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Experimental Data of Calophyllum Inophyllum Bio Diesel Effect by Varying Compression Ratio and Injection Pressure on Emissions

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ABSTRACT

Keywords:
Biodiesel,
Transesterification,
VCR Engine,
Injection pressure,
compression ratio,
Engine emission.

Degrading fossil fuel resources have thrown world into chaos, besides air pollution and green house gases are a major concern. The fossil fuel shortage in near future is inevitable. This situation triggered the awareness to find alternative and sustainable energy resources. Biodiesel is a better solution as its properties are close to petrodeisel. In this paper, Biodiesel is produced from Calophyllum inophyllum oil by two stage transesterification process using acid and base catalysts. Acid esterification is done by mixing 1%(by wt. of oil)of 99% pure anhydrous sulphuric acid in 1000 ml of oil with oil to methanol ratio 6:1 and maintained at a temperature of 55° C for 120 minutes. This reduces the acid value of the oil. Now the oil is subjected to base catalyst. 1% of KOH(by wt.of oil) is added to a mixture of oil to methanol ratio4:1. The mixture is stirred for two hours at 60° C. The yield is about 89%.

Due to high viscosity it is difficult for regular engines to inject biodiesel into combustion chamber. This results in improper mixing of fuel and reduces ignition quality. In this paper the fuel injection pressure has been increased and compression ratio has been varied and tested under different operating conditions. The increase in injection pressure resulted in better atomization of fuel and better mixing with the air in combustion chamber. The increase in compression ratio resulted in higher compression pressure which ensures complete combustion of fuel in the chamber. These modifications results in reduction of emissions and smoke up to about 10% compared to normal engines running on biodiesel.

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Introduction:

The rapid industrialization of 19th century resulted a significant change in human life style in the following years which demanded very high usage energy resources. The appetite only grew bigger with time which might push the existence of the fossil fuels to extinction. The energy consumption has almost doubled from 61.731 million barrels per day in1980 to 94.346 million barrels per day in 2013. The fossil fuel reserve has been depleting causing the price to hit a new record of 128$ in 2008. This issue challenged the sustainability of power sector. Besides, the world faced a problem of global warming and environmental pollution. The significant amount of the green house gases are released into the atmosphere by burning fossil fuels. Thus the world now has two issues to deal with, Fossil fuel depletion and environmental pollution. There is every need to find an alternative energy resource which is renewable, reliable, eco friendly and economically viable. The bio diesel is a possible solution for it.

Bio diesel can be used in any direct injection engine without modification. It is gaining acceptance as non polluting fuel and demand increases in the near future. Bio diesel is mono alkyl esters made from vegetable and animal fats which have properties very near to the diesel and can be blended with it in different percentages. The blends when used in engine reduce emissions without significant reduction in power. The use of vegetable oil in IC engines is dated back to 1895, but the drawbacks are high viscosity and poor volatility. The high viscosity would reduce the fuel atomization and increase the fuel spray penetration which would be responsible for high engine deposits and thickening of lubricating oil.

There are various methods to reduce the viscosity of the oil. Few of them are dilution with other fuels, transesterification, micro emulsification, pyrolysis, catalytic cracking. Among these techniques transesterification is preferred due its simplicity, economic viability and high yield. The transesterification is the reaction between oil and fat, with a short chain alcohol (methanol, ethanol, and propanol) in the presence of suitable catalysts, as they give high production yield. But there are certain exceptional cases wherein direct trans-esterification cannot be performed. Such cases appear in raw vegetables oils or in non edible oils like karanja, Jatropha, mahua, castor i.e. calophylluminophyllum. As these non edible oils possesses high free fatty acids (FFA). For determining whether the raw vegetable oils can be Trans-esterified directly, the acid value is the most important property that must be known.

