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Original Research Article

Experimental Exploration of Fuel Properties of Calophyllum Inophyllum Biodiesel and Its Blends

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Abstract

The calophyllum inophyllum is a potential source of non-edible vegetable oil for producing biodiesel because of its ability to grow in a wide range of climate conditions, easy cultivation, high fruit production rate, and the high oil content in the seed. The biodiesel is extracted through transesterification process with methanol and NaOH as catalyst. The biodiesel was blended with diesel by various percentages such as B0, B25, B50, B75 and B100. The blends were prepared on a volume basis. Density, kinematic viscosity, flash point and fire point, these are the four main fuel properties that were investigated. The results showed that the density, viscosity, flash point and fire point of diesel fuels (B0) are lower than the calophyllum inophyllum biodiesel (B100). Therefore, the density, viscosity, flash point and fire point of the blend increases with the increase of biodiesel concentration.

Keywords: Biodiesel, calophyllum inophyllum oil, density, viscosity, flash point, fire point.

INTRODUCTION

World population is growing at an exponential rate which is increasing the demand for energy. Major portion of today's energy demand in world is being met with fossil fuels (petroleum). Fossil fuels are used in almost all energy supply needs such as transportation, industry and power generation. Petroleum based fuels serve as a major conventional energy source, but it is depleting due to limited availability. Hence, researchers are on the quest for alternate fuels that can replace the fossil fuels. A lot of research work is being conducted from the past two decades to extract bio fuel from edible oil, non edible oil and waste cooking oil as well as waste industrial oil. The main source for bio-diesel in India can be non-edible oils obtained from plant species such as Madhuca Indica (Mahua), Jatropha curcus (Ratan jyot), Pongamia pinnata (Karanja), Calophyllum inophyllum (Nagchampa), Melia azadirachta (Neem), etc. The most important advantages of biodiesel are higher flash point, biodegradability, non-toxic, improved cetane number and reduced exhaust emissions. Transesterification process is a process which involves alcohol reacting with oil in the presence of catalyst which leads to formation of biodiesel. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend or can be used in its pure form.

LITERATURE REVIEW

Hossain A. B. M. S *et al.*, (2010) investigated the effect of different alcohol types on biodiesel production. Different types of alcohol used affected the percentage of yield of biodiesel. The yield of biodiesel from waste soybean oil. Methanol, ethanol and butanol were used in this experiment. The reactions were carried out by using 0.5% NaOH, 1:1 oil to alcohol molar ratio for 2 hrs at room temperature. The results show that methanol gave the best yield, followed by ethanol and butanol.

Foroutan R *et al.*, (2018) biodiesel produced from waste cooking oil by KOH and NaOH as two efficient catalysts. The effects of some parameters including reaction time, catalyst concentration, temperature and oil to methanol ratio were studied and the optimum conditions were obtained. The results showed that the optimal values for oil to methanol ratio, catalyst concentration, temperature and reaction time were obtained 1:6, 1 wt. %, 60 °C, and 90 min, respectively. Also the results show that NaOH gave the maximum yield, followed by KOH.

Rudi Hartono and his group (2020) manufactured biodiesel from low grade CPO. The effect of NaOH on the yield of the biodiesel was investigated at three different concentrations (0.5%, 1% and 1.5%). The results show that the catalyst ratio of NaOH 0.5% obtained product yield 54.8%, while for catalyst ratio as much as 1% obtained product yield 60.8% and for catalyst ratio as much as 1.5% obtained product yield 51.2%. Optimum operating conditions were obtained at NaOH catalyst ratio of 1% with the largest yield of 60.8%.

Manjunath S *et al.*, (2021) prepared biodiesel from Chia seed oil by transesterification process. NaOH was used as a catalyst. Characterization of the oil was used different blends from B05 - B25 in an incremental steps five percent by volume with diesel. Major fluid and thermodynamic properties like viscosity, density, specific gravity, etc. were extracted as per the ASTM prescribed standards. The results show that the flash and fire points of Chia seed oil are respectively 2.96 times and 2.57 times higher compared to Diesel, while the kinematic viscosity and density are comparable but 6.88% and 5.2% higher.

