A Study on the use of Biodiesel Produced from Pongamia Pinnata as an Alternative Fuel for Diesel Engine

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***Abstract:-* The ever increasing demand for conventional fuel, its escalating cost and influence on environmental pollution has necessitated the search for alternative energy sources. The fuel reserves of the world are perishing day by day and it has become a challenge for today's scientific workers to find alternate fuels which can not only replace the conventional fuels but also perform better. Biodiesel is an alternative fuel for diesel engines that is gaining attention all over the world. Its primary advantages of being one of the most renewable fuels available, non-toxicity and biodegradability make it a suitable alternative in most diesel engines without requiring extensive engine modifications. Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, non-edible oils, animal fats etc. This paper attempts to highlight the use of Pongamia pinnata oil as raw material to produce biodiesel. An attempt is made to give a detailed review of the production of biodiesel from Pongamia pinnata oil, its various properties, performance and emission in compression ignition (CI) engines and exploiting its feasibility as an alternative fuel for diesel engine.**

***Keywords:* Conventional fuel, biodiesel, Pongamia pinnata, alternate fuel, diesel engine.**

I. INTRODUCTION:

The diesel engine is an internal combustion engine that uses the heat of compression to initiate ignition and burn the fuel that has been injected into the combustion chamber [1]. They were originally used as a more efficient replacement for stationary steam engines. Since their origin they have been used in submarines, ships, locomotives (such as automobiles, trucks etc), heavy equipment and also in electricity generation plants [2]. Since 1970s, the use of diesel engines in larger on-road and off-road vehicles has grown exponentially and continues to do so. Diesel is the fuel used in diesel engine whose ignition takes place as a result of compression of the inlet air mixture and then injection of fuel. Diesel fuel originated from experiments conducted by German scientist and inventor Rudolf Diesel for his compression-ignition engine he invented in 1892[3]. Diesel fuel is produced from various sources, petroleum, biomass, animal fats, biogas, natural gas, coal etc. The most common and widely used type is the Petroleum diesel, also called petro-diesel or fossil diesel. This petro-diesel also known as conventional diesel is produced from the fractional distillation of crude oil [4]. Another type is the Synthetic diesel which can be produced from any carbonaceous material, including biomass, biogas, natural gas, coal and many others. The raw material is gasified into synthesis gas, which after purification is converted by the Fischer–Tropsch process to a synthetic diesel [5]. Finally, there is Biodiesel which is obtained from vegetable oil or animal fats (biolipids) after transesterification with methanol. Biodiesel fuel can be defined as medium length (C16 ± C18) chains of fatty acids and is comprised mainly of monoalkyl fatty acid esters [6].

A. Need for Biodiesel :

From 1971 to 2010, the world's consumption of oil rose from 2000 million tonnes per year to 4500 million tonnes per year and the price for crude oil on the world market went up from 20 US$ per barrel in 1990s to 145 US$ per barrel in July 2008, most analysts expect higher oil prices in the long term. India's vehicular population is estimated to have increase 8 times over the past 2 decades contributing about 243.3 million tonnes of carbon emissions globally. In India the present level of diesel consumption is 65 million metric tonnes. India is ranked 5th in the world when it comes to fossil fuel consumption. In view of rising prices, the environment and climate change concerns, countries all over the world have launched biodiesel programmes to develop alternatives to conventional diesel.

Biodiesel is an alternative diesel fuel that can be produced from renewable feedstock such as edible and non-edible vegetable oils, wasted frying oils and animal fats. Biodiesel is oxygenated, sulphur free, non-toxic, bio gradable and renewable fuel [7]. Of the various alternate fuels under consideration, biodiesel, derived from vegetable oils and non edible oils is the most promising alternative fuel to diesel due to the following reasons.

- Biodiesel can be used in the existing engine without any modifications.
- It has the benefits of being non-toxic, biodegradable and essentially free of sulphur and carcinogenic ring components
- Biodiesel is an oxygenated fuel.
- Emissions of carbon monoxide and soot tend to reduce. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.

- Biodiesel is produced from renewable vegetable oils/non edible oils/animal fats and hence improves the fuel or energy security and economy independence [8].

Biodiesel is gaining more and more importance as an alternative fuel due to the depletion of petroleum resources and price hike of petroleum products.

