Bio-diesel development process from Calophyllum Inophyllum Seeds

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3 authors:

Kr KANNA Ramesh
Government College of Technology

Dr.Amirthagadeswaran K S
Government College of Technology

Geen Paul V
Tata Consultancy Services Limited

Bio-diesel development process from Calophyllum Inophyllum Seeds

K Ramesh[1], K S Amirthagadeswaran[2], Geen Paul V[3]

[1] *Assistant Professor (SG), Department of Mechanical Engineering, Government College of Technology (Coimbatore), India.*

[1]dr_ramesh@live.com

[2] *Professor of Mechanical Engineering, Government College of Technology (Coimbatore), India.*

[2]ksag_eswar@rediffmail.com

[3] *P G Scholar, Department of Thermal Engineering, Government College of Technology (Coimbatore), India.*

[3]aerojeanz@live.com

***Abstract*— In the recent past, the crude oil prices have increased immensely and the fossil fuels are depleting. Global warming has become a global concern, which is highly contributed by the emissions of fossil fuel combustion products. In this context, bio-fuel has emerged as an alternative fuel for petroleum. Bio-fuels, due to their agricultural origin, are able to reduce net carbon dioxide and carbon monoxide emissions. Bio-fuels are having environmental benefits as they are made from renewable sources. Bio-diesel is biodegradable and it can be used in most diesel engines with minimum alterations in the engine manifold. However, the NO_x emissions are comparatively higher and they have higher viscosity and low volatility compared to mineral diesel fuel. The use of Bio-diesel blends in the Direct Injection Compression Ignition Engine seems to be a solution for power generation problems.**

The present paper discusses with the various phases of production of bio-diesel from calophyllum inophyllum seeds. The phases of shelling, milling, heating, moisture removal, pressing, filtration and transesterification are discussed. Bio-Fuel to bio-diesel transformation is also discussed. The bio-diesel characteristics are compared with neat diesel. The bio-diesel thus produced is noted to be more eco-friendly and provides better opportunities for sustainable development.

***Keywords*— Calophyllum Inophyllum, Transesterification, Honne Oil, Bio-diesel, HOME, Bio-fuel.**

I. Introduction

The idea of using bio-fuels for Direct Injection Compression Ignition Engine is not new. It dates back to early nineteenth century; Rudolph Diesel had tested his diesel engine with peanut oil at Paris Exposition of 1900. Inspite of the technical feasibility, the bio-fuels were unable to get wide acceptance in the engineering world as its manufacturing was more expensive than conventional petroleum and the environmental aspects were out of concern [1]. These fuels were not immediately popular; during the end of 2008, rises in fuel prices coupled with concerns about oil reserves, have led to more widespread use of bio-fuels and bio-diesels. In the recent past many researches have been carried out with systematic efforts in the field of developing and testing bio-fuels and bio-diesels. In the early 1930s and 1940s vegetable oils were used as diesel fuels from time to time, but usually only in emergency situations. Many vegetable oils were tried for this purpose. Palm oil was used in the early 1940s in Belgium for running buses; and many researches on palm oil bio-diesel blends as a fuel were carried out worldwide [2]. Honne Oil is one of the latest found source for bio-diesel [3]. Honge Oil is also used for the bio-diesel production in many areas [4]. Cottonseed Oil is found as one of the alternative sources especially where the cotton is major produce [5]. Jatropha Oil is widely accepted source of bio-diesel and are grown exclusively for biodiesel production [6]. Sunflower Oil has been tried for use in gas turbine engines [7]. Peanut oil is the first used bio-diesel source [1]. Coconut Oil is found to be useful especially when they are contaminated for edible uses and have exceptional lubricating properties[8]. Mustard Oil has also been tried for bio-diesel production[9]. Soya been Oil is noted to be useful in producing fuel for airplane power plants [10]. Olive Oil is also gaining wide acceptance as a bio-fuel source in the northern hemisphere [11]. Rapeseed Oil has been tried to prepare in supercritical methanol for bio-diesel production[12]. The other oils from Ponigamia, Rubber Seed, were developed and tested by various researchers globally.

II. Biofuel and Biodiesel

There is much difference between the bio-fuels and bio diesels. Biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as from solid biomass, liquid fuels and various biogases.

Whereas biodiesel is a clean burning, nontoxic, biodegradable and environmentally friendly fuel that can be used in any compression ignition (diesel) engine. It is non-petroleum based fuel - that means it is not made with fossil fuels like oil or coal. These environmentally friendly fuels are made from renewable sources like vegetable oils and fats.

These oils and fats are converted by a process called transesterification into a fuel that can be blended in any proportion to conventional petroleum based diesel or used it as is in any diesel engine without having to make any modifications to that engine. Straight vegetable oil used in vehicles is not biodiesel as there has been no transesterification process or conversion of the vegetable oil.