Asif Afzal *et al.*, (2018) produced biodiesel from pongamia pinnata, Calophyllum inophyllum and waste cooking oil by a transesterification process. The blends prepared were B50. B65, B80 along with pure biodiesel. The physical and chemical properties of this biodiesel were tested. They conclude that the density, viscosity, flash point and fire point increases with increase in biodiesel composition.

MATERIALS AND METHODS

Calophyllum Inophyllum

Calophyllum inophyllum is a species of family Guttifereae (Clusiaceae), native to India, East Africa, Southest Asia, Australia and South Pacific. Commonly it is called as 'Indian laurel', Alexandrian Laurel, Beach calophyllum, Beauty leaf, Pannay tree, Sweet Scented calophyllum (in English), Pongnyet, Burmese, Hawaii, Kokani, Nagachampa, (in Marathi), Sultan Champa, Surpan (in Hindi), Nagam, Pinmai, Punnagam, Punnai, Pinnay, Namere (in Tamil). Calophyllum inophyllum is a large tree of shorelines and coastal forests. It usually grows 7–20 m in height, leaf length ranged from 7 to 14 cm. Leaf width ranged from 5 – 7 cm. Calophyllum inophyllum flower and fruit in tree shown in Figure-1. Calophyllum inophyllum plant has 5-32 flowers per cluster. The diameter of the highest flowers was 3.2 cm and the lowest flower diameter was 1 cm. Calophyllum inophyllum seed weight ranged from 3 to 14 g. Whole seed shape is spherical/round (Figure-2). One large brown seed 2–4 cm in diameter is found in each fruit. Seeds are prepared by cleaning off the skin and husk from the shell of the seed. In each 1 kg of seeds, there are about 90-200 seeds with shells. Figure- 2 shows the dry seeds of Calophyllum inophyllum. The nut kernel contains 50-70% oil and the mature tree may produce up to 12 kg of oil per year depending upon the productivity of the tree and the efficiency of extraction process.

Figure-1: Calophyllum inophyllum flower and fruit in tree

Figure-2: Dry seeds of calophyllum inophyllum

Raw Material

Calophyllum inophyllum oil seeds collected from our area are dried in sunlight for a week and the dried seeds are peeled to obtain the kernel for extraction of calophyllum inophyllum oil by using a mechanical expeller.

Transesterification

Biodiesel production using transesterification is an economical and time-saving method. In this process chemical reaction take place with a fat or oil with an alcohol in a presence of a base catalyst. Methanol and ethanol are the most often used alcohols in biodiesel production. Methanol is preferably used for the transesterification due to its low cost and advantages in physical and chemical properties. Catalyst is usually sodium hydroxide (NaOH) or potassium hydroxide (KOH). NaOH is considered in transesterification due to its high purity and low cost. The major product of transesterification is biodiesel and the bi-product is glycerine.

1000ml of calophyllum inophyllum oil was taken in a round bottom flask and was heated up to 105°C in order to remove the moisture content present in it. Base catalyst (NaOH) was dissolved in methyl alcohol. The catalyst-alcohol solution was transfered into a flask containing oil and maintained at the reaction temperature of around 60°C for a period of 60 minutes. The reaction was considered to start at this moment, since heated oil assisted the reaction to occur. Then the final mixture was stirred for 2 hours. After transesterfication the total mixture was separated into two layers. The lower layer was glycerol and upper layer was methyl ester (biodiesel). The upper layer (methyl ester) was separated then the methyl ester layer was washed with warm water. After the washing, the methyl ester was subjected to a heating at 100^{O}C to remove excess alcohol and water.

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-1.

Table-1: Percentages of biodiesel and diesel fuel used in preparing samples

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

Apparatus and Measurements

Properties of the biodiesel and its blends were determined on different apparatus. Table-2 shows the list of the apparatus on which properties were tested and determined.

