International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.9, No.04 pp 220-229, 2016

Development of Calophyllum inophyllum Biodiesel and Analysis of its Properties at Different Blends

T.Elangovan*, G.Anbarasu, L.Jeryrajkumar

Department of Thermal engineering, Sri Ramakrishna Engineering College, Coimbatore-641022, Tamilnadu, India

Abstract: Biodiesel is a gifted substitute as an alternative fuel has gained significant attention due to the predicted littleness of conventional fuels and environmental concern. The utilization of liquid fuels such as biodiesel produced from Calophyllum inophyllum oil by transesterification process represents one of the most promising options for the use of conventional fossil fuels. The Calophyllum inophyllum oil is converted into Calophyllum inophyllum methyl ester known as biodiesel processed in the presence of homogeneous acid catalyst. The physical properties such as Kinematic viscosity, Density, Calorific Value, Cetane number, Fire point and Flash point were found out for Calophyllum inophyllum methyl ester at different blends. The objective of this study is to develop the mathematical relationships between these properties among various biodiesel blends. There is a high regression between several properties of biodiesel and the relationships between them are detected to be considerably regular. The same characteristics study was also carried out for the diesel fuel. The values obtained from the Calophyllum inophyllum methyl ester is nearly matched with the values of conventional diesel and can be used in the normal diesel engine without any modification.
Key Words : Calophyllum inophyllum oil, Biodiesel, Alternative Fuel, Properties Correlation, Transesterification.

1. Introduction

Biodiesel is an alternative fuel prepared from renewable biological sources such as vegetable oils both (edible and nonedible oil) and animal fats. The biodiesel have some rewards as compared to petroleum diesel. The most important advantages of biodiesel are higher flash point, biodegradability, improved cetane number and reduced exhaust emissions. Practically the higher viscosity of vegetable oils (30-200 Centistokes) as associated to that to Diesel (5.8- 6.4 Centistokes) leads to unfavourable pumping, inefficient mixing of fuel with the air contributes to the incomplete combustion, high flash point result in increased inferior coking and carbon deposit formation[1]. Due to these problems, vegetable oil wants to be modified to bring the combustion associated properties closer to those of Diesel oil. The fuel modification is majorly aimed at reducing the viscosity and increasing the volatility.

One of the major promising processes to transform from vegetable oil to methyl ester is the transesterification, in which alcohol reacts with triglycerides of free fatty acids (vegetable oil) in the presence of catalyst like NaOH/KOH. Jatropha vegetable oil is one of the leading non edible sources existing in India. The vegetable oil used for biodiesel production might contain free fatty acids which will improve saponification reaction as a side reaction during the transesterification process[2].

All countries are at currently heavily dependent on petroleum fuels for agricultural machinery and transportation. The fact that a few nations together to prepared the bulk of petroleum has led to high price variation and uncertainties in supply for the engrossing nations[4]. This in turn has led them to search for alternative fuels that they themselves can produce. Among the alternatives being treated are methanol, ethanol, vegetable oils and biogas.

Vegetable oils have some of features that make them attractive as substitute for Diesel. Vegetable oil has the characteristics compatible with the Compression Ignition engine systems. Vegetable oils are also mixing with diesel fuel in any proportion and can be used as extenders. India majorly depends on import of petroleum crude and almost two third of its requirement is met through imports[5]. Moreover the gases released by petrol, diesel driven vehicles have an opposing effect on the environment and human health.

The significant advantages of using the Biodiesel are its renewability, biodegradability, better quality exhaust gas emission, also it does not contribute to a increase in the level of carbon dioxide in the atmosphere. The major sources for biodiesel are both edible and non-edible oils can be reached from such as edible oils like Peanut oil, Palm oil, Sunflower oil, Seasame oil, Soyabeen oil etc., and the non-edible oils like Jatropha Curcas, PongamiaPinnata, Calophyllum inophyllum, Mahau, etc. Hence, it is assumed that non-edible oils can be one of the solutions to meet the world energy demand and decrease the dependency on the edible oils.[8]

Calophyllum inophyllum

Calophylluminophyllum is a species of family Guttifereae (Clusiaceae), native to East Africa, Australia, India, Southest Asia and South Pacific. Usually it is called as 'Indian laurel', Alexandrian Laurel, Pannay tree, Beach calophyllum, Beauty leaf, Sweet Scented Calophyllum (in English), Burmese, Pongnyet, Hawaii, Sultan Champa,Surpan (in Hindi), Kokani, Nagachampa, (in Marathi), Nagam, Pinmai, Pinnay, Namere, Punnagam, Punnai, (in Tamil).[3]

