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Properties of Karanj Oil and its Blends with Diesel as a Fuel for C.I. Engines

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Abstract: Biomass derived vegetable oils can be used an alternative fuels for CI engines. In this view the properties measurement of biodiesel and its blends were carried out. Also the efforts were made, to study the preparation method and its probable effect on CI engine is discussed. The blends of the biodiesel (Karanj oil) are formed in volume proportions of 10, 20, 30, 40, 50 and 100 percentage with high speed diesel. The various physical and the chemical properties of these biodiesel blends and crude oil were measured. From the measured data of these properties trend lines were plotted and the correlations are found. Also comparative studies of these properties of the blends are discussed in terms of its suitability as fuel in the CI engine with emission characteristics. The main objective of this study is to find the suitability of biodiesel as alternative fuel for CI Engine.

Keywords: Karanj oil; Biodiesel; C.I. Engine; Transesterification; Properties; Blends

1. Introduction

Biodiesel, which can be used as an alternative diesel fuel, is made from renewable biological source such as vegetable oil and animal fats. It is biodegradable, non-toxic and possesses low emission profiles. Chemically, Biodiesel is referred to as the mono-alkyl esters of long chain fatty-acids derived from renewable liquid sources. Biodiesel is the name for a variety of ester based oxygenated fuel from renewable biological sources. The use of vegetable oils as alternative fuels has been around for 100 years when the inventor of diesel engine Rudolph Diesel first tested peanut oil, in his compression ignition engine. However, with the advent of cheap petroleum appropriate crude oil fractions were refined to serve as fuel and diesel fuels and diesel engines started evolving together. Later in the 1940's vegetable oils were used again as fuel in emergency situations, during the period of World War II. Because of the increase in crude oil prices, limited sources of fossil fuels and the environmental concern, there has been renewed focus on vegetable oils and animal fats for the production of biodiesel fuel. The main sources for biodiesel in India can be non-edible oils obtained from plant species such as Karanj Curcas (Ratanjyot), Pongamia Pinnata (Karanj), Calophyllum inophyllum (Nagchampa), Hevca brasiliensis (Rubber) etc. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend or can be used in its pure form. Biodiesel can be used directly in C.I. engines with little or no modifications. While all vegetable oils have high energy content, most of them require some processing to assure safe use in internal combustion engines. Karanj oil is one of the biodiesel which obtain from the seeds of this plant. In this view some of the researchers have tested Karanj oil and its blends with diesel as fuel in CI engines.

Karmee and Chadha [1] prepared biodiesel from non-edible oil of Pongamia pinnata by transesterification of crude oil with methanol in the presence of KOH as catalyst. Important fuel properties of methyl esters of Pongamia oil compared well with ASTM and German biodiesel standards. Agarwal and Rajamanoharan [2] carried out experimental investigation to analyze the performance and emission characteristics of C.I. engine fuelled with karanj oil and its blends. Fuel preheating in the experiments has been done by specially designed heat exchanger, which utilizes waste heat from exhaust gases. Sureshkumar et al. [3] presents the results of performance and emission analysis carried out in an unmodified diesel engine fuelled with Pongamia pinnata methyl ester and its blends with diesel. Raheman and Phadatare [4] presents the results of investigations carried out in studying the fuel properties of Karanj methyl ester (KME) and its blend with diesel from 20% to 80% by volume and in running a diesel engine with these fuels. Engine tests have been carried out and conclude that the blends of karanja esteri4ed oil (B20 and B40) a suitable alternative fuel for diesel and could help in controlling air pollution. Srivastava and Verma [5] prepared Methyl ester of karanja oil from Jharkhand region by transesterification method. Physical and chemical properties of the karanja oil and that of the methyl ester have been determined. Also conclude that methyl ester of karanja oil is a suitable substitute of petroleum diesel fuel. Das et al. [6] blended non-edible, high viscosity Karanj (Pongamia pinnata) oil with conventional diesel in various proportions to evaluate the performance and emission characteristics of a single cylinder direct injection constant speed diesel engine. Diesel and Karanj oil fuel blends (5%, 10%, 15%, and 20%) were used to conduct short-term engine performance and emission tests at varying loads (0%, 20%, 40%, 60%, 80%, and 100%). Mahanta et al. [7] present work deals with testing a performance of a compression ignition (CI) engine with different blends of non-edible oil as well as their methyl esters with petrodiesel. Various blends of a non-edible vegetable oil, commonly known as honge (Pongamia pinnata L.) in India, were prepared and tested over a wide range of engine load. Yadav and Singh et al. [8] presents the results of tests using three non-edible oils, namely Karanj, karanja, and neem, at three different fuel injection temperatures in an unmodified small size compression ignition engine employing exhaust gas recirculation. Also conclude that oils at preheated temperatures can be a good substitute for conventional diesel fuel with a much smaller decrement in power and thermal efficiency in the case of engines without turbo charging.

