Experimental examination on physicochemical properties of the Tamarind seed biodiesel in comparison with petroleum diesel fuel

Ganesh Bharathi Ravikrishnan¹, S Venkatesan² and Bright Samuel³

¹Research Scholar, Department of Mechanical Engineering, Vinayaka Mission’s Kirupananda Vairiyar Engineering College, Vinayaka Mission’s Research Foundation (Deemed to be University), Salem 636 308, Tamilnadu, India
²Professor, Department of Mechanical Engineering, Vinayaka Mission’s Kirupananda Vairiyar Engineering College, Vinayaka Mission’s Research Foundation (Deemed to be University), Salem 636 308, Tamilnadu, India
³PG Scholar, Department of Mechanical Engineering, Vinayaka Mission’s Kirupananda Vairiyar Engineering College, Vinayaka Mission’s Research Foundation (Deemed to be University), Salem 636 308, Tamilnadu, India

E-mail: r.ganesh.bharathi@gmail.com

Abstract. The present escalating demand for the hydrocarbon fuel and its lack of availability move the automotive industries and the oil companies to urge the search for alternative resources and feedstocks to emerge a fuel for transportation to keep going. This paper deals with the examination of properties of the Tamarind seed Biodiesel and the petroleum diesel fuel with biodiesel oils of significant feedstocks. The raw oil extracted from Tamarind Seed was trans-esterified with methanol in the presence of potassium hydroxide to obtain biodiesel. The oil yield was 35%. The study was to figure out the variation in the physicochemical properties of the biodiesel for their progressive blend percentages with the petroleum diesel. The blends investigated were B20, B40, B60 and B80. The vital physicochemical properties of the biodiesel evaluated were a flashpoint, fire point, kinematic viscosity, and the calorific value. Importantly, the calorific value of B100 is 45.83 MJ/Kg and diesel is 45.49 MJ/Kg. The increasing biodiesel concentrations show, the kinematic viscosity of the blended fuel decreases to 2.4 cSt at B80 from 2.63 cSt for Diesel, which is 13%. The flash and fire point value of the diesel fuel which is 37.4 and 56.7ᵒC, was incremented with the higher concentrations of biodiesel as 41.2ᵒC and 57.7ᵒC at B80.

1. Introduction
India is one among the larger producers of tamarind having a production ranging from 2,00,000 to 2,50,000 tonnes annually, having the yield percentage of 20 to 40%, Tamarind could be an elegant feedstock for biodiesel [1]. Fossil fuels being non-renewable there are bright chances for exhausting those kinds of fuels in the very near future. This has to lead the global researchers to dig out the hidden renewable resources from the planet earth. The properties of the tamarind biodiesel for the three different blends have been studied with diesel fuel such as T5, T10, and T15. The values found were similar to that of diesel having the density value higher (0.86 g/cc) than the diesel (0.83 g/cc). Heating of planet earth and the depletion of atmospheric ozone happenings are the major products of burning hydrocarbons [2]. IC Engine Vehicles, Pollution causing plants, Agriculture and power production are the biggest reasons for Hydrocarbon forced into the atmosphere. Bolonia D et al [3] attempted to discover the possibilities of obtaining the oil from the grape seed. The waste from the wine industry including the waste grape skin was made to undergo the distillation process and then
transterified to produce fatty acid ethyl esters. The obtained biodiesel was carrying the cetane number more than 50 which is greater than the petroleum diesel. The biodiesel was prepared from the novel algae Scenedesmus vacuolatus X56104. The prepared biodiesel was balanced with the standard diesel and found the differences in the values were up to 20%. The flashpoint was 135°C and the yield percentage was 26.7% [4].