B. Why Pongamia pinnata and its oil?

The various alternative fuel options tried in place of hydrocarbon oils are mainly biogas, producer gas, ethanol, methanol and vegetable oils. Out of all these, vegetable oil offers an advantage because of their comparable fuel properties with that of diesel [9]. But due to growing population, increasing rate of consumption and increasing per capita income the demand for edible oil in India is accelerating leading to increased cost and shortage of supply. This puts pressure on the use of edible oil as a source for biodiesel. Consequently non-edible oils are used to produce biodiesel as they have similar properties. One such non-edible oil is the oil of Pongamia pinnata seeds (Fig 1). Pongamia pinnata (also known as karanja, honge etc) is one of the promising tree species belonging to family of Leguminaceae or papilionaceae which is suitable for providing oil for biodiesel production, which conforms to international standards. This tree species is found to be well spread throughout India, excluding temperate regions. Pongamia oil is very economical due to its non domestic usage.

Fig 1: Pongamia seeds[9]

The Pongamia pinnata seeds contain about 40٪ oil, which can be converted to biodiesel by transesterification method [10]. Pongamia biodiesel requires no engine modification, when blended with diesel in proportions as high as 20 percent. India has about 80-100 million hectares of waste land, which can be used for the plantation of Pongamia and others. The viscosity of Pongamia oil is very high to be directly used as diesel fuel substitute. By the transesterification process the viscosity is reduced [11]. Basically, Karanja is a medium sized fast growing evergreen tree, which reaches 40 feet in height and spread, forming a broad, spreading canopy casting moderate shade . It is one of the various nitrogen fixing trees. Karanja have better performance and emission characteristics than Mahua, Sesame and Kusum Biodiesels [12].

II. LITERATURE REVIEW :

Studies have revealed the availability of variety of alternative fuels such as hydrogen, alcohols, biogas, producer gas and fuels from various types of edible and non- edible oils. However, in Indian context, the bio-origin fuels like alcohols, vegetable oils, and biogas can contribute significantly towards the problems related to fuel crises.[13]

Onkar S. Tyagi et al. [14] conducted experimental investigation of performance and emission of karanja oil and its blend(10%,20%,50% and 75%) visa-vis mineral diesel in a single cylinder agricultural diesel engine. Physical and thermal properties of karanja oil were evaluated by conducting two sets of experiments. One set for unheated and second for preheated fuel samples. They found that, for the first set that is without preheating, showed higher brake thermal efficiency except B100 and BSFC up to 50% was lower than diesel. For the pre-heating set, results shows higher brake thermal efficiency and lower BSFC for all blends as compared with diesel fuel. BSFC for unheated and heated karanja oil were lower and exhaust gas temperature was generally higher than diesel for all blends. NOx emission was found to be less as compared with diesel for both set oil.

Shivakumar et al. [15] conducted an experiment in which biodiesel was prepared from Honge oil (Pongamia) and used as a fuel in C.I engine. Performance studies were conducted on a single cylinder four-stroke water-cooled compression ignition engine. Experiments were conducted for different percentage of blends of Honge. Brake thermal efficiencies of Pongamia oil methyl ester blends are very close to diesel and 20% blend with diesel, B20 provided the maximum efficiency for biodiesel operation for all compression ratios. An improvement in BTE was observed for higher compression ratios. Brake specific energy consumption for biodiesel blends is more than that of diesel and decreases for higher compression ratios. Exhaust emissions Smoke, CO, HC were reduced for Diesel-biodiesel blends when compared with diesel values for all compression ratios and higher compression ratios have the advantage further reduction in those emissions.

A. Haiter Lenin & K. Thyagarajan [16] prepared Pongamia methyl ester by transesterification and used it as fuel in a 4 stroke, water cooled, single cylinder, direct injection diesel engine. Pongamia methyl ester fuel blends (75% and 100%) were used for conducting the engine performance tests at varying loads (20%, 40%, 60%, 80%, and 100%). Tests were carried out over entire range of engine operation at varying conditions of load. They found that, when the load increases brake specific fuel consumption decreases to the minimum of at 90% load and then increases for all the fuel samples tested. The carbon monoxide emissions from methyl ester blends of Pongamia oil B75 (75% biodiesel & 25% diesel) and B100 is more than the standard diesel. But the low load condition the methyl ester blends B75 and B100 is lower than the standard diesel. At low load condition the brake thermal efficiency of Pongamia oil blends is closer to the standard diesel but at full load condition, it gives the lower value than the standard diesel. But the Pongamia oil blends B100 is the nearest value to the standard diesel. The smoke densities of the Pongamia oil blends B75 and B100 were higher than the standard diesel at all load condition. The hydrocarbon emission of the Pongamia oil blends of B75 and B100 are 28.85% and 46.43%, lower than the standard diesel at all load condition.

