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Experimental Investigation of Fuel Properties of Pongamia Pinnata Biodiesel and Its Blends with Diesel

P. Senthilkumar[*1], Dr. R. Suresh[2], B. Selvasundaram[3]
[1]Lecturer, Department of Mechanical Engineering, Valivalam Desikar Polytechnic College, Nagapattinam, Tamil Nadu, India.
[2]Vice Principal, Valivalam Desikar Polytechnic College, Nagapattinam, Tamil Nadu, India.
[3]Lecturer, Department of Mechanical Engineering, Sankar Polytechnic College, Tirunelveli, Tamil Nadu, India.
**Corresponding Author.*

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Abstract: *In this research, biodiesel was produced from the non-edible oil of Pongamia pinnata through a transesterification process using potassium hydroxide as a catalyst and methanol as the alcohol. The biodiesel was blended with diesel in different proportions such as B0, B25, B50, B75, and B100 on a volume basis. The key fuel properties investigated were density, kinematic viscosity, flash point, and fire point. The experimental results indicate that pure biodiesel (B100) exhibits higher density, kinematic viscosity, flash point, and fire point compared to diesel fuel (B0). Furthermore, it was observed that these properties increase with an increase in the biodiesel concentration in the blends.*

Key Words: *non-edible oil, pongamia pinnata, biodiesel, density, kinematic viscosity, flash point, fire point.*

I.INTRODUCTION

Energy consumption across the world is continuously increasing. India, being the second most populous country, has an ever-growing demand for petrochemical products. In terms of energy demand, India ranks sixth in the world. In India, diesel consumption is approximately five times higher than petrol. Diesel engines are widely used in transportation, commercial and domestic applications, as well as in generator sets across industrial and agricultural sectors. India is not self-sufficient in petroleum products and imports a large quantity of crude oil from other countries. Biodiesel is considered one of the most promising alternative fuels. It is defined as a long-chain fatty acid mono-alkyl ester, typically produced from plant oils, animal fats, or other lipid sources. The advantages of biodiesel over fossil diesel include biodegradability, lower toxicity, higher flash point, improved cetane number, and enhanced lubricity. Several production methods are available for biodiesel synthesis, including microemulsion, pyrolysis, and transesterification. Among these, the transesterification process is most widely used in industrial biodiesel production due to its cost-effectiveness and high conversion efficiency. Overall, transesterification is considered the most economical and practical method for biodiesel production, offering a high yield compared to other techniques. Transesterification reduces the viscosity of vegetable oils while maintaining a calorific value close to that of the original oil. The production of biodiesel from edible oils is not economical in India because of their high cost. Therefore, non-edible oilseeds such as Jatropha, Karanja, Mahua, and Neem are considered suitable alternative feedstocks for biodiesel production. These non-edible oils are widely available in India and are generally less expensive than edible oils.

A wide variety of non-edible oilseeds are available worldwide. Table 1 presents 30 important non-edible oilseed plants and trees that have been investigated or considered as potential feedstocks for biodiesel production.

S. No.	Scientific name	English name(s)
1	Jatropha curcas	Physic nut, Jatropha, Purging nut
2	Pongamia pinnata	Indian beech, Pongam tree, Karanja
3	Azadirachta indica	Neem, Indian lilac, Margosa tree
4	Madhuca longifolia	Mahua, Butter tree, Indian butter tree
5	Ricinus communis	Castor bean, Palma Christi
6	Calophyllum inophyllum	Alexandrian laurel,Tamanu
7	Hevea brasiliensis	Rubber tree, Para rubber tree
8	Simarouba glauca	Paradise tree, Bitterwood
9	Cascabela thevetia	Yellow oleander, Lucky nut,
10	Cerbera odollam	Sea mango, Pong-pong tree
11	Aleurites moluccanus	Candlenut tree, Kukui nut, Indian walnut
12	Vernicia fordii	Tung tree, Chinese wood-oil tree

13	Sapindus mukorossi	Soapnut tree, Soapberry
14	Simmondsia chinensis	Jojoba, Deer nut, Goat nut
15	Nicotiana tabacum	Tobacco, Common tobacco
16	Swietenia macrophylla	Big-leaf mahogany, Honduras mahogany
17	Swietenia mahagoni	West Indian mahogany, Cuban mahogany
18	Aphanamixis polystachya	Pithraj tree, Indian ash tree
19	Mesua ferrea	Ceylon ironwood, Indian rose chestnut
20	Shorea robusta	Sal tree, Indian dammar tree
21	Sterculia foetida	Wild almond, Java olive
22	Putranjiva roxburghii	Lucky bean tree, Child-life tree
23	Annona squamosa	Sugar apple, Custard apple
24	Melia azedarach	Chinaberry tree, Bead tree
25	Brachychiton rupestris	Queensland bottle tree
26	Moringa oleifera	Drumstick tree, Ben oil tree
27	Gossypium hirsutum	Upland cotton, Mexican cotton, American cotton
28	Linum usitatissimum	Flax, Linseed
29	Hibiscus cannabinus	Kenaf, Java jute
30	Anacardium occidentale	Cashew tree