Pandian AK et al [5] analyzed the effects of the oil prepared from the cashew nutshell through the transesterification process. The biodiesel blended with the hexanol in different blending ratios were utilized. The increase in the hexanol part, increased the calorific value CNSBD to 38.1 MJ/Kg. CNSBD900H100 had the calorific value of 38.8 MJ/Kg and CNSBD800H200 had the value of 38.91 MJ/Kg. The higher Hexanol ratio resulted in increased heating value not more than diesel fuel. Kader MA et al [6] underwent pyrolyzing the tamarind seeds for oil production. The yield percentage obtained was 45% at 400°C. The kinematic viscosity, 6.51 cSt resulted from low specific gravity, 1.15. The fire point was 90°C with the calorific value of 25 MJ/Kg. The study concluded with optimizing the operating variables for better results. The tamarind seed could clearly be a resource for biodiesel production. Zannis TC et al [7] studied the various physicochemical properties of diesel in the DI diesel engine. It was found that the increase in the distillation temperature by replacing the paraffines with naphthenes concluded in the higher viscosity, density, and the cetane number. Sahoo PK et al [8] conducted an analysis in combusting polanga based biodiesel and found that Polanga biodiesel having the calorific value of 41 MJ/Kg was higher with 43 MJ/Kg in the B20 biodiesel which shows the lowering calorific values with increasing biodiesel concentrations. Ozdogan S et al [9] Predicted that the viscosity of the given petroleum fuel depends on the density and the molecular weight. S.S. Hoseini et al [10] Suggested, the biodiesel and diesel blend when further blended with the ethanol, emissions could be greatly minimized. Nayan NK et al [11] Pyrolysed the Neem seed for oil production which resulted in a very high kinematic viscosity of 22.6 cSt and a low flash point of 42°C. The Pyrolysed oil had a low gross calorific value of 32.3 MJ/Kg which might be suitable for the low power engine power production.

Yarkasuwa CI et al [12] prepared biodiesel from the yellow Oleander oil and tested the properties and the biodegradability of the oil. The biodiesel had 45 MJ/Kg calorific value and the yield percentage of 91.6%. The flashpoint was 175°C making oleander a better feedstock.

2. Methodology
Efficient feedstock from the environment is required for the production of biodiesel. The collection of quality raw material stands the first step for the quality oil. The quality seeds with the higher fatty acid percentage results in the higher yield percentage of the oil from seeds. The figure 1, 2 and 3 are the images of seeds, raw tamarind seed oil, and transesterified biodiesel.

The collected seeds have been mechanically crushed for extracting the oil from the seeds. The obtained tamarind oil extract is then purified to remove the dust particles and the contamination. The oil undergoes the transesterification process. The process of transesterification in the presence of methanol (CH3OH) with the Potassium Hydroxide (KOH) as the catalyst breaks the molecules of oil into ester and glycerol.

The oil is then reacted with the alcohol and the glycerine is removed which is a by-product of the reaction. This is done with the help of the separator device. At the final stage, the collected biodiesel is washed repeatedly to overcome the water content in biodiesel and in the end the quality biodiesel is obtained.

The next step of the process is finding the chemical properties of the obtained biodiesel and comparing it with the other existing biofuel and the petroleum diesel.
3. Results and Discussions

The biodiesel prepared is tested for the physicochemical properties such as Kinematic Viscosity, Calorific Value, Flash Point and Fire Point. The test is conducted for the different blend percentages of the prepared biodiesel with the petroleum diesel. Due to the availability and feedstock resource, the blending of biodiesel with diesel fuel will help to overcome and reduce the demand and the dependency of fossil fuels without any energy compromise. Each and every property tested has its own effects on the operational performance of the engine in the future. The following test results show the chemical properties of the produced tamarind biodiesel and the comparison with the different kinds of fuels. The results show the compatibility of the produced biodiesel for the internal combustion engine operation.

