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# Detail study on the Properties of Pongamia Pinnata (Karanja) for the Production of Biofuel

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## Abstract

*An ever increasing demand of fuels has been a challenge for today's scientific workers. The fossil fuel resources are dwindling day by day. Biodiesel seem to be a solution for future. It is an environmental viable fuel. Several researchers have made systematic efforts to use plant oil and their esters (biodiesel) as a fuel in compression ignition (CI) engines .There is various types of raw material like Jatropha curcus L, Pongamia Pinnata (Karanja), Moha, Undi, Castor, Saemuruba, Cotton seed etc. An non- edible oil seeds and Various vegetable oils including palm oil, soybean oil, sunflower oil, rapeseed oil and canola oil have been used to produce biodiesel fuel and lubricants. Out of these Pongamia pinnata can be a definite source of raw material due to its easy availability in wild. Pongamia pinnata 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. After tranesterification of crude oil shows excellent properties like calorific value, iodine number, cetane number and acid value etc. Detail study intends to identify all advantages and disadvantages of pongamia pinnata as a sustainable feedstock for the production of Biodiesel equivalent to fossil fuel as per ASTM 6751-9B.*

**Keywords:** Biodiesel, esterification reaction, trans-esterification reaction, pongamia pinnata oil, American standards for testing and materials (ASTM), deoiled cake (DOC)

## Introduction

Using straight vegetable oil in diesel engines is not a new idea. Dr. Rudolf Diesel first used peanut oil for demonstration of his newly developed compression ignition (CI) engine in year 1910. Later with the availability of cheap petroleum, crude oil fractions were refined to serves as 'diesel', a fuel for CI engines[1-5]. During the period of world war-II, vegetable oils were again used as fuel in emergency situations when fuel availability became scarce. Now days, due to limited resources of fissile fuels, rising crude oil prices and increasing concerns for environment, there has been renewed focus on vegetable oil and animal fats as an alternative to petroleum fuels[6,7]. In India only non edible oil can be used as a raw material for biodiesel production. These non edible oil seeds plants can be grown in non fertile land and waste lands. In our country these lands are much available. Non edible oil seed like jatropha curcus, pongamia pinnata, moha, undi, saemaruba contains oil in seed. In our country there are more than 300 species of trees, which produce oil bearing trees. The collection and extraction of oil is carried out by Indian Biodiesel Corporation, Baramati. These non edible oil seeds are also used for lightning purpose at night. The use of these oils gives a best way to reduce the production cost of biodiesel. Also the processed vegetable oil can be used in any existing CI engine without any modification[8-10.]

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]. 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 has slight corrosive effect on the piston liner[14,15]. Bradshaw[16] stated that 4.8:1 molar ratio of methanol to vegetable oil leads to 98% conversion. He noted that the ratio of greater than 5.25:1 interfered with the gravity separation of the glycerol and added useless expense to the separation. Freedman studied the effect of molar ratio of methanol to oil and effect of changes in concentrations of tri-, di-, and monoglyceride on ester yield[17]. He obtained results for methanolysis of sunflower oil, in which the molar ratio varied from 6:1 to 1:1 and concluded 98% conversion to ester was obtained at a molar ratio of 6:1[18].

**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[19]. 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 and mature 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.

**Uses:** The total karanja tree has got excellent medicinal properties.

**Wood:** Karanja is commonly used as a fuel. Its wood is susceptible to insect attack, so wood is not considered as quality timber. But it may be used in agricultural implements, tools and combs.

**Oil:** A thick yellow – orange to brown oil is extracted from seed. About 24% of yield is obtained by mechanical expeller. The oil has bitter test and disagreeable aroma, so it is considered as a non edible one. In our country this oil can be used as a fuel for cooking and lamps. Also oil is used as lubricant, pesticide and in soap making industries. The oil has medicinal value in the treatment of rheumatism and in skin diseases. The crude oil for analysis is collected from Indian Biodiesel Corporation, Baramati and Maharashtra, India.

**Leaves:** Leaves can be used for anthelmintic, digestive, and laxative, for inflammations, piles and wounds. Their juice is used for colds, coughs, diarrhea, dyspepsia, flatulence, gonorrhea, and leprosy. The fresh leaves are eaten by cattle and by goats in arid regions.

**De oiled Cake:** It constitutes flavonoids, uranoflavonoids, and furan derivatives and is used in treating skin diseases and in bio pesticide. The meal cake can be used as fertilizer, pesticide and used for organic farming. Seed shells can be used as combustibles.

**Kernel:** It is used for oil extraction and the oil can be used as fuel, soap production, insecticide and medicinal use.