Table 1: Top 30 non-edible oilseed plants and trees for biodiesel production

Vernacular names of Pongamia pinnata

Pongamia pinnata is known by different vernacular names in various Indian languages across India, as presented in Table 2.

S.No.	Language	Vernacular name(s)
1	Tamil	Pungai, pungam, punka, Punku
2	Sanskrit	Karanjaka, Naktamala, Karanjah
3	Hindi	Kanji, Karanj, karanja
4	Bengali	Karanja, Natakaranja, Daharakaranja
5	Telugu	Ganuga, Kanuga, Pungu
6	Kannada	Honge Mara, Huligili Mara, Karanja
7	Malayalam	Pongam, Pungu, Unnu, Ungu
8	Marathi	Karanja
9	Gujrati	Kanaji, Karanja
10	Oriya	Karanjo, Karani, Koranga
11	Assamese	Korach, Korosh
12	Punjabi	Karanj

Table 2: Vernacular names of Pongamia pinnata

II. MATERIALS AND METHODS

Pongamia pinnata

Pongamia pinnata is a non-edible oilseed tree whose seeds contain about 30–40% oil, making it a sustainable feedstock for biodiesel production. *Pongamia pinnata*, also called karanja, is a fast growing tree that becomes mature in 4–7 years and produces fruits. It is commonly found in rural areas and forests throughout India. The *Pongamia pinnata* pods are oval-shaped and usually contain one or, rarely, two seeds. The pods are 2–3.5 cm wide and 4–7 cm long with a thick outer covering. The seeds are brownish-red in color. *Pongamia pinnata* seeds are commonly traded every year in states such as Tamil Nadu, Kerala, Karnataka, Maharashtra, and Andhra Pradesh. The flowers, green immature seed pods, mature dry seed pods, and seeds of Pongamia pinnata are shown in Figure 1.

Figure 1: Flowers, green immature seed pods, mature dry seed pods, and seeds.

Raw Material

In the present work, Pongamia pinnata oil was used as the raw material for biodiesel production. In the first step, oil was extracted from Pongamia pinnata seeds using a mechanical expeller at room temperature.

Transesterification

The transesterification process involves the reaction of alcohol with vegetable oil in the presence of a catalyst to produce biodiesel. The catalyst increases the reaction rate and improves the biodiesel yield. Different alcohols, such as methanol, ethanol, propanol, butanol, and amyl alcohol, can be used in this process. Methanol and ethanol are the most commonly used. Methanol is widely used because of its high reactivity, low cost, and easy separation from the reaction mixture. The efficiency of the transesterification process depends on several parameters, which are presented in Figure 2.

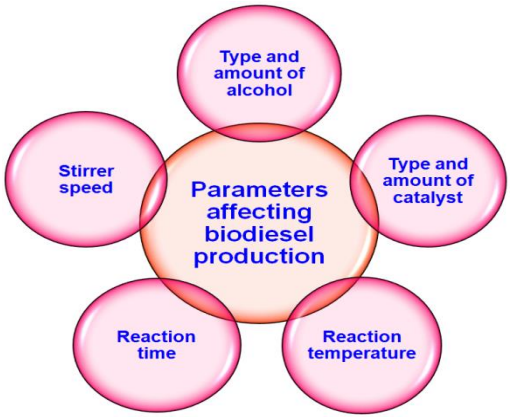

Figure 2: Transesterification process parameters

Biodiesel production

1000 ml of oil was taken in a round-bottom flask and heated to 105°C to remove the moisture present in the oil. The oil was then filtered using a strainer to remove solid particles and other impurities. The catalyst was dissolved in methanol by stirring in a separate flask. The catalyst was used at 1% of the oil weight. The catalyst–methanol solution was then added to the flask containing the oil, and the mixture was maintained at a reaction temperature of approximately 60°C. The mixture was stirred continuously for 2 hours. After 2 hours, heating and stirring were stopped, and the resulting mixture was transferred to a separating funnel and allowed to settle for 24 hours. During this period, the biodiesel and glycerol separated into two layers. The lower layer was glycerol, while the upper layer was biodiesel. The upper biodiesel layer was carefully separated and washed with warm water. Finally, the biodiesel was heated to 105°C to remove excess methanol and water. The process flowchart for biodiesel production is shown in Figure 3.