3.1. Kinematic Viscosity

The friction of the oil from inside which resists the flow is the kinematic viscosity [13] The vaporization characteristics increase with the decrease kinematic Viscosity of the fuel. However, the studies on the low biodiesel concentration were mostly successful, issues still exist at the higher blends [14]. The tested kinematic viscosity of the tamarind biodiesel is 2.31 cSt whereas for the diesel it is 2.63 cSt. The kinematic viscosity was tested in ISO 3104:1994 at 40°C. The kinematic viscosity of the blended fuel increases on blending with diesel fuel. Lower kinematic viscosity gives the reduced size of the droplet during the process of atomization in IC engines. The reduced droplet size reduces the ignition delay and in turn, improvises the combustion rate [21]. The kinematic viscosity values of the other biodiesel oils from the literature review are compared in the following table.

| Fuel Properties | Table 1. Kinematic Viscosity. |
|-----------------|---------------------------------|
|                 | Fuel                          | Diesel | TSBD | Palm oil[18] | Fish oil[13] | Coconut Testa oil[13] | CNSB [5] | Sunflower oil[20] | Peanut Oil[20] |
| Kinematic Viscosity (cSt) | 2.683 | 2.31 | 4.6 | 2.63 | 4.01 | 4.3 | 3.96 | 4.75 |

*CSBD – Cashew nut Shell Biodiesel, TSBD- Tamarind Seed Biodiesel
3.2. Calorific Value

The calorific value of the fuel is the direct measure of the heat energy packed in the fuel. The heat energy of the fuel is a very important property of the fuel deciding the amount of mechanical energy that could be produced by the internal combustion engine. Higher the calorific value, the higher will be the conversion percentage of the heat energy to the mechanical energy. Compared to the diesel fuel having 45.49 MJ/Kg the tamarind biodiesel has a mostly similar calorific value of 45.83 MJ/Kg which shows that the tamarind biodiesel is alternate fuel for a compression ignition engine. The calorific value was tested in ASTM D4868-2017. Every 10% of the increase in blend ratio, there is a drop in calorific value for about 1.42%. Mustard oil calorific value hiked from 38.2 to 39.4 MJ/Kg on raising the blend percentage with octanol from 10% to 30% [15].

With tamarind seed biodiesel, the blend B80 has a calorific value of 45.76 MJ/Kg which is higher than B20 having the value of 45.55 MJ/Kg, it shows that the fuel comprises heat energy that could run a compression ignition engine [16]. The compared values of calorific values with the other referred different biodiesels are tabulated below.

| Fuel Properties | Diesel | TSBD | Palm oil[18] | Fish oil[13] | Coconut Testa oil[13] | CNSB [5] | Sunflower oil[20] | Peanut Oil[20] |
|-----------------|--------|------|--------------|--------------|----------------------|---------|-----------------|---------------|
| Calorific Value (MJ/Kg) | 45.49 | 45.83 | 39 | 41 | 37 | 38.2 | 39.69 | 39.4 |

Figure 4. Kinematic Viscosity.
3.3. Flash Point
The flashpoint is the temperature of vaporizing the fuel. The test method EN ISO 2719 was used to test the flashpoint. This in turn with external heat, the gaseous fuel starts to burn to 3 to 5 seconds. The flashpoint exhibits the risk in production, processing, storage and transporting [17].

Hence the higher flash point increases the flexibility of fuel transportation. The flashpoint decides also conditions for undergoing the process and sets the limitations. The flashpoint of the tamarind biodiesel is 42 °C. The diesel fuel has a flashpoint of 37.4 °C. The test method used for measuring the flashpoint of the TSBD is EN ISO 2719. The biodiesel produced from palm has a flashpoint of 180 °C [18]. The Pyrolysed tamarind seed has a flashpoint of 90 °C [6].