From above survey, as biodiesel occupy a prominent position in the development of alternative fuels although, there are many problems associated with using it directly in CI engine. These include, choking and trumpet formation on the injectors to such an extent that fuel atomization does not occur properly or even prevented as a result of plugged orifices, carbon deposits, oil ring sticking, thickening or gelling of the lubricating oil as a result of contamination by vegetable oils and lubricating problems Other disadvantages to the use of vegetable oils are the high viscosity, about 11-17 times higher than diesel fuel and lower volatilities that causes the formation of deposits in engines due to incomplete combustion and incorrect vaporization characteristics.

Also lot of work was carried out to use vegetable oil both in its pure form and modified form. These studies show that the usage of vegetable oils in pure form is possible but not preferable. Also it can possible to use of biodiesel in its blended form. Also less research was directed towards overall study properties of biodiesel and its blends as fuel for C.I. engine. In search good alternative Karanj oil blends with diesel are selected for this study.

So the main objective of proposed work is to study the properties Karanj oil blends and its suitability as fuel for CI engines. In this view the process of preparation of Karanj biodiesel and its physical and chemical properties of its blends with diesel were studied. The Karanj oil which is used for the preparation of blends with commercially available diesel oil was supplied by Indian Biodiesel Corporation; Baramati, Maharashtra (India).

2. Preparation of Karanj Biodiesel:

The yield of Karanj per tree is reported between 8 to 10 kg. The maximum amount of oil that can be extracted from a given sample of the seed depends on the method of extraction and perhaps the quality of the feedstock.

2.1. Extraction

Fig. 1 shows the process flow for biodiesel pilot plant of IBDC, Baramati. Karanj seeds are collected from nearby area of Baramati. The collected seeds were dried for 2-3 days in the sun. These seeds of Karanj were separated from the shell manually by a wooden hammer or manually operator decorticator. However, the electric decorticators of Karanj fruits have been fabricated and are being used for efficient processing.

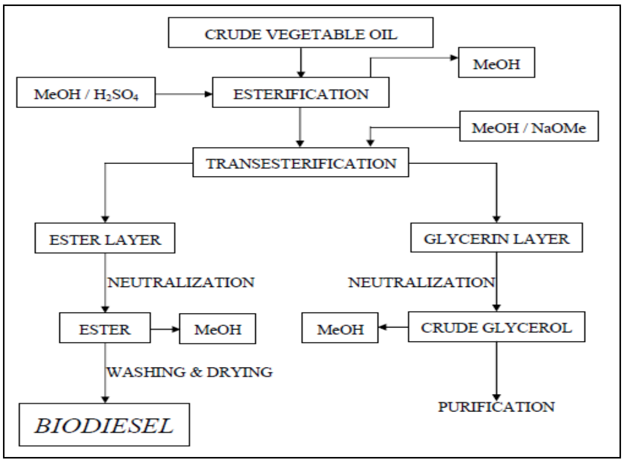
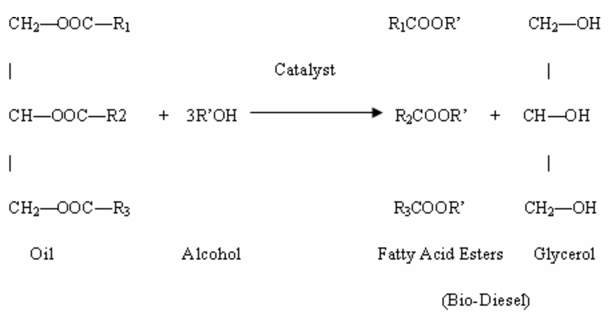