III. Calophyllum Inophyllum

The Calophyllum Inophyllum plants are widely dispersed throughout the tropics, including the Indian Peninsula, Hawaiian and other pacific islands. They typically grow into eight to twenty meters at maturity.[The common habitats include strand or low-elevation riverine, 0–200 m (660 ft)in tropics, up to 800 m (2000 ft) at the equator; mean annual temperatures 18–33°C (64–91°F); annual rainfall 1000– 5000 mm(40–200 in).] They are also commonly found on beaches and in coastal forests. They grow best in sandy, well drained soils. They may initially grow up to 1 m (3.3 ft) in height per year on good sites, although usually much more slowly. The agro forestry uses include mixed-species woodlot, windbreak, and homegarden; with their main products of timber and seed oil. Studies reveal that the annual yield of 100 kg (220 lb) nuts/tree/yr yields 5kg (11 lb) of oil on an average. These trees have low potential for being invasive.

Fig. 1 Calophyllum Inophyllum Tree

The Calophyllum inophyllum Common Names :

Calophyllum inophyllum(kamani)Clusiaceae (syn. Guttiferae) (mangosteen family), alexandrian laurel, beach mahogany, beauty leaf, poon, oil nut tree (english); beach calophyllum (papua new guinea),biyuch(yap); btaches(palau); daog, daok(guam, n. Marianas); dilo(fiji); eet(kosrae); feta‘u(tonga); fetau(samoa);isou(pohnpei); kamani, kamanu(hawai‘i); lueg(marshalls); rakich(chuuk); tamanu(cook islands, society islands,Marquesas); teitai(kiribati).

Fig. 2 Canophyllum Inophylum Flower

The species have been planted widely throughout the tropics and it is uncertain from where it originates. It is believed to be indigenous to India, Malaysia, Indonesia and the Philippines. It grows in areas with 1000–5000 mm rain per year at altitudes from 0–200 m. It essentially falls to a group of coastal species that grows on sandy beaches and, to a lesser extent, along river margins further inland. 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.

Fig. 2 Canophyllum Inophylum Fruit

The fruits are used for human consumption although they are reported to be slightly toxic. It is a medium- sized tree, normally up to 25 m tall, occasionally reaching up to 35 m high and with diameter up to 1.50 m. The bowl is without buttresses; it is usually twisted or leaning especially on wind exposed sites. It has sticky latex that is either clear or white to yellowish. The fruit is a round drupe, 2–4 cm in diameter. The single, large seed is surrounded by a shell (endocarp) and a thin, 3–5 mm layer of pulp.

Fig. 2 Canophyllum Inophylum Seed

The fruit is at first pinkish-green later turning into bright green and when ripe, it turns dark grey-brown and wrinkled. There are about 100–200 seeds/kg. The tree can flower and bear fruit all year round in Indian conditions and in Tamil Nadu and Mysore (India) flowers usually appear in the cold season and fruits ripen in March. In Kerala (India), flowers appear in March–April and fruits ripen in May–June, although both flowers and fruits can be found at other times of the year. In Orissa (India), there are two seasons, with flowering during May–June and October–November. In the Andaman Islands (India), the tree will flower profusely during the rainy season and, to a lesser extent, at other times of the year, with fruiting from June to august. The flowers are pollinated by bees and other insects, and fruits are dispersed by sea currents and fruit bats.

The unrefined but filtered Honne oil is dark green in colour and is used as feedstock for the biodiesel production in this study. The fatty acid composition and the important properties of Honne oil in comparison with other non-edible oils is given in Table I. The type and percentage of fatty acids contained in vegetable oils depend on the plant species and on the growth conditions of the tree. Honne oil contains 24.96% saturated acids (palmitic and stearic) and 72.65% unsaturated acids (oleic, linoleic and linolenic). Saturation fatty acid alkyl esters increase the cloud point, cetane number and stability. The free fatty acid content of unrefined filtered honne oil was found to be 22% and Acid value greater than 44 mg KOH/g. Its free fatty acid content was determined by standard titrimetric method. The yield of esterification process and quality of biodiesel decreases considerably if acid value is greater than 4 mg KOH/g, i.e. Free fatty acid content is 2%. Therefore, development of method to produce biodiesel from high acid value oils is significant. Efforts have been made to esterify a typical high free fatty acid type of oil, Honne oil in this study.

TABLE I
COMPARISON OF PROPERTIES: DIESEL AND HONNE OIL

Properties	Units	Diesel	Honne Oil
Density	kg/m^3	830	906
Viscosity	mm^2/s	3.12	31.2
Fire Point	^{o}C	65	118
Flash Point	^{o}C	56	157
Cloud Point	^{o}C	(-8±1)	(-2.5±1)
Pour Point	^{o}C	(-16±1)	(-8±1)
Caloific Value	kJ/kg	43,000	39,200

IV. PRODUCTION OF HONNE OIL

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

A. Drying

The seeds collected were made to dry under hot sun, causing the inner seeds to detach from the outer shell.

B. Shelling

The shelling process is to remove the seed coat of the calophyllum inophyllum seeds. It was carried out manually. This process was tiresome and needs automation.