1. Calophyllum Inophyllum:-

Calophyllum inophyllum, commonly known as PUNNA in Telugu, is an non-edible oilseed ornamental evergreen tree belonging to the *Clusiaceae*family as shown in figure below. The scientific name of "*Calophyllum*" comes from the Greek word for "*beautiful leaf*". It grows along coastal areas and adjacent lowland forests, although it occasionally occurs inland at higher elevations. It is native of eastern Africa, southern coastal India, Southeast Asia, Australia and the South Pacific. Calophyllum inophyllum is also often called as 'Alexandrian Laurel' in English and other vernacular names in various countries. Calophyllum inophyllum is a medium and large-sized evergreen sub-maritime tree that averages 8–20m(25–65 ft) in height with a broad spreading crown of irregular branches. It has elliptical, shiny and tough leaves. The flower is around 25mm wide and occurs in racemose or paniculate inflorescences consisting of 4–15 flowers. The fruit (ballnut) is a round, green drupe reaching 2–4cm (0.8–1.6 in.) in diameter and having a single large seed as shown in Figure. When it is ripe, the fruit is wrinkled and its colour varies from yellow to brownish-red. The grey, ligneous and rather soft nut contains a pale yellow kernel, which is odourless when fresh. Calophyllum inophyllum kernels have very high oil content (75%) and the oil contains approximately 71% of unsaturated fatty acids (essentially oleic and linoloeic acids). It is obtained by cold pressing and yields refined, greenish yellow oil, similar to olive oil, with an aromatic odour and an insipid taste. Fruits are usually borne twice a year and it produces up to 100 kg of fruits and about 18 kg of oil. Calophyllum inophyllum is grown in warm temperatures in wet or moderate conditions and requires mean annual rainfall around 1000 5000m. It is highly tolerant to strong winds, salt spray and brackish water tables. The trees are sensitive to frost and fire. The wind and salt tolerance makes it suitable for sand dune stabilization. Plantation can be done at a density of 400 tree/ha. The average oil yield is 11.7 kg-oil/tree or 4680 kg-oil/ha.


2. Uses:-

Traditional Pacific Islanders used Calophyllum wood to construct the keel of their canoes. In Java, the tree is believed to have diuretic properties. The emetic and purgative gum extracted from the plant is used for the treatment of wounds and ulcers. An infusion of gum, bark and leaves is used for sore eyes. Calophyllum inophyllum oil from the fruit traditionally has been used for medicine and cosmetics. It has been used empirically for centuries in Madagascar to treat wound, facial neuralgia, skin ailment and hair loss. Moreover, it is used in acute skin irritation including burns, rashes, impetigo, insect bites and abrasions. It is also applied topically in cases of rheumatism. Besides, the oil is used in varnishes and as lamp oil. In Southern India, the oil of the seeds is used specifically for treating skin diseases

3. Esrerification:-

Calophyllum inophyllum oil contains 19.58% free fatty acids. The methyl ester is produced by chemically reacting Calophyllum Inophyllum (punna) oil with an alcohol (methyl), in the presence of catalyst (Potassium Hydroxide). For the stoichiometric transesterification reaction, three moles of methanol are required per mole of triglyceride to yield three moles of methyl esters and one mole of glycerol. However, the ratio of alcohol to oil used in the reaction is much higher than this to promote complete conversion of oils to FAME and varies with oil quality and the type of catalyst used. A two stage process is used for the transesterification of Calophyllum Inophyllum (punna) oil. The first stage (acid catalyzed) of the process is to reduce the free fatty acids (FFA) content in oil by esterification with methanol (99% pure) and acid catalyst sulfuric acid (99% pure) in one hour time at 57ºC. The oil is first heated to 50°c and 1% (by wt. of oil) sulpuric acid and methanol in the ratio 1:6 is added to oil. Excess methanol is added as the reaction is reversible. The reaction proceeds at a speed of 650 rpm at 50°c-60°c. The mixture is allowed to settle for 5hrs and fatty esters are separated in separating flasks. The FFA of the oil is reduced significantly. This process is called esterification. In the second stage, the oil is transesterified with base catalyst. Potassium hydroxide (KOH) 0.5% (by wt. of oil) and methanol in the ratio 1:4 is added to the oil. KOH is mixed with methanol and methoxide is added to oil at temperature of 50°C. The reaction proceeds at a speed of 450 rpm at a temperature of 50°C to 60°C. The mixture is allowed to settle for 8hrs. The glycerol settles at bottom and the bio-diesel on the top. The bio diesel contains lot of impurities such as soap, traces of glycerol, and traces of methanol. These impurities can damage the engine. Hence should be removed by washing with distilled water.