Table-2: Apparatus used for determination the properties

Properties	Apparatus
Density	Weighing balance
Kinematic viscosity	Redwood viscometer
Flash and fire point	Open cup apparatus

Density, kinematic viscosity, flash point and fire point were measured using standard methods. The density was measured using weighing equipment. The viscosity was measured using redwood viscometer. The flash point and fire point were measured using open cup apparatus.

RESULTS AND DISCUSSION

The fuel properties of diesel, biodiesel and its blends with diesel fuel are given in Table-3.

Table-3: Properties of different blends of biodiesel and diesel.

Properties	Density (gm/cm^3)	Kinematic viscosity (mm^2/s)	Flash point (^{O}C)	Fire point (^{O}C)
B0	0.824	3.51	52	57
B25	0.842	4.10	81	90
B50	0.859	4.69	113	125
B75	0.877	5.28	146	159
B100	0.895	5.87	170	185

Density

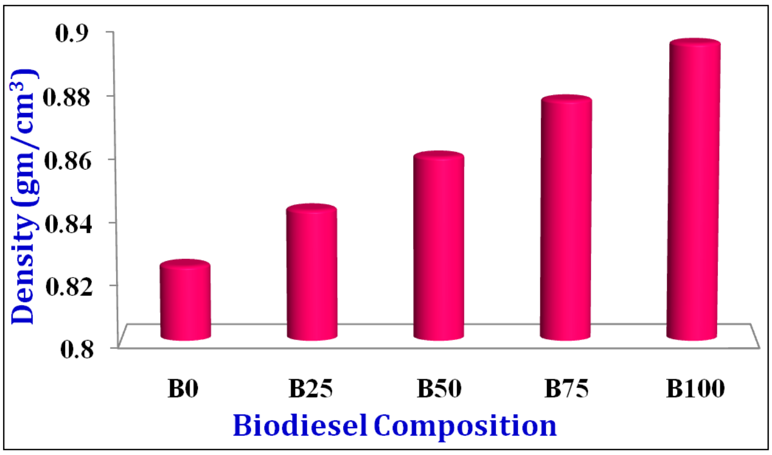

Figure-3: Density of different blends of biodiesel and diesel

Density is an important biodiesel parameter, with impact on fuel quality. Density is the measure of mass per unit volume of a solid or liquid. The variation of density and biodiesel blends is depicted in figure-3. The density of B100 is higher than those of the fuel types (B25, B50 and B75) and B0. Thus, the density of biodiesel is only 1.086 times that of diesel, and the density of the blend was between the two values. The density of biodiesel is normally higher than diesel, because the density of biodiesel is dependent on its fatty acid composition, molar mass, water content, purity, and temperature. T. Venkateswara Rao *et al.*, (2008) investigated the effects of blending on the properties of diesel and biodiesel (Pongamia, Jatropha and neem). Methyl ester of Pongamia (PME), Jatropha (JME) and Neem (NME) are derived through transesterification process. Experimental investigations have been carried out to examine properties of different blends (B5, B10, B15, B20, B30, B40, B60, B80 and B100) of PME, JME and NME in comparison to diesel. Results indicated that the density of biodiesel blends increases as the percentage of biodiesel increases in the blends due to the higher values of biodiesel than that of diesel. Deshmukh S *et al.*, (2017) studied the physical and chemical properties of biodiesel (Karanj oil) and diesel fuel blends (B10, B20, B30, B40, B50 and B100). The density of diesel is 0.84 gm/cc whereas it is 0.88 for Karanj biodiesel. The experimental results showed that the density of biodiesel–diesel fuel blend increased as the volume fractions of the biodiesel increased.