Gaurav Dwivedi & M.P. Sharma [17] focused on the work done in the area of production of biodiesel from Pongamia and characterization of properties of various blends of Pongamia biodiesel. The work also includes the impact analysis of Pongamia oil and its biodiesel on engine performance and exhaust emission. The research has indicated that up to B20, there is no need of any modification. From the test result it was found that the use of biodiesel leads to the substantial reduction in particulate emission, CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional diesel engine with no or fewer modification. The fuel properties like density, flash point, viscosity and calorific value of B10, B20 are very similar to diesel. The performance evaluation of engine has found that BSFC for B100 in case of Pongamia biodiesel was 30.4 % higher than diesel at full load, thereby indicating that more amount of B100 produce power similar to diesel.

III. PROPERTIES OF CRUDE PONAGAMIA OIL:

Pongamia oil is extracted from the seeds by expeller pressing, cold pressing, or solvent extraction. The oil is yellowish-orange to brown in colour. It is toxic and will induce nausea and vomiting if eaten but it is used in many traditional remedies. Pongamia oil is antiseptic and resistant to pests. It has a high content of triglycerides, and its disagreeable taste and odour are due to bitter flavonoid constituents primarily including karanjin, pongamol, tannin and karanjachromene[18]. The large size of the vegetable oil molecules and the presence of oxygen in the molecules suggest that some fuel properties of the vegetable oils would differ markedly from those of hydrocarbon fuels [19]. The fresh extracted crude oil is yellowish red/ brown and it get darkened during the storage. The solvent extraction method gives good quality oil than ordinary extraction methods. The iodine value is a measurement of the unsaturation of fats and oils. Higher iodine value indicated that higher unsaturation of fats and oils. Table 1 shows the fatty acid composition and Table 2 shows Physicochemical Properties of Pongamia pinnata - crude oil [20].

Table 1: Fatty acid composition of Pongamia oil [20]

Fatty acid composition of pongamia oil	**Percentage (%)**
Palmatic acid(C16)	11.65
Stearic acid(C18)	7.5
Oleic acid(C18:1)	51.59
Linoleic acid(C18:2)	16.64
Eicosanoic acid(C20)	1.32
Dasocasanoic acid(C22)	4.45
Tetracasanoic acid(C24)	1.09

Table 2: Physical-Chemical properties of Pongamia pinnata crude oil [20]

SL NO.	**Property**	**Unit**	**Value**
1	Colour	-	Yellowish Red
2	Odour	-	Characteristic Odd Odor
3	Density	gm/cc	0.924
4	Viscosity	mm^2/s	40.2
5	Acid Value	mg/KOH	5.40
6	Iodine Value	-	87
7	Saponification Value	-	184
8	Calorific Value	Kcal/kg	8742
9	Specific Gravity	-	0.925
10	Unsaponifiable Matter	-	2.9
11	Flash Point	^0C	225
12	Fire Point	^0C	230
13	Cloud Point	^0C	3.5
14	Pour Point	^0C	-3
15	Boiling Point	^0C	316
16	Cetane Number	-	42
17	Copper Strip Corrosion	-	No Corrosion observed
18	Ash Content	In%	.07

IV. PROCEDURE FOR PRODUCING PONGAMIA BIODIESEL:

There are basically two processes in the production of Pongamia biodiesel:

A. Esterification:

The production of biodiesel using Esterification is explained as follows. The methyl ester is produced by chemically reacting karanja oil with an alcohol (methyl), in the presence of catalyst. A two stage process is used for the transesterification of karanja oil. The first stage (acid catalyzed) of the process is to reduce the free fatty acids (FFA) content in karanja oil by esterification with methanol (99% pure) and acid catalyst sulfuric acid (98% pure) in ne hour time at 57oC in a closed reactor vessel. The karanja crude oil is first heated to 50^0 C and 0.5% (by wt) sulfuric acid is to be added to oil then methyl alcohol about 13% (by wt) added. Methyl alcohol is added in excess amount to speed up the reaction. This reaction proceeds with stirring at 700 rpm and temperature was controlled at $55\text{-}57^0$ C for 90 min with regular analysis of FFA every after 25-30 min. When the FFA is reduced up to 1%, the reaction is stopped. The major obstacle to acid catalyzed esterification for FFA is the water formation. Water can prevent the conversion reaction of FFA to esters from going to completion. After dewatering the esterified oil was fed to the transesterification process[21].