Fig 1. Calophyllum inophyllum FlowerFig 2. Calophyllum inophyllum Tree

It is a wide leaved evergreen tree up as a littoral species along the beach crests, although sometimes happening inland and adjacent lowland forest. It has been broadly planted throughout the tropics and is established in the main Hawaiian Islands. The tree is used for its hardiness and beauty as an attractive tree. Oil from the nuts has been traditionally helped for medicine and cosmetics and is nowadays being produced commercially in the South Pacific.[6] The calophyllum inophyllum tree grows finest in direct sunlight, but grows slowly. Annual yield of 22-100 kg/tree of whole fruits have been reported. Trees begin to bear significantly after 4-6 years. The nut kernel encloses 50-75% oil and the mature tree may produce 1-10 kg of oil per year dependent upon the productivity of the tree and the yield of extraction process.

Although wildings happen, it can be moderately challenging to propagate. Its slow growth and large seeds make it improbable that the tree will become an invasive weed if announced into new areas. Tree grow to height of 8-20m (25-66ft), sometimes reaching up to 36cm (11ft). Canopy width is often better than the tree's height when the calophyllum inophyllum tree is grown in open location. It has a wide spreading crown often with gnarled, large, horizontal branches.[7]

`

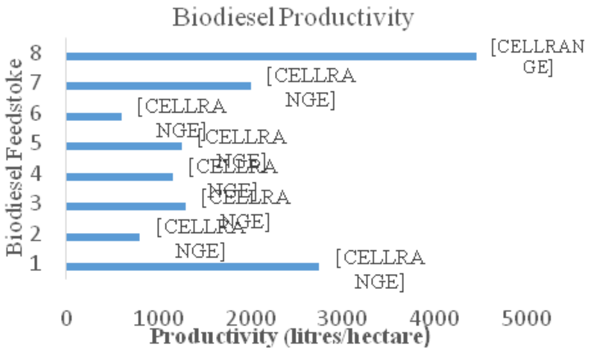


Fig 3. Biodiesel Productivity

Advantages of Calophyllum inophyllumTree[2]

1. It does not compete with food crops (it is non-edible oil).
2. High survival potency in nature, however productive until 50 years.
3. It has more oil yield than Jatropha.
4. It has more heating value
5. As windbreaker, soil and seashore conservation.
6. Multipurpose in use of its seed, wood, gum, processing by products.

2. Materials and Methods

2.1.Production of Calophyllum inophyllum Oil

The production of Calophyllum inophyllum oil was carried out in the following order.

(a) (b) (c)

Fig 4. Biodiesel Extraction Fresh Fruit, (b) Dried Seeds, (c) Extracted oil

`

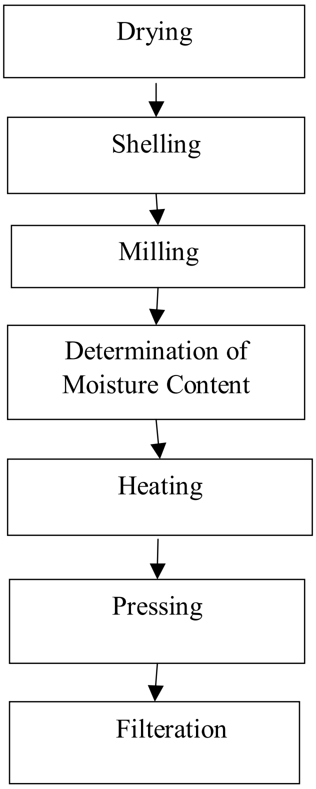


Fig 4.Calophyllum inophyllum Oil Extraction Process

2.2.Transesterification

In this process chemical reaction take place with a fat or oil with an alcohol in a presence of a base catalyst. Alcohol used is mostly methanol or ethanol. Catalyst is usually sodium hydroxide (NaOH) or potassium hydroxide(KOH). The major product of transesterification is biodiesel and the bi-product is glycerine.