Kinematic Viscosity

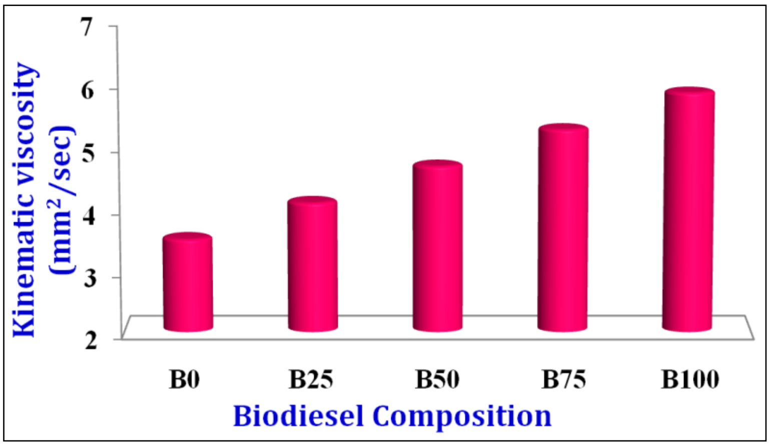

Figure-4: Kinematic viscosity of different blends of biodiesel and diesel

The kinematic viscosity of the different blends of diesel and biodiesel in varying proportions from 0 to 100% (pure diesel to 100 % biodiesel) are shown in figure-4. It is observed that increasing concentration of biodiesel in the diesel (B0) resulted in the corresponding increase in the kinematic viscosity. Biodiesel has more polar structure than diesel fuel because of the oxygen, which is an electronegative element present in its structure, and therefore biodiesel has higher viscosity comparing with diesel fuel. Minh Tuan Pham and his group (2018) studied the effects of volume fraction of biodiesel and diesel on the properties of blends. Three types of biodiesel were examined: Coconut oil-based biodiesel (COB), Jatropha oil-based biodiesel (JOB), and Waste oil-based biodiesel (WOB). Twenty-four samples of the three types of biodiesel–diesel fuel blends were created by blending 5% (B5), 10% (B10), 20% (B20), 40% (B40), 50% (B50), 60% (B60), 75% (B75), and

100% (B100) of biodiesel with conventional diesel fuel to produce the corresponding blends for experimental purposes. They conclude that the kinematic viscosity of biodiesel–diesel fuel blend increased as the volume fractions of the biodiesel increased. J. D. Mejía *et al*., (2013) researched viscosity, cloud point and flash point of Palm-Castor biodiesels and its blends. Six different volume based blends were prepared for each Diesel-POB and Diesel-COB mixtures (100:0, 80:20, 60:40, 40:60, 20:80 and 0:100). The kinematic viscosity test was carried out U-tube viscometer kept at 40^{O}C accordingly with ASTM D-445. They conclude that the fire point increases linearly with increase in biodiesel composition. The highest kinematic viscosity is found to be associated with pure biodiesel (B100), and the lowest with pure diesel (B0).

