characteristics in diesel engines. A.V. Krishna Reddy et al[9] have discussed about prospects of biodiesel production from vegetable oils in India. They have also given the yield and production cost of various methyl esters, in general non-edible oils. The methyl esters of non-edible oil are much cheaper than petroleum diesel. The yield of oil is about 90-95% depending on the oil. Prepared biodiesel of Pongamia Pinnata with an yield of 95% using methanol and potassium hydroxide as a catalyst. The viscosity of the oil decreased from 74.14 Cst (at 30°) to 4.8 Cst (at 40°C) on transesterification and the flash point was 150°C. Both these properties meet the ASTM and German biodiesel standards[10, 11].

Technical Definition:

Biodiesel, a fuel composed of mono- alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated as B100 and meeting the requirements of ASTM (American Society for Testing and Materials) D 6751[4]. Biodiesel is viewed as with enthusiasm and hopefully because: i. It may reduce the current importance of diesel or even can substitute if proper research is done. ii. Ultimately it will reduce dependence of a country on import of oil. iii. It is more environmental friendly fuel. iv. It is an alternative to reduce greenhouse gas (GHG) emission such as CO_2, as well as CO, Particulate matters (PM) and hydrocarbon (HC) emissions. v. Able to stimulate agricultural market and reduce poverty in rural areas by providing jobs to poor. Biodiesel which is derived from triglycerides by the chemical process known as tranesterification. Biodiesel is usually produced by the transesterification of vegetable oils or animal fats with methanol or ethanol[11,12].

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This source of diesel is attracted considerable attention during the past decade as a renewable, biodegradable, eco friendly and non toxic fuel. Several processes have been developed for production of biodiesel. Methyl esters (biodiesel) are a clean burning fuel with no sulfur emission. Methyl esters are non corrosive and are produced at low pressure and temperature conditions and gives methyl ester (80%) and glycerin (20%) as a byproduct. Although its heat of combustion is slightly lower than that of the petro-diesel, there is no need to modify the engine and there is no loss in efficiency[13]. Methyl esters are non corrosive and are produced at low pressure and low temperature conditions whereas biodiesel produced from jatropha and karanja has slight corrosive effect on the piston liner[14,15].

Why Pongamia pinnata?:

Due to pressure on edible oils like groundnut, rapeseed, mustard and soybean etc. non-edible oil of jatropha curcas and karanja (PongamiaPinnata) are evaluated as diesel fuel extender[16]. Pongamia pinnata is a species of family Leguminasae, native in tropical and temperate Asia including part of India, China, Japan, Malaysia, Australia. Commonly it is called as karanja (in MS), pongam (in Gujarat), dalkaramch (in Tamilnadu). Karanja is drought resistant, semi-deciduous, nitrogen fixing leguminous tree. It grows about 15-20 meters in height with a large canopy which spreads equally wide. The leaves are soft, shiny burgundy in early summer andvmature to a glossy, deep green as the season progresses. Flowering starts in general after 4-5 years. Cropping of pods and single almond sized seeds can occur by 4-6 years and yields 9-90 kg's of seed. The yield potential per hectare is 900 to 9000 Kg/Hectare. As per statics available pongamia oil has got a potential of 135000 million tones per annum and only 6% is being utilized. The tree is well suited to intense heat and sunlight and its dense network of lateral roots and its thick long tap roots make it drought tolerant.

Material and Method

Transesterification:

Transesterification of vegetable oil was conducted as early as 1853, by scientists Roudolf. Diesel and J.Patrick, many years before the first diesel engine become functioned. Roudolf Diesel prime modes 10 ft (3m) iron cylinder with a flywheel at its base, ran on his own power for the first time in Germany. This engine stood as an example of Diesel's vision because it was powered by peanut oil, a biofuel, though it was not strickly bio-diesel, since it was not transesterified. He believed that the utilization of biomass fuel was the real future for his engine. The tranesterification process is the reaction of triglyceride (fat/oil) with an alcohol in the presence of acidic, alkaline or lipase as a catalyst to form mono alkylester that is biodiesel and glycerol. However the presence of strong acid or base accelerates the conversion. It is reported that alkaline catalyzed transesterification is fastest and require simple set up therefore, in current study the oil of pongamia pinnata were transesterified with methyl alcohol in presence of strong alkaline catalyst like sodium hydroxide or potassium hydroxide in a batch type transesterification reactor[1,17]. The transesterification reaction is given below[18] this process has been widely used to reduce the high viscosity of triglycerides