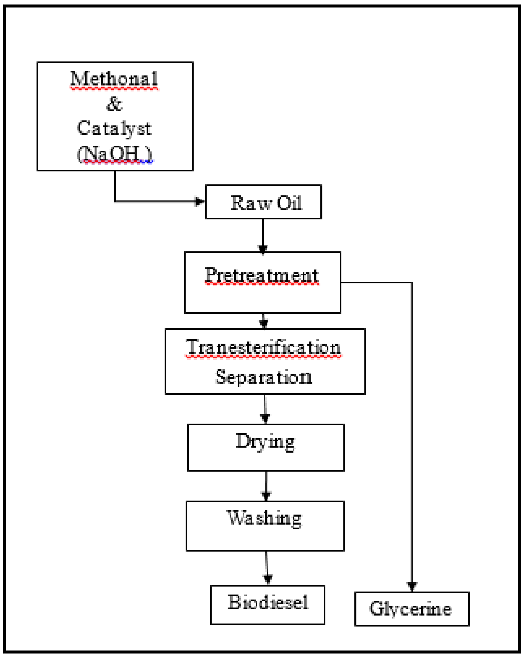


Fig 6. Tranesterification Process

`

2.3.Separation

After the transesterification process, the biodiesel layer is separated from the glycerin layer, both undergo purification .The chemical properties of Calophyllum inophyllum oil are given in Table 1.

Table 1. Chemical Properties of Calophyllum inophyllum Oil

Properties	Unit	Value
Color	-	Greenish yellow
Odor	-	Disagreeable
Density at 15°C	gm/cc	910
Kinematic Viscosity @ 40°C	cSt	38.17
Free Fatty Acid	mgKOH/g	28.16
Moisture	%	12
Calorific Value	MJ/Kg	32.50
Specific Gravity	-	0.908
Flash Point	°C	224
Fire Point	°C	253

3. Experimental Procedure

3.1.Neutralization

The vegetable oil contains about 14- 19.5% free fatty acids in nature, it must be freed before taken into actual conversion process. The presence of about 19% of free fatty acid makes Calophyllum inophyllum oil unsuitable for industrial biodiesel production. The dehydrated oil is agitated with 6 % HCL solution for 25minutes and and 0.88 gram of NaOH was added per 100 ml of oil to neutralize the free fatty acids (FFA) and to coagulate by the following reaction.

$RCOOH + NaOH \rightarrow RCOONa + H_2O$

The coagulated free fatty acid (soap) is separated by filtration. This process brings the free fatty acid (FFA) content to below 3 % and is perfect source for biodiesel production.

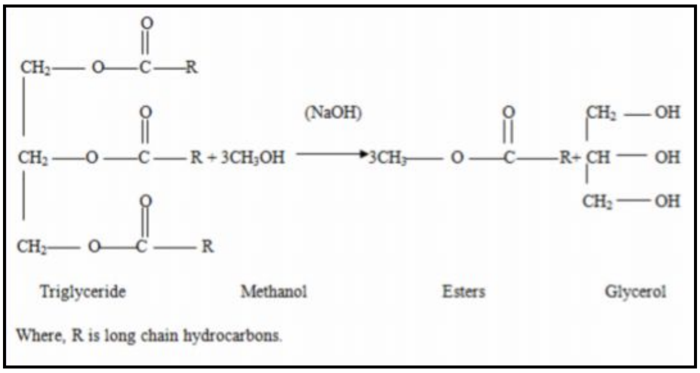


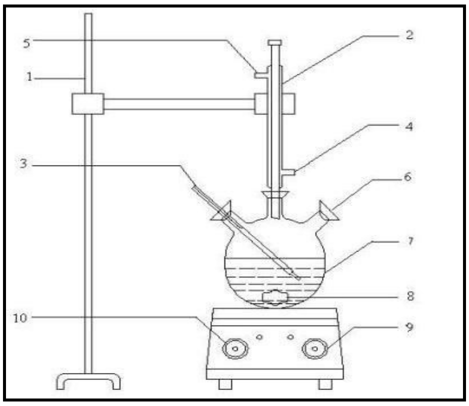
Fig 7. Tranesterification reaction of a triglyceride

3.2.Biodiesel Production

In the esterification process, the base catalyzed transesterification is preferred as the process to make biodiesel from Calophyllum inophyllum oil. Transesterification reaction is carried out in a batch reactor. For transesterification process 1 litre of Calophyllum inophyllum oil is heated up to 60°C in a round bottom flask to

`

drive off moisture and stirred vigorously. Methanol of 99.5 % purity having density0.790 g/cm³ is used. 9 gram of catalyst NaOH is dissolved in Methanol in 6:1 molar ratio, in a separate vessel and was spill into round bottom flask while stirring the mixture continuously. The mixture was kept at atmospheric pressure and 60°C for 60 minutes.