Fig. 1 Process Flowchart for Biodiesel Production

Crude Karanj oil produced in the oil extraction unit. The crude oil obtained after extraction may be used as a fuel for lamp/ stove or furnace oil. The crude Karanj oil was passing to the transesterification reactor. Products of the transesterification reaction are crude biodiesel and glycerol. They are separated by gravity. Biodiesel was then purified by washing gently with water or by using bubble wash arrangement. The important factor that affects the transesterification reaction was the amount of methanol and sodium or potassium hydroxide, reaction temperature and reaction time. With higher molar ratios conversion increased but recovery decreased due to poor separation of glycerol.

2.2. Transesterification Process:

Transesterification is most commonly used method to reduce the viscosity of crude vegetable oils. After transesterification the properties of crude vegetable oil like density, viscosity, cetane number, calorific value, vaporization rate, and molecular weight are improved. The transesterification reaction is shown as.



The triglycerides called as vegetable oil and R1, R2 and R3 represents the fatty acid. One part vegetable oil reacting with three parts methanol gives three parts methyl esters (biodiesel) and one part glycerol. In practical terms, the volume of biodiesel obtained will be equal to the crude oil.

2.3. Properties of Karanj Crude Oil and Karanj Biodiesel:

The properties of Karanj crude oil and biodiesel after and before transesterification were measured in IBDC Baramati, India and tabulated in Table 1. These properties were measured by using standard methods and supplied along with biodiesel fuel.

After the transesterification process the properties of biodiesel are changed drastically. That is significant reduction in density, viscosity and flash point occurred. The density is reduced up to 0.88 gm/cc which is still higher than diesel, this indicated that the higher molecular weights of the triglyceride molecules are present in biodiesel. Kinematic viscosity of crude Karanj oil was reduced from 52 to 4.34 Cst which is nearer to the diesel. That indicated that less power is required to atomize the fuel. Calorific value of biodiesel improved up to 6 % by esterification. This value is still lesser than diesel this may be due to the presence of oxygen molecules in the biodiesel. Also the flash point is reduced by esterification process but it is still higher than diesel which indicates that its handling is safe. Also the contents of the fatty acid and acid value were drastically reduced.

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Table1. Properties of Crude Oil & Biodiesel of Karanj

Property	Karanj Crude Oil	Karanj Biodiesel	Diesel
Density (gm/cc)	0.92	0.88	0.84
Viscosity (cst)	52	4.34	2.65
Flash Point (°C)	237	187	82
State	Liquid	Liquid	Liquid
Solubility	Organic Solvent	Organic Solvent	-
Appearance	Similar to Caster Oil	Similar to Caster Oil	-
Color	Dark Brown	Pale brown	-
Refractive Index	1.4734	1.4734	-
Free Fatty Acid (%)	4.54 – 6.7	< 0.5	-
Acid Value (mgKOH/gm)	0.62	0.37	-
Calorific Value (MJ/kg)	34.00	36.11	43.00

3. Preparation of Karanj diesel oil blends

The properties of the biodiesel are approaching towards the diesel fuel; therefore it becomes strong contender to replace the diesel fuels. Still small deviation of these properties like density, viscosity and calorific values are playing important role in the operation of the CI engine. So instead of it use in pure form it can be used in the blends with diesel. Percentage of biodiesel in blends play vital role in the performance and emission characteristics of CI engine. So to use the biodiesel blends in commercial scale their physical and chemical properties are need to be studied. The preparation of the Karanj oil blends with diesel were made by adding it in commercially available diesel oil (HSD) by volume of 10%, 20%, 30%, 40% and 50%, these are named as K10, K20, K30, K40 and K50 respectively. The pure Karanj oil is named as K100.