4. Water Washing:-

The oil is washed with distilled water. The distilled water is heated to 70°C and added to oil in equal amount. Air bubbles are through bio diesel and water from the bottom of the container using electronic bubbler. The air will then take away all impurities from the biodiesel; they will be dissolved in water as the bubbles move up. The unused methanol will be diluted in water. The traces of glycerol and soap particles make the water to become like soap water. Once the water becomes like soap water, the bubbler is stopped. After allowing some time for impurities to settle, the biodiesel is drained from the separating funnel and heated up to 110°C. This heat is maintained up to 30 minutes until remains of water are evaporated. The pure biodiesel will be directly used, with or without blending, in the engine.

5. Methodology:-

As per the authors knowledge the use of calophylluminophyllum methyl ester (CIME) at full load conditions by varying compression ratio and injection pressure is not reported in literature. The objective of the present work is to study through the experiments on the performance and the emission characteristics of CIME at various compression ratios and injection pressures.

Esterification Process

Engine Setup

The engine used is a research engine which can work with both diesel and petrol by changing heads. The special features are variable compression ratio and variable injection timing.

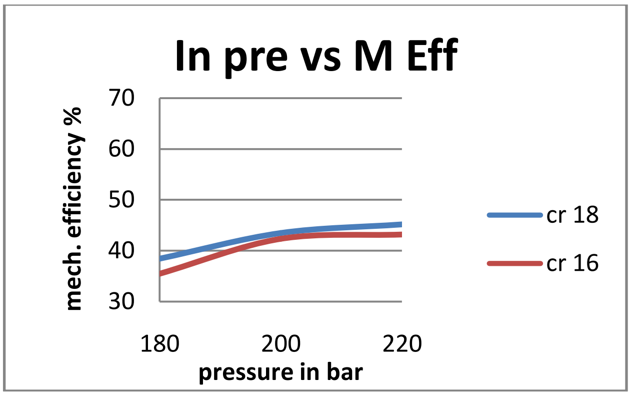
ENGINE SPECIFICATIONS:

S.No	Description	Specification
1	No. of cylinders	1
2	No. of strokes	4
3	Bore	875mm
4	Stroke	110mm
5	Connecting rod	234mm
6	Orifice diameter	20mm
7	Dynamometer arm length	185mm
8	Power	3.5 Kw
9	Speed	1500 rpm

6. Results & Discussion:-

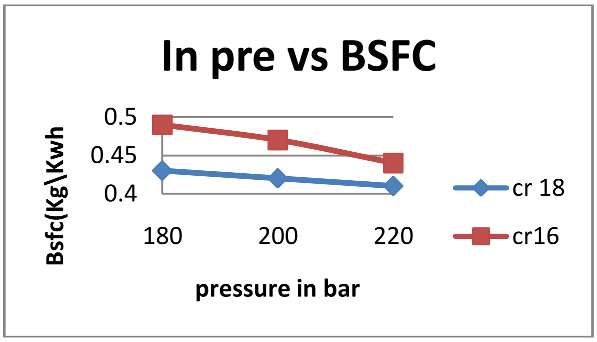
A. Variation of mechanical efficiency:

It has been observed from the graph that there is a steady increase in the mechanical efficiency as the injection pressure increases at both the compression ratios. This is due to the better atomization of the fuel during spray. The mechanical efficiency is low at lower compression ratio and vice versa. The higher compression ratios help the fuel and air to mix properly. So, the combination of both high compression ratio and high injection pressure give better results



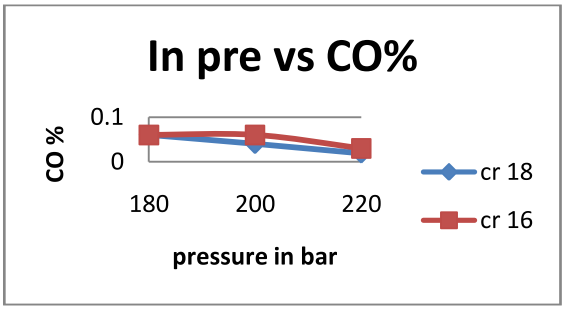
B. Variation of BSFC:

Break specific fuel consumption (BSFC) decreases with the increase in the compression ratio and injection pressure. This is due higher power generation at high compression ratios for the the same fuel consumed. Increased injection pressure contributes to this by better atomization of spray ensuring complete combustion.