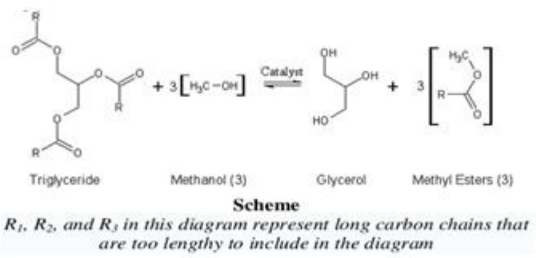

Figure-1: Transesterification reaction scheme

Process variable:

The most important variables that influence transesterification reaction time and conversion are: i. Reaction temperature, ii. Ratio of alcohol to oil, iii. Catalyst type and concentration.

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Reaction temperature: The rate of reaction is strongly influenced by the reaction temperature. However given enough time the reaction will proceed to near completion even at room temperature. Generally the reaction is conducted close to the boiling point and methanol (60 to 70^{0}C) at atmospheric pressure. The maximum yield of esters occurs at temperature ranging from 60 to 75^{0}C at the molar ratio of 6:1, further increase in temperature reported to have a negative effect on the conversion.

Ratio of alcohol to oil:

It is also important variable in the affecting the yield of esters. The stichimetry of transesterification reaction requires 3 mole of alcohol per mole of triglyceride to yield 3 mole of fatty ester (BD) and 1 mole of glycerol to shift the transesterification reaction to the right, it is necessary to use large excess of methanol. The molar ratio like 4:1, 6:1, 8:1, 10:1 and 12:1 have been used earlier and it is shown that 6:1 molar ratio gives highest conversion but the excess alcohol may interferes in the separation of glycerol after transesterification.

Catalyst type and Concentration:

Alkali metal alkoxides are the most effective transesterification catalyst compared to the acidic catalyst. Sodium alkonides are among the most efficient catalysts used for this purpose, although NaOH or KOH can also be used. As the alkaline catalysts are less corrosive than acidic catalysts. Most commercial transesterification conducted with alkaline catalysts. The alkaline catalyst con in 0.5%, 0.7%, 0.9%, 1.0%, 1.2%, 1.5% have been used earlier by many researchers, and it is shown that 0.5 % to 1.0 % catalyst by weight is used for maximum conversion. Further increase in catalyst concentration does not increase the concentration.

Production of biodiesel through Transesterification reaction:

To prepare biodiesel from pongamia crude oil first sodium hydroxide was added in to the methyl alcohol to form sodium methoxide, simultaneously oil was heated in a separate vessel of tranesterification reactor and subjected to heating and stirring. When temperature of oil reached at 60^{0}C then sodium methoxide was mixed in to the preheated oil and reaction mixture was stirred for one and half hour. After reaction completion, the reaction mixture was transferred in separating funnel. The mixture of glycerol and methyl ester was allowed to settle for 8-10 hours. After settling, raw glycerol and methyl esters was separated manually. The methyl ester was theh washed with hot water to remove traces of sodium hydroxide impurity. Phosporic acid was added for neutralization of biodiesel. The washed product then distilled to remove moisture and final good quality biodiesel was subjected for chemical analysis. The physic chemical properties of karanja methyl ester are given in table -2[19].

Experimental Set-up:

A multi cylinder, 4-stroke,rated speed (2500rpm) diesel tractor engine which is used for agricultural applications in rural India was selected for investigation to study the performance and emissions.