Table 2: Properties of biodiesel Blends

No.	Property	Diesel	B10	B20	B30	B40	B50	B100
1	Density (gm/cc)	0.84	0.842	0.844	0.847	0.851	0.857	0.88
2	Flash Point (°C)	82	111	122	130	142	150	187
3	Fire Point (°C)	110	120	135	141	152	163	196
4	Cetane No.	50	50	51	52	52.5	53	59
5	Carbon Residue (%)	1.10	1.18	1.32	1.40	1.47	1.50	1.7
6	Sulphur (%)	0.1	0.09	0.07	0.05	0.04	0.02	0.01
7	Ash Content (%)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	Calorific Value (kJ/Kg)	43000	42738	41956	40887	39850	38965	36119

3.1 Properties of Karanj Biodiesel Blends:

The various properties of prepared blend samples were measured at Nikhil Analytical & Research Laboratory (Approved by Govt. of India) using standard methods at room temperature. These properties are tabulated in the Table 2. The measured properties like density, flash and fire point, viscosity, Cetane number, carbon residue, calorific value, sulphur and ash content these are related with the performance and the emission characteristics of the engine. Also the trends of these properties were plotted with the percentage of biodiesel and it discussed in terms of their suitability and possible causes if it is used as fuel in CI engine. Figures 2 show the various physical and chemical properties with respect to the percentage of Karanj biodiesel in the blends. From these curves equation were fitted so as to one can find the properties of the any percentage of biodiesel. Dilution effect of biodiesel on the properties is discussed as follows.

3.1.1 Density:

The density of diesel is 0.84 gm/cc whereas it is 0.88 for Karanj biodiesel. Fig. 2 shows the effect of addition of biodiesel in diesel on density. With the addition of biodiesel in diesel, the density goes on increasing. The equation of curve is,

$\rho = -4E\text{-}6x^2 + 0.837$……………………….(1)

where, ρ and x are the density and percentage of biodiesel blend. The increased density of Karanj blended fuels reflects its unsuitability as diesel fuel in cold climatic conditions. In general,the injection pressure required will be more and its penetration is also deeper. It may cause problems in fuel atomization.

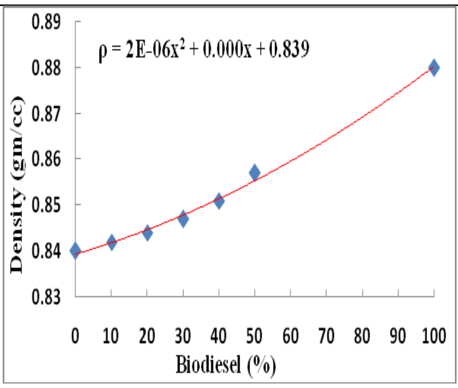

Fig. 2. Variation of Density with Biodiesel addition

3.1.2 Flash Point:

Fig. 3. shows the effect of dilution of biodiesel on flash point. As the biodiesel addition in diesel goes on increasing the flash of blends increased. The trend curve for flash point is,

$T_{flash} = 0.007x^2 + 1.63x + 87.86$……………… (2)

This indicates that the biodiesel is extremely safe to handle. As the flash point of blended fuels increases, engine is required to operate at higher compression ratio. Increased compression ratio increases the air temperature inside the cylinder consequently reducing ignition lag causing better and more complete burning of blended fuel.

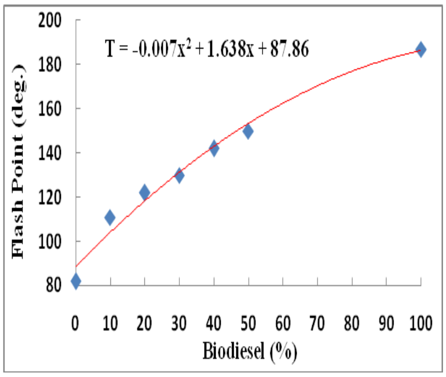

Fig. 3. Variation of Flash Point with Biodiesel addition

3.1.3 Fire Point:

The effect of addition of biodiesel in diesel on fire point is shown in Fig.4. As the biodiesel addition in diesel goes on increasing the fire point of blends increases.