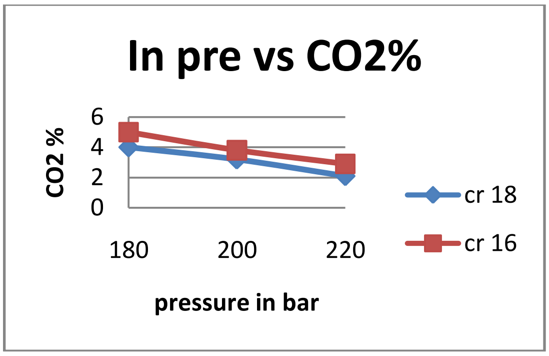
C. Variation of CO%:

The CO emissions for bio diesel are higher compared to normal diesel. This is due to the low volatility of bio diesel. From the graph below it is observed that the CO emissions decreased with the increased pressure of injection. This reduces the volatility of the fuel by better atomization of spray. This ensures better combustion. High compression ratio with high injection pressure gives better results.



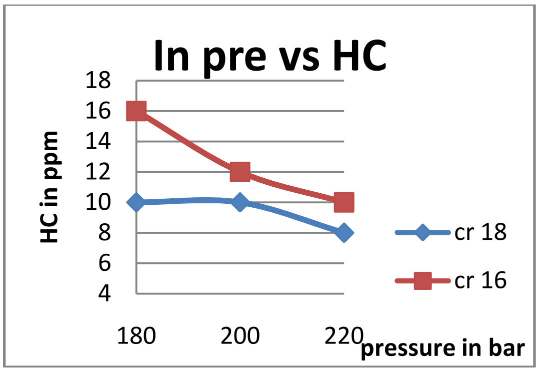
D. Variation of CO_2:

Bio diesel has lower CO_2 emissions compared to diesel. This is due to the fact that bio diesel contains oxygen components in in. The carbon content in the same amount of fuel is lower compared to diesel. The CO_2 emissions reduce as the injection pressure and compression ratio increases. This is due to better combustion and reduced fuel intake.



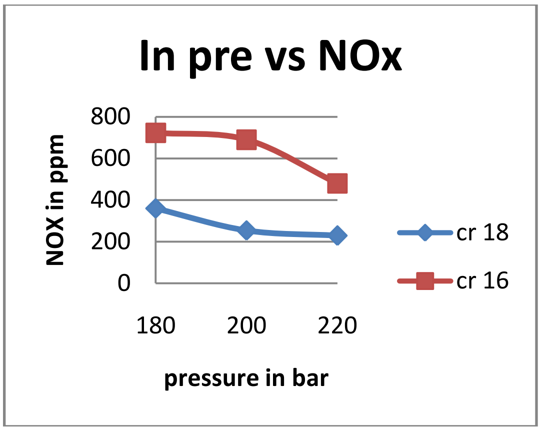
E. Variation of Hydro carbons (HC):

HC emissions decrease with the increase in the injection pressure over both the compression ratios. This is due to the complete combustion of fuel. The high pressure injection and high compression ratio gives better atomization and mixing. This makes the fuel volatile and ensures better combustion.



F. Variation in Oxides of Nitrogen (NO_x):

It is observed from the graph that the NO_X emissions are higher at lower injection pressure and lower compression ratio.



7. Conclusions:

The study aims to evaluate the emission characteristics of calophylluminophyllum methyl ester (CIME), when used on a VCR engine at different injection pressures. The following conclusions are drawn from the study.

1. Bio diesel at low compression ratio and low injection pressure has slightly slightly high sfc. This is due to the low volatility of oil, poor atomization and poor spray characteristics. The factors improved at higher CR and injection pressures.
2. The CO, CO_2 emissions are higher at lower CR and injection pressures and decreased by increasing them. This is due to relatively higher combustion at high CR and injection pressures.
3. NO_x emissions should increase with the increase in temperature. But it decreased at higher CR and injection pressure where the combustion temperature will be high. This needs further study.

The overall emission characteristics of CIME improved at compression ratio of 18:1 and injection pressure at 220 bars.

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