**Root and bark:** (as alexipharmic, anthelmintic) used for abdominal enlargement, ascites, biliousness, diseases of the eye, skin, and vagina itch, splenomegaly, tumors, ulcers and wounds as cleaning gums, teeth and ulcers.

**Fruit hull:** It can be used as green manure, biogas production and combustibles. Oil cake can be used as fertilizer and combustibles.

**Other uses:** Dried leaves are used as an insect repellent in stored grains. The deoiled cake when applied to soil, has pesticidal value, especially against nematodes and also helps in improving soil fertility. Karanja is often planted in home steads as a shade or ornamental tree and in avenue planting along roadside and canals. It is preferred species help in controlling soil erosion and binding sand dunes due to its dense network of lateral roots.

## Material and Method

**Seed Material:** The seed are collected from Indian Biodiesel Corporation, Baramati, and Maharatra. The seeds are selected according to their conditions where damaged seeds were discarded before seeds in good conditions were cleaned, de-shelled and dried at high temperature at 100-105 $^{O}$c. For 30 minutes. Seeds where then taken for oil extraction.

**Extraction of oil:** The oil can be extracted by mechanical expeller and by soxhlet extraction method. We are chosen soxhelt extraction method for best result. Mechanical press extraction method-(Single chamber and double chamber oil Expeller). It is an ordinary method used for the extraction of all types of oil. This process requires extra time and recovers oil in fewer amounts as compared to other methods.

**Cold Percolation Method:** This is a gravimetric method used for the extraction of oil in laboratory. The word cold means no heat is applied and extraction occurs at room temperature only.

**Soxhelt Extraction Method- (Solvent extraction method):** The seeds were grinded into fine particles and 50gms of grinded was taken and a thimble was made. The soxhelt apparatus was set up and 300ml hexane was added to thimble from above.

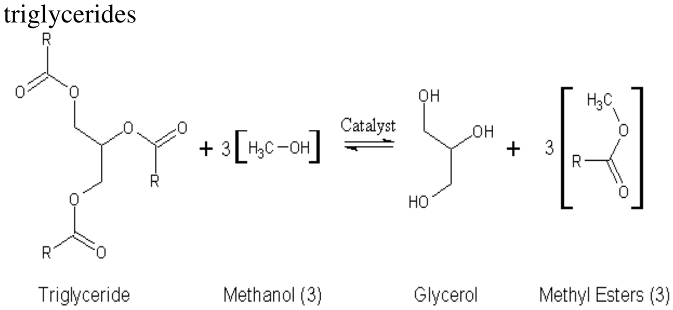
**Working of apparatus:** A soxhelt extractor is a piece of laboratory apparatus invented in 1879 by Franz Von Soxhlet. Typically, a soxhlet extraction is only required where the desired compound has a limited solubility in a solvent and the impurity is insoluble in that solvent. Normally a solid material containing some of the desired compound is placed inside a thimble made from thick filter paper, which is loaded into the main chamber of the Soxhlet extractor. The Soxhlet extractor is placed onto a flask containing the extraction solvent. The Soxhlet is then equipped with a condenser.

The Soxhlet is then heated to reflux. The solvent vapor travels up a distillation arm and floods into the chamber housing the thimble of solid. The condenser ensures that any solvent vapors cools and drips back down into the chamber housing the solid material. The chamber containing the solid material is slowly filled with warm solvent. Some of the desired compounds then get dissolved in the warm solvent. When Soxhlet chamber is almost full, the chamber is automatically emptied by a siphon side arm, with the running back down to the distillation flask. This cycle is allowed to repeat several times within 8hrs of extraction. During each cycle, a portion of the non- volatile compound dissolves in the solvent. After many cycles the desired compound is concentrated in the distillation flask. After extraction, the solvent is removed, typically by means of a rotary evaporator at 40-50$^0$C, yielding extracted oil. The non soluble portion of the extracted solid remains in the thimble, which is removed separately. The physic chemical properties of pongamia oil is shown in table- 2

**Production of biodiesel through Transesterification reaction:** 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 alkyl ester 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 [20,21]

The transesterification reaction is given below [22] this process has been widely used to reduce the high viscosity of triglycerides




**Scheme**

*$R_1$, $R_2$, and $R_3$ in this diagram represent long carbon chains that are too lengthy to include in the diagram*

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 tranesterifaction reactor and subjected to heating and stirring. When temperature of oil reached at 60$^o$C then sodium methoxide was mixed in to the 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 hours. After settling for 8 hours glycerol and methyl esters was separated manually. The methyl ester was the washed with hot water to remove traces of sodium hydroxide impurity. The washed biodiesel then distilled to remove moisture and final good quality biodiesel was subjected for chemical analysis. The property table is given in table-4.