$T_{Fire} = -0.005x^2 + 1.379x + 107$………... (3)

This indicates that the biodiesel is extremely safe to handle. As the flash point of blended fuels increases, engine would be operated at higher compression ratio. Increased compression ratio increases the air temperature inside the cylinder consequently reducing ignition lag causing better and more complete burning of blended fuel.

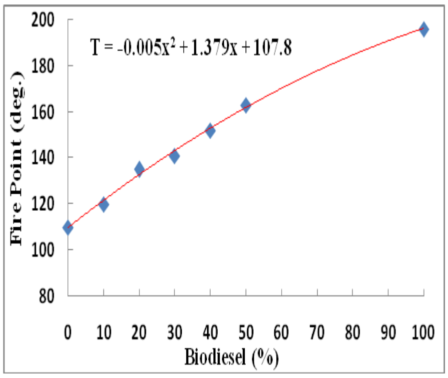

Fig. 4. Variation of Fire Point with Biodiesel addition

3.1.4 Cetane Number:

Cetane rating of fuel is a measure of its ability to auto-ignite quickly when it is injected into the compressed and heated air in the engine. The cetane number of diesel and biodiesel is 50 and 58.4 respectively. Percentage increment of biodiesel in diesel causes 1 to 2 percent increment in Cetane number as shown in Fig. 5.

CN = 0.045x + 49.86………………………… (4)

Where, CN is a cetane number. Straight chain compounds chemical structure of biodiesel has higher cetane number than branched chain compounds structure of diesel. In general lower the cetane number higher is the hydrocarbon emissions and noise levels due to increased rate of pressure rise.

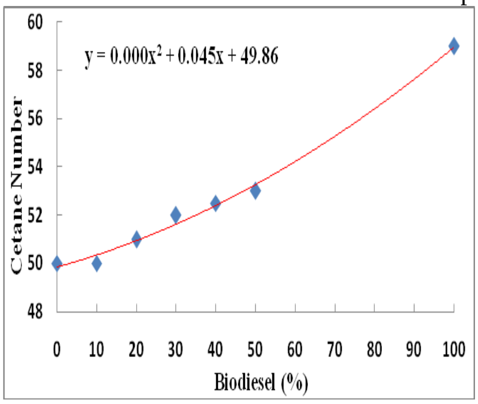

Fig. 5. Variation of Cetane Number with Biodiesel addition

3.1.5 Calorific Value:

Figure e shows the effect of addition of biodiesel in diesel on calorific value.

CV = - 0.058x + 43.58…………………………(5)

Lower calorific of value causes the percentage increase in specific fuel consumption with increased amount of biodiesel fuel in the blend. This also leads to lower brake thermal efficiency of the engine.

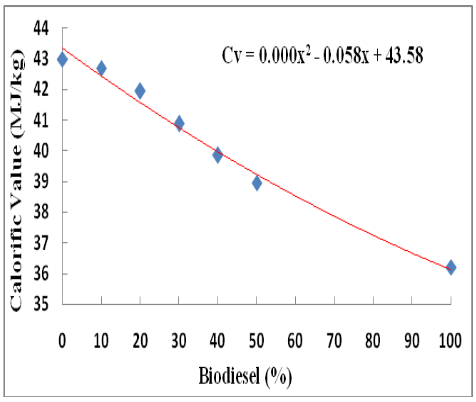

Fig. 6. Variation of Calorific Value with Biodiesel addition

3.1.6 Carbon Residue:

Carbon residue percentage for biodiesel is higher than pure diesel. Fig.7 shows that it increases with increasing the amount of biodiesel in diesel.

C % = -5E.-5x^2 + 0.011x + 1.097………………(6)

Higher carbon residue from Karanj oil may possibly lead to higher carbon deposits in combustion chambers of the engine. It can also lead to choking and trumpet formation on the fuel injectors and can lead to high smoke levels.