B. *Transesterification:*

During the production of biodiesel using trans-esterification, the catalyst used is typically sodium hydroxide (NaOH) with 1% of total quantity of oil mass. It is dissolved in the 13% of distilled methanol (CH_3OH) using a standard agitator at 700 rpm speed for 20 minutes. The alcohol - catalyst solution was prepared freshly in order to maintain the catalytic activity and prevent the moisture absorbance. After completion it is slowly charged into preheated esterified oil. When the methoxide was added to oil, the system was closed to prevent the loss of alcohol as well as to prevent the moisture. The temperature of reaction mix was maintained at 60 to 65^0 C (that is near to the boiling point of methyl alcohol) to speed up the reaction. The recommended reaction time is 70 min. The stirring speed is maintained at 560- 700rpm. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. The reaction mixture was taken each after 20 min. for analysis of FFA. After the confirmation of completion of methyl ester formation, the heating was stopped and the products were cooled and transferred to separating funnel. Once the reaction is complete, it is allowed for settling for 8-10 hours in separating funnel. At this stage two major products obtained that are glycerine and biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. The glycerine phase is much denser than biodiesel phase and is settled down while biodiesel floated up. The two can be gravity separated with glycerine simply drawn off the bottom of the settling vessel. Once the glycerine and biodiesel phases were been separated, the excess alcohol in each phase was removed by distillation. Once separated from the glycerine and alcohol removal, the crude biodiesel was purified by washing gently with warm water to remove residual catalyst or soaps [21]. Transesterification process is shown in Fig. 2 and the observation table of biodiesel production in Table 3.

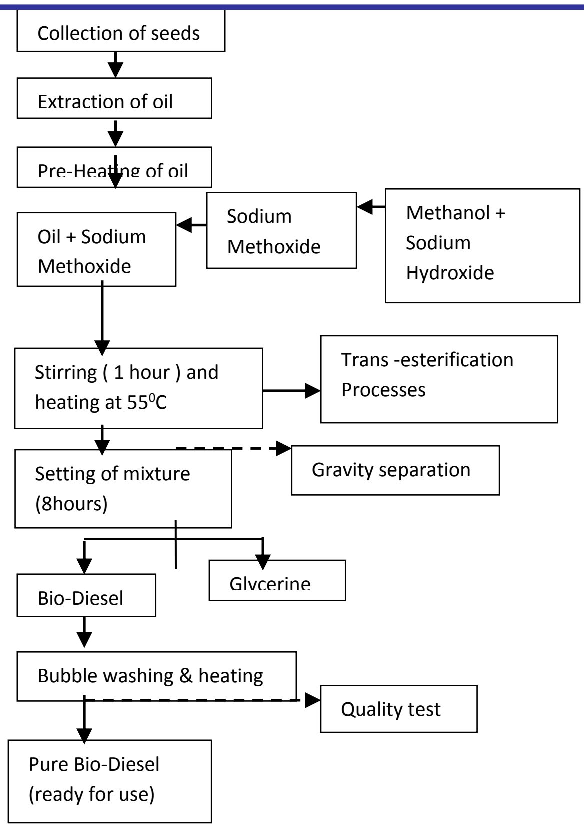

Fig 2 Transesterification Process[22].

Table 3: Observation table (Oil taken for reaction = 1 Lit. Karanja oil)[21].

Esterification Reaction			
Reaction Time	Reaction Temperature	Chemicals	Quantity
60-80min	$60\text{-}65^0C$	H_2SO_4	0.5%
		Methanol	13%
Trans-esterification Reaction			
After esterification to check fatty acid level (<1 % suitable for trans esterification)			
60-65min	$60\text{-}65^0C$	NaOH	1%
		Methanol	13%