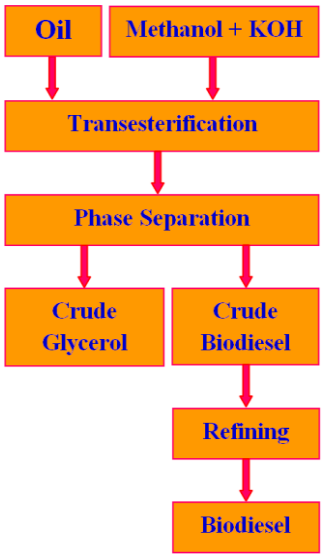

Figure 3: Flow chart of biodiesel production.

Preparation of samples

The blends of biodiesel and diesel were prepared in glass container at *ambient* temperature. The homogeneity of the fuels was achieved by rotating agitator at medium speed for 10 minutes. The percentage of samples is given in table-3. The fuel blends in this report were labeled as BX, where B represents biodiesel and X represents the volume percentage of biodiesel in each fuel blend.

Biodiesel Blend	Percentage of Biodiesel (%)	Percentage of Diesel (%)
B0	0	100
B25	25	75
B50	50	50
B75	75	25
B100	100	0

Table 3:Percentages of biodiesel and diesel fuel used in preparing samples

III. RESULTS AND DISCUSSION

The fuel properties of the diesel, biodiesel and its blends were tested. Table 4 shows the fuel properties of diesel, biodiesel and its blends.

Biodiesel Blend	Density (g/cm^3)	Kinematic viscosity (cSt)	Flash point (°C)	Fire point (°C)
B0	0.832	2.73	52	58
B25	0.848	3.18	91	98
B50	0.864	3.58	104	113
B75	0.880	4.03	136	146
B100	0.896	4.34	158	171

Table 4: Fuel properties of diesel, biodiesel and its blends

Density

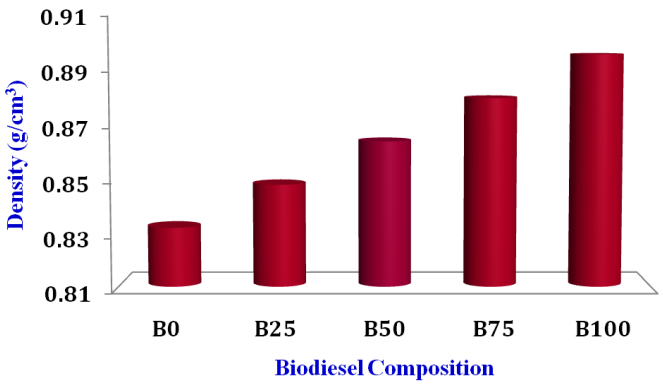

Figure 4: Density of diesel, biodiesel and its blends

Density is the mass of a unit volume of a fluid. It is an important parameter of biodiesel because it affects fuel quality. The relationship between biodiesel percentages and density is shown in Figure 4. As observed in Figure 4, the density of the fuel blends increased with an increase in biodiesel content. The density of biodiesel (B100) was 1.076 times higher than that of diesel (B0). The density of biodiesel is generally higher than that of diesel because it depends on factors such as fatty acid composition, molar mass, purity, water content, and temperature. Seung Hyun Yoon et al. [1] investigated the fuel properties of biodiesel produced from soybean oil and its blends with diesel. Soybean oil biodiesel was produced through the transesterification process. Test fuels used were a conventional diesel, soybean oil biodiesel, and their blends with blending ratios of 20%, 40%, 60%, and 80%. The results showed that the density of the biodiesel–diesel blends increased with an increase in the biodiesel content. Shuman Guo et al. [2] studied the physical and chemical properties of biodiesel produced from waste cooking oil and its blends with diesel (B10, B20, B30, B40, B50, B60, B70, B80, and B90). They reported that the density of the blends gradually increased with an increase in the biodiesel content. The density of biodiesel was 1.055 times higher than that of diesel, and the density of the biodiesel–diesel blends was between the density values of pure biodiesel and diesel.