1	Iron Stand	6	Closed Neck
2	Condenser	7	Three neck Flask
3	Thermometer	8	Magnetic Stirrer
4	Coolant in	9	Magnetic Stirrer Controller
5	Coolant out	10	Temperature Controller

Fig 8. Experimental Setup

After completion of transesterification process, the mixture is allowed to settle under gravity for overnight separation in a separating funnel. The products developed during transesterification process were Calophyllum inophyllum methyl ester and Glycerin. The bottom layer consists of Glycerin, excess catalyst, alcohol, impurities and traces of unreacted oil.

Fig 9. Biodiesel Production at Various Stages

The upper layer consists of biodiesel, alcohol and some soap. The evaporation of water and alcohol gives 80-88 %pure glycerin, which can be sold as crude glycerin is distilled by simple distillation. Calophyllum inophyllum methyl ester (biodiesel) is mixed and washed with hot distilled water to eliminate the unreacted alcohol; oil and catalyst and permitted to settle under gravity for 24 hours. The separated biodiesel is taken for characterization.

Fig 10. Biodiesel Separating Funnel

`

3.3.Biodiesel Characterization

The specific gravity reduces after transesterification, viscosity from 38.17 to 3.7 centistokes, which is acceptable as per ASTM norms for Biodiesel. Flash point and fire point are important temperatures specified for safety during storage, handling and transport. The flash point and fire point of biodiesel was found to be 24°C and 34°C respectively by PMCC method. Flash point of Calophyllum inophyllum oil decreases after transesterification, which shows that its volatile characteristics had developed and it is also safe to handle.

Table 2. Calophyllum inophyllum Biodiesel Properties at different Blends

Fuel Properties	Unit	B20	B40	B60	B80	B100	Diesel
Density @15^{O}C	Kg/m^3	847.6	854.6	857.5	867.3	868.6	840
Kinematic Viscosity @40 ^{O}C	cSt	2.85	3.03	3.3	3.54	3.7	3.12
Flash Point*	^{O}C	30	28	26	26	24	25
Fire Point*	^{O}C	40	38	36	36	34	36
Calorific Value	MJ	43.86	41.21	40.13	39.02	36.86	44.34
Cetane Number		56	55	54	53	52	48

*by Pensky Martens Closed Cup(PMCC) Method

Fig 11. CalophyllumInophyllum Biodiesel at different Blends

Higher fuel density means high mass of fuel per unit volume for vegetable compared to diesel oil. The higher mass of fuel would give high energy available for work output per unit volume. Higher viscosity is a major problem in using vegetable oil as fuel for IC engines. Cloud and pour point are criterion used for low temperature performance of fuel. The higher cloud point can disturb the engine performance and emission adversely under cold climatic conditions. The cloud point for Diesel is 4^{0}C .The pour point for Diesel is - 4^{0}C. In general higher pour point often limits their use as fuels for IC engines in cold climatic conditions. When the atmosphere temperature is below the pour point of the oil, wax precipitates in the vegetable oils and they drop their flow characteristics, wax can block the filters and fuel supply line. Under these kind of conditions fuel cannot be pumped through the injector. In India, ambient temperatures can go down to 0^{0}C in winters.

4. Results and Discussion

4.1 Density vs Viscosity

Density is the relationship between the mass (m) and volume(V) of a solid or a liquid and can be denoted in units of grams per litre (g/L). The density of diesel oil is important because it gives a signal of the

`

delay between the fuel injection and combustion of the fuel in a diesel engine and the energy per unit mass. This can guidance the efficiency of the fuel atomization for airless combustion systems.

Viscosity is defined as the resistance of liquid to flow. It denotes the thickness of the oil, and it is firm by measuring the amount of time consumed for a given measure of oil to pass through an orifice of a detailed size. Kinematic viscosity is the major important property of biodiesel since it disturbs the operation of fuel injection equipment (nozzle), particularly at low temperatures when rises in viscosity affects the fluidity of the fuel. Moreover, high kinematic viscosity may lead to the engine deposits and formation of soots due to inadequate fuel atomization. It has been shown that the viscosity oil methyl esters reduces sharply after transesterification processes of biodiesel. The kinematic viscosity of biodiesel is determined by using ASTM D445 (1.9–6.0 mm^2/sec). The relationship between Kinematic viscosity and density is shown in Figure 12. From that, the correlation between density and viscosity is: Viscosity= 0.0238 * Density – 17.121 with coefficient of regression value of 0.6674