V. PROPERTIES OF BIODIESEL OF PONGAMIA PINNATA:

The fuel properties of biodiesel will affect engine performance and emission characterization in single cylinder engine. These properties are greatly relevance between biodiesel and diesel of CI engine. Many researchers studied the effect performance of biodiesel and its blends in diesel engine such as brake power, brake specific fuel consumption and exhaust emission. [23]. The properties of the honge biodiesel satisfy the biodiesel fuel standards. The honge oil contains more than 50% unsaturated fatty acids which makes them prone to oxidation. During the storage period of six month, the acid value and viscosity of the honge biodiesel were increased but the iodine value decreased [24]. Bio-diesels flash and fire points and auto-ignition temperatures are high, when compared with the petro-diesel. As a result a sudden raise of pressure and temperature will exist during the combustion of bio-diesel. An important property of biodiesel is its Oxygen content of about 10% which is usually not contained in diesel fuel. Moreover, they are non-toxic has higher biodegradability and contains almost no sulphur [25]. Bio-fuels have some advantages over petroleum fuels, such as the reduction CO and HC emissions and well antiknock performance, which allow the use of higher compression ratio of engines. According to observed properties of karanja methyl ester, it is then proved that, the methyl ester of karanja oil shows good properties of a suitable alternative fuel. These properties are compared with fossil fuel that is shown in following table 4.

Table 4: Comparison of properties of Pongamia biodiesel and petroleum diesel [26].

Property	**Pongamia oil methyl ester**	**Petroleum diesel**
Viscosity(cst)(30^{0}C)52.6	*5.51*	*3.60*
Specific Gravity (15^{0}C/4^{0}C)	*0.917*	*0.841*
Solidifying point (^{0}C)	*2*	*0.14*
Cetane value	*51*	*47.8*
Flash point (^{0}C)	*110*	*80*
Carbon Residue (%)	*0.64*	*0.05*
Distillation (C)	*284-295*	*350*
Sulphur (%)	*0.13-0.16*	*1.0*
Acid value	*1.0-38.2*	-
Saponification Value	*188-198*	-
Iodine Value	*90.8-112.5*	-
Refractive Index (30^{0}C)	*1.47*	-

VI. RESULTS AND DISCUSSIONS:

There were many research works on the karanja oil and they found some interesting results. Brake thermal efficiency of karanja oil methyl ester was found lower than that of diesel fuel. However thermal efficiencies of Blends up to B-20 were very close to diesel. When injection pressures varied from 180 bar to 200 bar emissions reduced and performance increased. For 200bar injection pressure HC emissions decreased by 12.8 % for B20 and 3 % for B40 at full load but the BSEC was slightly more for B20 and B40. Volumetric efficiency for diesel and Karanja methyl ester blends was constant at different BP since the injection pressure of single cylinder diesel engine was constant. BSFC was found to increase with increase in blend proportion as compared to diesel fuel in the entire load range. NOx decreased by 39 % for B20 and 28 % for B40 at full load. When the load was varied by keeping other parameters constant, the thermal efficiency, bsfc, mechanical efficiency, volumetric efficiency were all comparable with diesel for diesel engine. Smoke density, CO, HC and even NOx emissions are less in case of Karanja biodiesel. Higher viscosity is a major problem in using vegetable oil as fuel for diesel engine. In the present study, viscosity was reduced by esterification followed by tranesterification from 40.2 to 5.51mm^2/s. Biodiesel can also be used in its pure form (B-100), but it may require engine modifications to avoid maintenance and performance problems. Biodiesel is typically blended with diesel fuel in certain proportions to perform efficiently without the need of any modifications.

VII. CONCLUSIONS:

Many researchers used different techniques for investigation and results were compared with the diesel fuel. Many experiments were conducted with Pongamia methyl ester (PME) by various Injection pressures, Compression ratios, additives, load etc; which have resulted in adequate and satisfactory performance. Injection pressure of 200 bar and 16:1 compression ratio can be used as optimum values and CI engines can be run with karanja biodiesel. The blends of honge methyl ester with diesel up to 40% by volume could replace diesel for running the diesel engine for getting less emissions without sacrificing the power output and will thus help in controlling air pollution to a great extent.

Demand for transport fuel is increasing unabatedly in India. On the other hand, there are frequent hikes of prices of fossil fuel and uncertain supply in international market. To minimize the import of crude oil, it is essentialto go for biofuels which are renewable and eco friendly. Pongamia biodiesel is renewable, safe and non-polluting. It holds great promise to the rural sectors of India to meet the energy and organic fertilizer requirements. Of course researches are to be carried out on Pongamia to standardize agro-technology, low cost and efficient mechanical device to expel oil, to find out the economics, high yielding and high oil content varieties suitable to the different agro-climates of India.

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