Flash Point

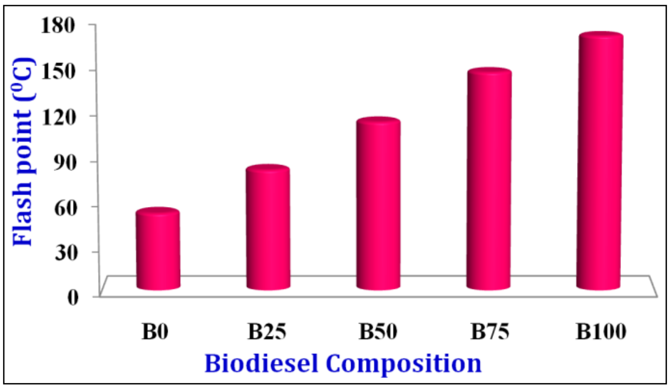

Figure-5: Flash point of different blends of biodiesel and diesel

The flash point for any volatile material is defined as the lowest temperature at which vapors of the material will ignite when ignited by a source. At the flash point, the flame will stop as soon as the ignition source is removed. It is a very important property to measure the hazardous level of fuel, because it influences fuel storability, transportability, and distribution. The variation of flash point for different blends is as shown in figure-5. The flash point of the various blends with increasing biodiesel concentration is found to increase, due to the higher value of flash point for the biodiesel than diesel. The value of flash point depends on the boiling point which increases as the molecular weight increases; so the flash point of biodiesel is higher than diesel as a result of increases in the molecular weight of the biodiesel. T. Venkateswara Rao and his group (2008) investigated the effects of volume fraction of biodiesel and diesel on the properties of blends. Three types of biodiesel were examined: Pongamia-based biodiesel, Neem-based biodiesel, and Jatropha-based biodiesel. Thirty samples of the three types of biodiesel–diesel fuel blends were created by blending 5% (B5), 10% (B10), 15%(B15), 20% (B20), 25%(B25), 30%(B30), 40% (B40), 60% (B60), 80% (B80), and 100% (B100) of biodiesel with conventional diesel fuel to produce the corresponding blends for experimental purposes. The experimental results showed that the flash points of biodiesel–diesel fuel blend increased as the percentage of biodiesel increased. Bhojraj N. Kale *et al*., (2021) researched density, viscosity, flash point and fire point of microalgae biodiesel and its blends. The microalgae biodiesel was blended with diesel by various proportions such as B0, B10, B20, B30, B40, B50 and B100. They conclude that the flash point increases with increase in biodiesel composition. The highest flash point is found to be associated with pure biodiesel (B100), and the lowest with pure diesel (B0).

Fire Point:

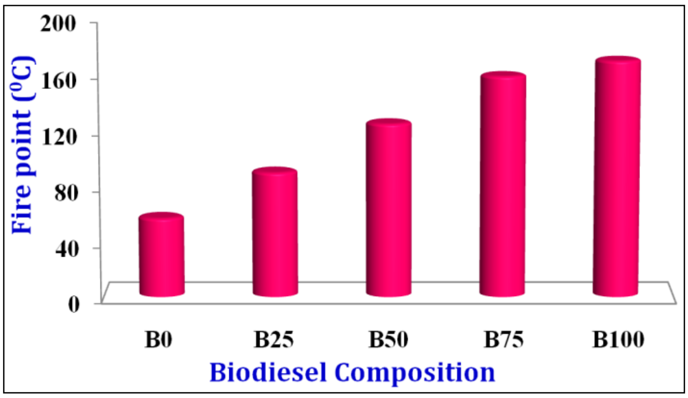

Figure-6: Fire point of different blends of biodiesel and diesel

The fire point is defined as the lowest temperature at which vapors of the material will catch fire and continue burning even after the ignition source is removed. The fire point is higher than the flash point because the vapors produced at the flash point are not sufficient enough to ignite the fuel. The effect of addition of biodiesel in diesel on fire point is shown in figure-6. As the biodiesel addition in diesel goes on increasing the fire point of blends increases**.** G. Vinoth *et al*., (2019) investigated the fuel properties of biodiesel from lemon grass oil and its blends. The biodiesel was extracted through transesterification process. The physical and chemical properties of the lemon grass oil bio-diesel were tested through 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. Experimental results show that the fire point increases linearly with increase in biodiesel composition. The highest fire point is found to be associated with pure biodiesel (B100), and the lowest with pure diesel (B0). Praveen A. Harari (2017) prepared biodiesel from watermelon seed oil by a transesterification process. Experimentations were conducted on six samples on the basis of volume % for water melon biodiesel and diesel blends in the step of 20 varying from 0% (diesel) to 100% (water melon biodiesel). The results revealed that the values of flashpoint of biodiesel blends increases as the percentage of biodiesel increases in the blends due to the higher values of biodiesel than that of diesel.

CONCLUSION

This investigation has established relationships between the percentage of calophyllum inophyllum biodiesel blended with diesel and the properties like density, kinematic viscosity, fire point and flash point. The values of density, kinematic viscosity, flash point and fire point of biodiesel blends increases as the percentage of biodiesel increases in the blends due to the higher values of biodiesel than that of diesel.

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