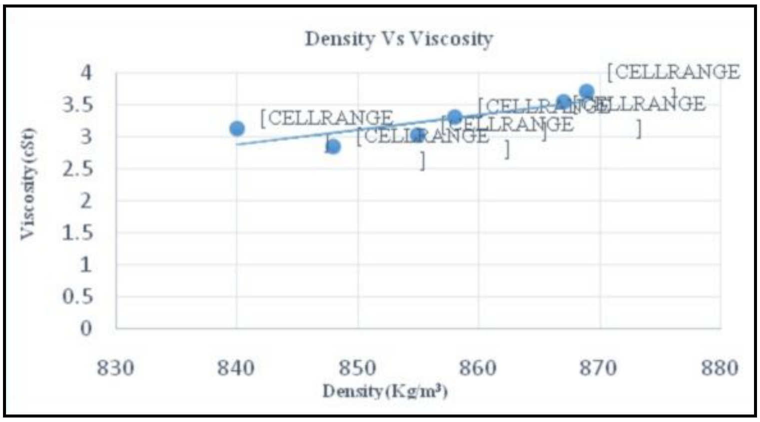


Fig 12. Correlation between Density and Viscosity

4.2 Viscosity vs Flash Point

Flash point is another major property for biodiesel fuel. Flash point of the fuel is the temperature at which fuel will ignite when exposed to a spark or a flame. Flash point differs inversely with the fuel's volatility. The flash point is the lowest temperature at which the fuel emits enough vapours to ignite. The relationship between viscosity and Flash point is shown in Figure 13. From that, the correlation between viscosity and Flash Point is: Flash point= 5.5044 * Viscosity +440426 with coefficient of regression value of 0.6629

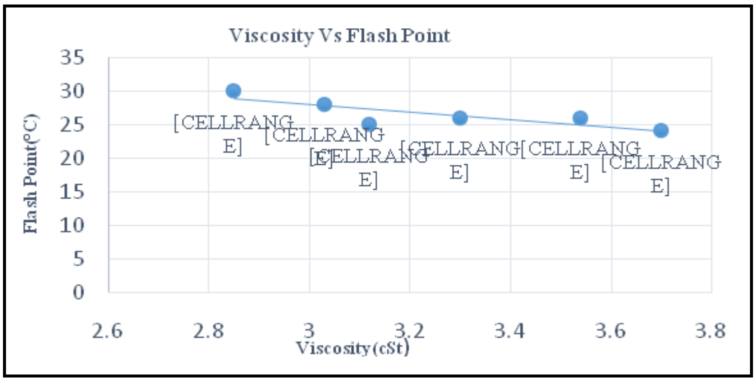


Fig 13. Correlation between Viscosity and Flash Point

4.3 Density vs Flash point

The relationship between density and Flash point is shown in Figure 14. From that, the correlation between density and Flash point is: Flash point= -0.0724 * density +88.467 with coefficient of regression value of 0.1371.

`

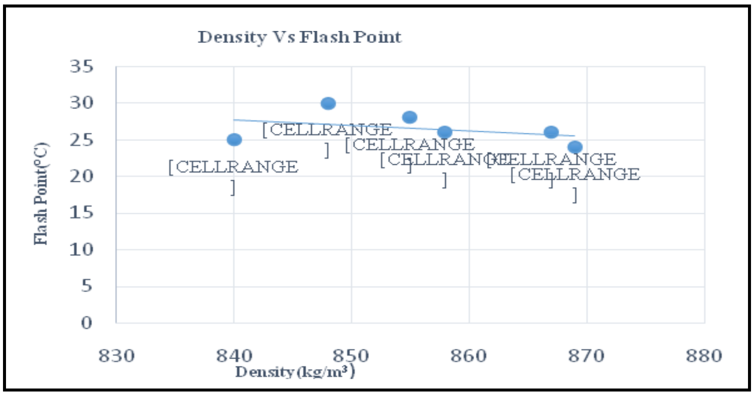


Fig 14. Correlation between Density and Flash Point

4.4 Density vs Calorifiv Value

Calorific value is major parameter in the selection of a fuel. The caloric value (Heating Value) of biodiesel is lower than of diesel because of its higher oxygen content. The relationship between density and calorific value is shown in Figure 15. From that, the correlation between density and calorific value is: Calorific Value= -0.2502 * density +255.14 with coefficient of regression value of 0.935