Kinematic viscosity

The kinematic viscosity of the fuel samples was measured using a Redwood viscometer. The measurement was based on the time required for a fixed volume of the sample to flow under gravity. Viscosity is an important property of fuel because it indicates its resistance to flow. Figure 5 shows the relationship between kinematic viscosity and the different biodiesel blends. The kinematic viscosity increased gradually with an increase in the percentage of biodiesel in the blend. This increase is mainly due to the higher viscosity of biodiesel compared with diesel. The higher viscosity of biodiesel can be attributed to its higher molecular weight and the presence of long-chain fatty acid molecules compared with diesel. Praveen A. Harari [3] prepared biodiesel from watermelon seed oil using the transesterification process. Six samples of biodiesel–

diesel blends were prepared on a volume basis, ranging from 0% (neat diesel) to 100% (neat watermelon biodiesel), in steps of 20%. The results showed that the kinematic viscosity of the blends increased with an increase in biodiesel content because biodiesel has a higher viscosity than diesel. Anh Tuan Hoang et al. [4] investigated the effects of blending on the properties of diesel–biodiesel fuels. A total of 24 biodiesel–diesel blends were prepared by adding 5%, 10%, 20%, 40%, 50%, 60%, 75%, and 100% of coconut oil biodiesel (COB), Jatropha oil biodiesel (JOB), and waste oil biodiesel (WOB) to diesel. The experimental results showed that the kinematic viscosity of the biodiesel–diesel blends increased with an increase in the volume fraction of biodiesel.

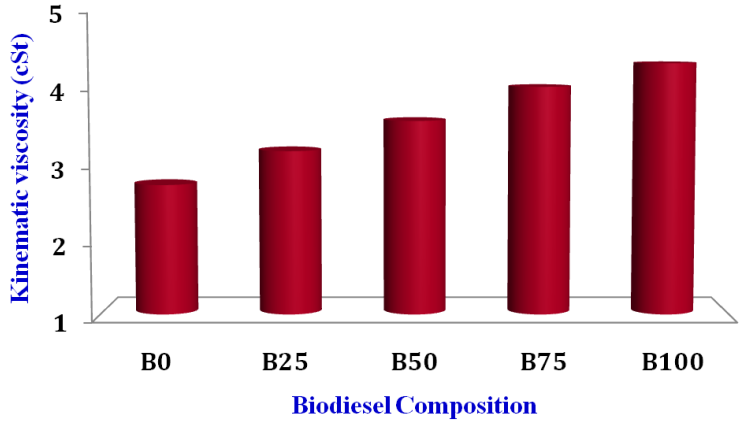

Figure 5: Kinematic viscosity of diesel, biodiesel and its blends

Flash point

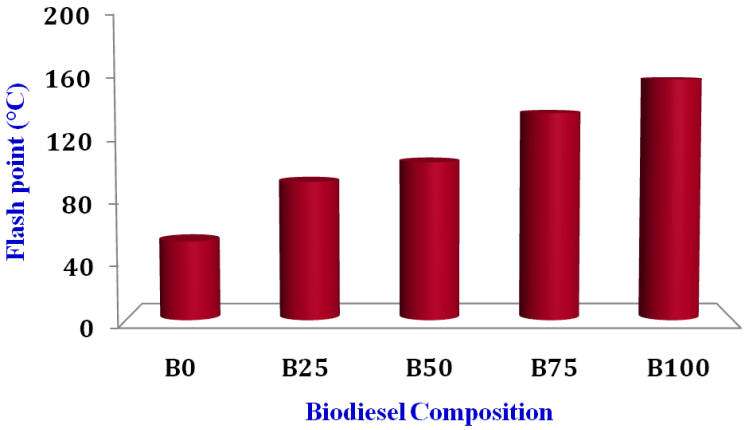

Figure 6: Flash point of diesel, biodiesel and its blends

The flash point of a volatile material is defined as the lowest temperature at which its vapors ignite in the presence of an ignition source. At the flash point, the flame will stop as soon as the ignition source is removed. Flash point is an important fuel property for assessing the safety and handling of fuels, as it affects their storage, transportation, and distribution. Figure 6 depicts the relationship between fire point and different blends of biodiesel. The flash point increases with an increase in the percentage of biodiesel in the blend. This is because biodiesel has a higher flash point than diesel. The flash point of biodiesel is 3.03 times higher than that of diesel. Biodiesel has a higher flash point than diesel because it is less volatile. Ganesh Bharathi Ravikrishnan et al [5] researched physicochemical properties of the tamarind seed biodiesel and its blends. Biodiesel was produced from tamarind seed oil through transesterification using methanol and potassium hydroxide (KOH) as a catalyst. The tamarind seed biodiesel was blended with diesel by various proportions such as B0, B20, B40, B60, B80 and B100. The experimental results showed that the flash point increases with increase in biodiesel composition. Dhruva D. et al. [6] investigated the fuel properties of rice bran oil biodiesel and its blends. Rice bran oil methyl ester was prepared from crude rice bran oil using a three-stage transesterification process. Fuel properties, such as viscosity, gross calorific value, flash point, and fire point, were compared with those of conventional diesel. The experimental results showed that the flash point increased linearly with increasing biodiesel content in the blends.