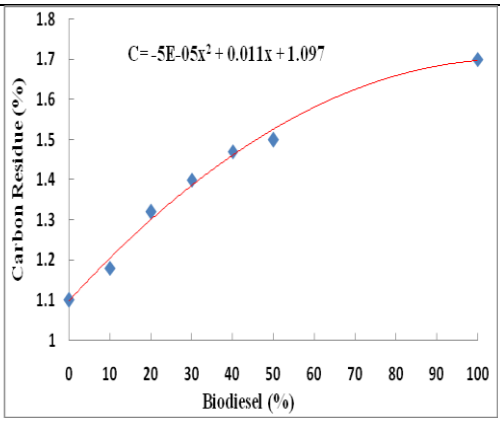

Fig. 7. Variation of Carbon Residue with Biodiesel addition

3.1.7 Sulphur content:

Sulphur content for biodiesel is very less than the diesel. Fig. 8 shows that sulphur content decreases with addition of biodiesel in diesel.

$$S = 2E\text{-}5x^2 – 0.002x + 0.115 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

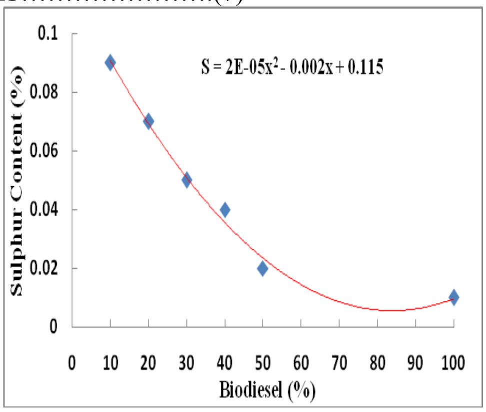

Fig. 8. Variation of Sulphor Content with Biodiesel addition

3.1.9 Variation of Viscosity with Temperature:

The addition of biodiesel in diesel causes viscosity goes on incresing which shown in Fig. 9. It is highest for pure biodiesel. The viscosity goes on decreasing with increase in temperature and percentage of diesel in biodiesel. High viscosity of biodiesel limits the use of pure biodiesel in the C.I. engine. Higher viscosity is a major problem in using Karanj biodiesel as fuel for C.I. engines which produce undesirable high pressure on fuel injection system that can cause undue wear of pump and increased maintenance. Significant reduction in viscosity was achieved by heating the oil and dilution of Karanj oil with diesel. Since the viscosity of Karanj oil is higher than diesel it can lead to poor atomization and mixture formation with air. This will lead to slower combustion, lower thermal efficiency and higher exhaust emissions.

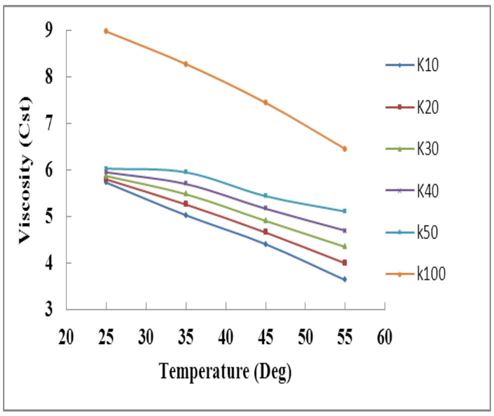

Fig. 9. Variation of Viscosity with Temperature

4. Conclusions

From the results of this study the following major conclusions are drawn.

1. The density, cloud point and pour point of Karanj oil was found higher than diesel. Higher cloud and pour points reflect unsuitability of Karanj oil as diesel fuel in cold climatic conditions.
2. Higher viscosity is a major problem in using vegetable oil as fuel for diesel engines. Significant reduction in viscosity was achieved by heating the oil and dilution of vegetable oil with diesel in varying proportions.
3. The flash and fire points of Karanj oil was quite high compared to diesel. Hence, It oil is extremely safe to handle.
4. Higher carbon residue from Karanj oil may possibly lead to higher carbon deposits in combustion chambers of the engine. It can also lead to choking and trumpet formation on the injectors to such an extent that fuel atomization will not occur properly.
5. Presence of oxygen in fuel improves combustion properties and emissions but reduces the calorific value of the fuel. Karanj oil has approximately 85% calorific value compared to diesel.

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