C. Milling

The unshelled seeds were milled into dough by using the corn milling machine. Not much difficulties were faced during this process.

D. Determining Moisture Content

The moisture content was determined and was found to be more than 12 percentage by Karl Fischer titration method. The water was to be removed to achieve 12% moisture content.

E. Heating

Heating of the seeds was done in an oven. The temperature was raised to 80- 85^{o}C, so as to remove the moisture content completely. The heated dough is thus free from moisture.

F. Pressing

Pressing was done by using an Oil press and the Honne oil was extracted from the dough and taken for filteration.

G. Filteration

The oil was collected and filtered using coarse and fine filters. Thus removing the finest dust and slag particles left over the pressing process.

V. PRODUCTION OF BIO-DIESEL

The quality of oil is expressed in terms of its fuel properties such as viscosity, density, flash point, acid value, iodine value and saponification value. Density, kinematic viscosity and flash point of Honne oil were determined as per the methods approved by Bureau of Indian Standards. Determination of density, kinematic viscosity and flash point were carried out using Redwood viscometer and Cleveland open cup apparatus. The apparatus used for transesterification consists of an oil bath, a 500 ml three necked round bottom flask equipped with digital controlled mechanical stirrer, a platinum RTD (Resistance temperature detection) sensor with an accuracy of ±1^{o}C connected to a digital indicator and a condenser. A separating funnel with a valve at the bottom was used for collection of the final product. Honne oil was heated to 110^{o}C for 30 min to remove moisture and was allowed to cool in a desiccator.

Stage 1: Pre-treatment process (acid esterification)

High FFA (Free Fatty Acid) Honne oil was converted to triglycerides in a pre-treatment process with methanol using anhydrous H_2SO_4 (acid catalyst). The variables affecting acid esterification, such as methanol to Honne oil molar ratio and acid catalyst concentration were studied to get the maximum conversion efficiency of FFA to triglycerides. The reaction was conducted at 60±1^{o}C for 120 minutes. When the first stage of the acid esterification was complete, the product was transferred to a separating funnel, where the excess methanol along with impurities were removed. The bottom layer was used for the alkali transesterification.

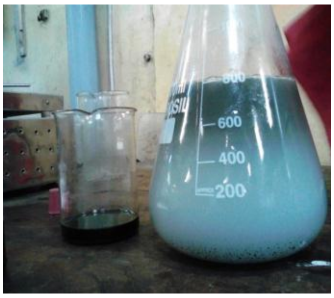

Fig. 5 Washing of Bio-diesel in Apparatus

Stage 2: Alkali catalyzed transesterification process

The bottom layer product of acid esterification was heated to the desired temperature before starting the reaction. The potassium hydroxide–methanol solution was prepared. The alkali methoxide solution was added to preheated product of the acid esterification while mixing by means of a mechanical stirrer fixed in the transesterification flask. The product was allowed to settle under gravity for 8 hours in a separating funnel. The products of the alkali transesterification process result in the formation of two layers viz., an upper layer containing a mixture of small quantities of unreacted oil, glycerol and transesterified products (esters) and a lower layer of glycerol. The lower layer of glycerol was then removed.

Fig. 4 Transesterification Apparatus

Stage 3: Post treatment process

The upper layer of alkali transesterification product was mixed with petroleum ether. The esters and un-reacted oil readily mixed into the petroleum ether with glycerol as a separate layer. The separated layer was also removed. The upper layer was a mixture of esters and un-reacted oil. These two were separated by diluting the mixture with fresh and sufficient quantity of methanol. The esters went into the methanol and un-reacted oil remained as a separate layer. The lower layer of un-reacted oil was removed. The upper layer was heated to 65^{o}C to remove methanol. The product was Honne oil methyl ester (HOME), a biodiesel. The HOME was mixed gently with distilled water (30% of volume of distilled water to volume of biodiesel) at 60^{o}C in order to remove impurities like catalysts. The mixture was allowed to settle under gravity for 8 hours. The settled layer of mixture with impurities was drained out. Water wash was repeated till the pH value of drained water was nearly same as that of distilled water before water wash. The water wash was done to increase the purity of the product by removing the finest dust particles and other impurities. After washing, the final product was again heated to 110^{o}C for 10 min to remove moisture.

VI. Results and Conclusions

The calophyllum inophyllum seed oil was successfully extracted from the seeds. The oil (Honne oil) thus extracted was made to undergo the transesterification process and conditioned. The transesterified oil is called as Honne Oil Methyl Ester (HOME) Bio-diesel. HOME Bio-diesel properties are then compared with neat diesel. Comparing the properties of Honne Oil Methyl Ester (HOME) Bio-diesel it is observed that it may be used as an alternative fuel in internal combustion compression ignition engines. It is noted that the bio-diesel blends comply with the American, German and European Bio-diesel standards. The HOME Bio-diesel produced has been tested to determine its properties and suitability for use in IC engines.

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