Fire point

The fire point is the lowest temperature at which the vapours of a fuel ignite and continue to burn even after the ignition source is removed. The fire point is higher than the flash point because a higher temperature is required to produce sufficient vapour for continuous burning. The fire points of diesel, biodiesel, and their blends are shown in Figure 7. It is observed that the fire point increases with an increase in the biodiesel content of the blend. The maximum fire point of 171 °C was measured for B100 biodiesel, while the minimum fire point of 58 °C was measured for diesel. S. Savariraj and his group [7] investigated the effects of blending on the properties of diesel and mango seed biodiesel. Mango seed oil was

extracted from waste mango seeds, and biodiesel was produced through the transesterification process. The experiments were conducted using different blends of mango seed biodiesel and diesel (B0, B50, B75 and B100). The results indicated that the fire point of the biodiesel blends increased with an increase in the percentage of mango seed biodiesel because biodiesel has a higher fire point than diesel. G. Vinoth et al. [8] investigated the fuel properties of lemongrass oil biodiesel and its blends. Biodiesel was produced from lemongrass oil through the transesterification process. The physical and chemical properties of the biodiesel were tested according to ASTM standards and compared with diesel fuel. The lemongrass oil biodiesel was blended with diesel by various proportions such as B0, B20, B40, B60, B80 and B100. The results revealed that the fire point increases linearly with increase in biodiesel composition.

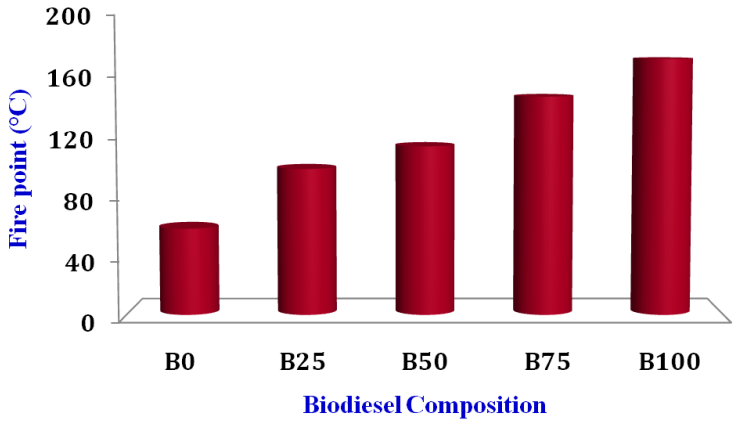

Figure 7: Fire point of diesel, biodiesel and its blends

IV. CONCLUSIONS

In the present investigation, biodiesel was produced from Pongamia *pinnata* oil. The fuel properties, such as density, kinematic viscosity, flash point, and fire point, of diesel, Pongamia *pinnata* biodiesel, and their blends were measured using laboratory equipment according to ASTM standards. The experimental results revealed that the density, kinematic viscosity, flash point, and fire point of the fuel blends increased progressively with an increase in the proportion of Pongamia *pinnata* biodiesel. B100 (Pongamia *pinnata* biodiesel) showed the highest values for all four fuel properties, while B0 (diesel) showed the lowest values.

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AUTHOR BIOGRAPHY

P. Senthilkumar completed his B.E. degree in Mechanical Engineering from E.G.S. Pillay Engineering College, Nagapattinam, in 2004 and his M.E. degree in Manufacturing Engineering from Annamalai University, Chidambaram, in 2017. He is working as a Lecturer in the Department of Mechanical Engineering at Valivalam Desikar Polytechnic College, Nagapattinam, since June 2005. He has published 27 research articles in leading journals. His research interest areas are composites, heat treatment, machining, welding and biodiesel.

Dr. R. Suresh is working as Vice Principal at Valivalam Desikar Polytechnic College, Nagapattinam, Tamilnadu. He completed his B.E. degree in Mechanical Engineering from Shanmugha College of Engineering, Thanjavur, in 1996 and his M.E. degree in Thermal Engineering from Anna University in 2010. He received his Ph.D. from SASTRA University, Thanjavur, in 2025. He has published more than 10 research articles in leading journals. His research interest areas are biodiesel and composites.

B. Selvasundaram completed his B.E. degree in Mechanical Engineering from Einstein college of Engineering, Tirunelveli, in 2011 and his M.E. degree in Production Engineering National Engineering College, Kovilpatti, in 2014. He is working as a Lecturer in the Department of Mechanical Engineering at Sankar Polytechnic College, Tirunelveli, Tamilnadu.