## Results and Discussion

Seed characterization- Moisture content- @10% (fresh seed); Oil content- 35% (available)

**Percentage Yield of Oil:** The extraction of oil from pongamia pinnata seeds were done by three methods that are- mechanical expeller, solvent extraction method and by cold percolation method. See table no. 1

**Table-1**
**Percentage yield of ponagamia pinnata seed**

| Extraction Method | Yield in % |
|---|---|
| Mechanical expeller | 24 |
| Soxhelt extraction | 31 |
| Cold percolation method | 27 |

**Physico-Chemical Properties of oil:** As we know the fresh extracted crude oil is yellowish red/ brown and it get darkened during the storage. The oil having disagreeable odor and bitter taste. The solvent extraction method gives good quality oil than ordinary extraction methods. According to the Kriakidis, the iodine value is a measurement of the unsaturation of fats and oils. Higher iodine value indicated that higher unsaturation of fats and oils[12,23]. All properties are given in table no 2 and were carried out as per American Standards' For Testing and Material (ASTM)

**Fatty Acid Composition of Crude Oil**- The percentage composition of fatty acids present in Pongamia pinnata crude oil is represented in table 3.

**Properties of Pongamia pinnata methyl ester:** According to observed properties of karanja methyl ester, it is then proved that, the methyl ester of karanja oil shows good properties. These properties are comparing with fossil fuel that is shown in following table no 4.

## Conclusion

The major fatty acids in Pongamia pinnata crude oil were palmic acid, stearic acid, lenoleic acid, ecosenoic acid observed. The oil extracts exhibited good physic chemical properties and could be used as a biodiesel feedstock and industrial application. The way of reducing the biodiesel production costs is to use less expensive feedstock containing fatty acids. Such ac non edible oils waste vegetable oils, animal fats and byproducts of refining oil. With no competing food uses, this characteristic turns attention to Pongamia pinnata which grows in tropical and subtropical climates across the world.

The productions of biodiesel from these oils provide a valuable local, regional and national benefit. To develop biodiesel into an economically important option in India. It is required to work on biological innovations to increase the yield and minimize the gestation period of pongamia pinnata tree.

**Table- 2**
**Physico-chemical Properties of Pongamia pinnata -crude oil**

| Property | Unit | Value |
|---|---|---|
| Color | - | Yellowish red |
| Odor | - | Characteristic odd odor |
| Density | gm/cc | 0.924 |
| Viscosity | $mm^2/sec$ | 40.2 |
| Acid Value | mg/KOH | 5.40 |
| Iodine Value | - | 87 |
| Saponification Value | - | 184 |
| Calorific Value | Kcal/KG | 8742 |
| Specific Gravity | - | 0.925 |
| Unsaponifiable matter | - | 2.9 |
| Flash Point | $^0C$ | 225 |
| Fire Point | $^0C$ | 230 |
| Cloud Point | $^0C$ | 3.5 |
| Pour Point | $^0C$ | -3 |
| Boiling Point | $^0C$ | 316 |
| Cetane Number | - | 42 |
| Copper strip Corrosion | - | No Corrosion observed |
| Ash Content | in % | 0.07 |

**Table-3**
**Fatty acid composition of pongamia pinnata crude oil**

| Fatty Acid % pongamia crude oil | Molecular Formula | Percentage | Structure |
|---|---|---|---|
| Palmitic Acid | C16H32O2 | 11.65 | CH3(CH2)14COOH |
| Stearic Acid | C18H36O2 | 7.50 | CH3(CH2)16COOH |
| Oleic Acid | C18H34O2 | 51.59 | CH3(CH2)14(CH=CH)COOH |
| Linoleic Acid | C18H32O2 | 16.64 | CH3(CH2)12(CH=CH)2COOH |
| Eicosanoic Acid | C20H40O2 | 1.35 | CH3(CH2)18COOH |
| Dosocasnoic Acid | C22H44O2 | 4.45 | CH3(CH2)20COOH |
| Tetracosanoic Acid | C24H48O2 | 1.09 | CH3(CH2)22COOH |

**Table- 4**
**Properties of Karanja Methyl Ester–**

| Property | Unit | ASTM Test Method | Karanja Biodiesel | Diesel |
|---|---|---|---|---|
| Density | gm/cc | D1498 | 0.860 | 0.824 |
| Calorific value | Kcal/KG | D240/ D 4868 | 3700 | 4285 |
| Cetane Number | Number | D613 | 41.7 | 49 |
| Acid Value | mg/KOH | D664 | 0.46 | 0.36 |
| Iodine Value | Number | D1510 | 91 | - |
| Water and sediments | % vol, max | D2709 | 0.005 | - |

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Pongamia-Leaves


Pongamia fruit


Pongamia -seed


Pongamia- oil cake

**Figure-1**
**Pictures of Karanja Plant, PODS, SEED and DOC**