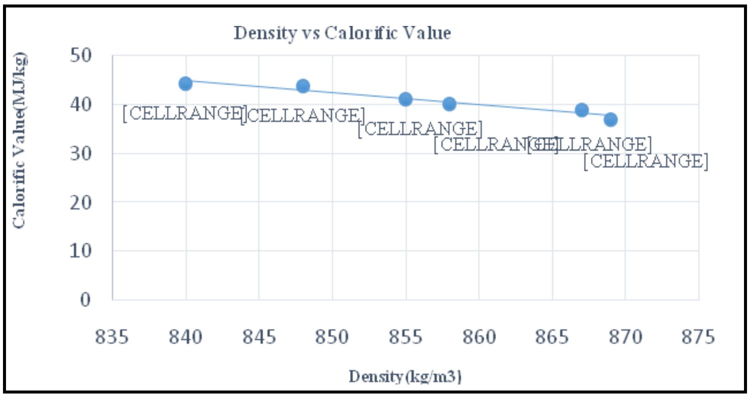


Fig 15. Correlation between Density and Calorific Value

4.5 Fire Point vs Cetane Number

Cetane number is used to measure of ignition quality of diesel fuels. The high cetane number implies short ignition delay. Higher molecular weight usual alkanes have high cetane numbers. It influences both gaseous and particulate emissions. The fuels with higher auto ignition temperatures are more likely to cause diesel knock. The relationship between Fire point and cetane number is shown in Figure 16. From that, the correlation between Fire point and Cetane number is: Cetane number= 0.8438 * fire point +22.063 with coefficient of regression value of 0.3797.

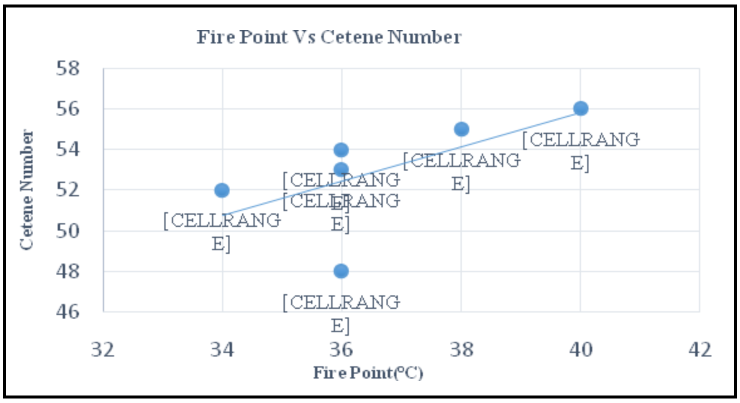


Fig 16. Correlation between Fire Point and Cetane number

`

5.Conclusion

In the present investigation, it has confirmed that Calophyllum inophyllum oil used as resource to obtain biodiesel. That seeds having more oil content. The extracted oil has more Free Fatty Acids (FFA) about 19%. The calophylluminophyllum oil having more viscosity, so it needed two step of esterification. The best combination of the parameters was found as 6:1 molar ratio of Methanol to oil, 9 gram of sodium hydroxide (NaOH) catalyst, 60^0C reaction temperature. The viscosity of Calophyllum inophyllum oil reduced considerably after transesterification and is comparable to diesel. The experimental result shows that base catalyzed transesterification is a promising area of research for the production of biodiesel in large scale.

Biodiesel characteristics like kinematic viscosity, density, flash point, fire point, calorific value and cetane number are comparable to diesel. The pure biodiesel (B100) had almost nearer Kinematic viscosity and Calorifc value to diesel. Correlations have been established between Kinematic viscosity, flash point, fire point, density, and Calorific value value. The Calophyllum inophyllum Methyl Ester (CIME) biodiesel it is observed that it may be used as the alternative fuel in Internal Combustion (IC) engine.

6.References

1. S.Antony Raja, Biodiesel production from jatropha oil and its characterization. Vol. 1 (1) April(2011)
2. A.E. Atabani, Calophyllum inophyllum L. – A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance.
3. K Ramesh, Bio-diesel development process from Calophyllum inophyllum Seeds. Venkanna BK, Reddy CV. Biodiesel production and optimization from Calophyllum inophyllumlinn oil (hone oil) – a three stage method. Bioresour Technol2009;100(21):5122–5.
4. Gaurav Dwivedi, Diesel engine performance and emission analysis using biodiesel from various oil sources-Review.
5. H. Suresh Babu Rao, Palm oil and Calophyllum inophyllum oil are potential feed Stocks for future Biodiesel in Compression Ignition Engines: A Review.
6. Y.C. Sharma, Advancements in development and characterization of biodiesel: A review.
7. Chavan S.B, Callophyllum inophyllum Linn ("honne") Oil, A source for Biodiesel Production.

*****