Test Engine Specifications:

The engine was coupled to a exhaust gas analyzer Emissions such as carbon monoxide (CO) were measured by an NEPTUNE OPAX2000 exhaust gas analyzer. Vibration diagnosis was carried out by means of a Vibrometer (Spectrum analyzer Model Type VA-11) mounted on the cylinder head in the standard position. The experiments were carried out by using various blends of karanja methyl ester (KME5,10,20, 50,100) with diesel at different load conditions on the engine keeping all the independent variables same. The detail engine specifications are shown in table- 1.

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Table-1: Test Engine Specification

Model	MDI
HP	45 hp Category
Type	Water cooled four stroke, Direct
No. of Cylinders	Four
Rated Engine Speed	2300
C ooling System	Water cooled
Lifting capacity	1600 kgs
Fuel tank	45 lit

Results and Discussion:

The exhaust emissions are compared for Karanja biodiesel and diesel fuel, at full load and the engine speed of 1280 to 2400 rpm. The measured exhaust emissions were CO. In diesel engine, CO concentration in the exhaust increases steadily as the amount of excess fuel increases. The CO exhaust emissions of diesel and pure Karanja oil biodiesel are shown in graph1. The CO emissions were lesser for biodiesel fuel as compared with diesel fuel, the CO emission of biodiesel was reduced by 78% at full load. This is because biodiesel contains 11% additional oxygen, which leads to complete combustion of fuel. Other researchers also found that biodiesel fuel has lower COemissions compared with diesel, when the engine was running at full load condition[10].

Table-2: Physico- chemical properties of karanja methyl ester

Fuel Property	Diesel (K0)	Karanja
Specific Gravity	0.84	0.860
Density (Kg/m^3)	840	860
API Gravity	40.24	29.3
Ash Content (%)	0.060	0.094
Water Content (%)	0.070	NA
Carbon residue (%)	0.080	0.530
Flash Point (°C)	66	128
Pour Point (°C)	15	7
Fire Point (°C)	72	134
Calorific Value (KJ/Kg)	44000	37700
Viscosity (cSt)	4.2	5.14
Cetane Number	48	49
Stoichiometric AFR	14.45	12.7

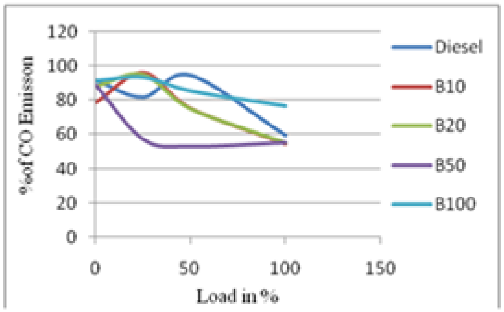

Figure-2 CO emissions for diesel and Karanja biodiesel fuel

The figure-1 shows that as the load increases the exhaust emission decreases and it also shows that B50 have lower emission than that of diesel as the load increases while emission for B20 and B10 almost were same but the CO emission increases for B100. Based on engine emission studies i.e. CO emission, we can say that all the parameters are within maximum limits that conclude safer use as an alternate fuel.

Conclusion:

The effects of pure Karanja biodiesel fuel on performance, emission, and engine wear of a 45HP, 04 cylinders, Tractor engine have been investigated and compared with the baseline diesel fuel. The main observations are as follows: CO emission decreases by 80% when diesel engine fuel is replaced with pure Karanja oil biodiesel fuel at full load condition.From the basis of experimental result of performance and emissions following conclusion may be given – i. Without any modification karanja biodiesel-diesel blend up to 20% can be easily used in CI engine. ii. The emissions of CO were decreased and it found minimum at around 10% blend. The suitability of Karanja BD as an alternative fuel to fossile fuel was investigated by looking at the variations of its properties namely moisture, density, viscosity, flash point, fire point , calorific value, cetane number. which shows karanja methyl ester matches standard properties with ASTM and Indian standard of BD[19,20]

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