3.4. Fire Point
A fire point helps to decide the working condition of the system at which the fuel to be maintained or transported. Processing, transportation, and storage of the fuel cost less for maintenance for the increased fire point. The fire point for the tamarind biodiesel having 58 °C is more than the diesel fuel which is having 42 °C. The test method used for testing the fire point is ASTM D92-2018. In addition to that, the higher biodiesel concentration in the blends increases the flash and fire points of the tamarind seed biodiesel.

| Fuel Properties | Diesel | TSBD | Palm oil[18] | Fish oil[13] | Coconut Testa oil[13] | CNSB[5] | Sun-flower oil[20] | Peanut Oil[20] |
|-----------------|--------|------|-------------|-------------|----------------------|--------|-------------------|--------------|
| Flash Point (°C)| 37.4   | 42   | 180         | 115         | 129                  | 140    | 174               | 168          |
| Fire Point (°C) | 56.75  | 58   | 194         | 129         | 135                  | 152    | 183               | 179          |

**Figure 5.** Calorific value.
3.5. Tamarind seed biodiesel and blend properties

Further investigation of the tamarind biodiesel in blend with the diesel fuel in the ratios, 20%, 40%, 60%, and 80% are tested for the change in physicochemical properties. The blending of biodiesel fuel with petroleum diesel enhances the blend fuel properties and could be used in the diesel engine with having zero modification with IC engines. The property changes in the fuel blends of the biodiesel and the diesel are compared and tabulated.

| Fuel Properties | Diesel | B20  | B40  | B60  | B80  | B100 |
|-----------------|--------|------|------|------|------|------|
| Kinematic Viscosity (cSt) | 2.68   | 2.609| 2.53 | 2.45 | 2.38 | 2.31 |
| Calorific Value (MJ/Kg)   | 45.49  | 45.55| 45.62| 45.69| 45.76| 45.83|
| Flash Point (°C)         | 37.4   | 38   | 38.94| 40.06| 41.12| 42   |
| Fire Point (°C)          | 56.75  | 57   | 57.25| 57.5 | 57.75| 58   |

The tested kinematic viscosity value of the TSBD is lesser than the diesel as shown in Figure 7. The TSBD having lower kinematic viscosity when blended with the diesel, the blended fuel has the value greater than the fuel having less kinematic viscosity. For the decreasing blend ratios, as shown in Figure 7, the kinematic viscosity of the blended fuel decreases progressively.

The biodiesel mixture of Glauca, Yellow Oleander, and Dairy scum when blended with the petroleum diesel, the kinematic viscosity value increases with the increase in biodiesel concentration Arun S.B et al [19]
Figure 7. Kinematic viscosity of TSBD.

Figure 8. The calorific value of TSBD.

The measured calorific value of the diesel is lesser than the TSBD (B100) as shown in Figure 8. The calorific values of the blends from B20 to B80 go in increasing order. This is because, the TSBD with higher calorific value, blended with the diesel, increases the calorific value of the blended fuel.
Figure 9. Flash and Fire point of TSBD.

The flashpoint has always a higher difference than the fire point. The flash and fire point of the diesel having 37.4 and 56.75°C is less than the TSBD having 42 and 58°C. The ability of TSBD to vaporize in the lowest possible temperature is less than diesel. When TSBD is blended with diesel, the blended fuel has a temperature value of fire point higher than diesel fuel and lower than the TSBD. The value for the blended fuel varies with the percentage of concentration of the TSBD in the blend as shown in Figure 9.

4. Conclusion
The Tamarind seed biodiesel was prepared in the four different blend ratios B20, B40, B60 and B80. The physicochemical properties of the blended fuels were evaluated and the following conclusions were derived.

- The calorific value of the diesel is 45.49 MJ/Kg whereas, the tamarind seed biodiesel has 45.83 MJ/Kg which is slightly higher. On blending the Biodiesel with the diesel fuel, the Blend fuel properties have a maximum of 45.76 MJ/Kg at B80 and a minimum of 45.55 MJ/Kg at B20 showing that the increase in biodiesel ratio in the blend increases the calorific value. Hence the tamarind seed could serve as an efficient alternative feedstock for biodiesel production.
- The calorific value is dependent on the size of the hydrocarbon chain decides the burning tendency of the fuel. The transesterification process was done using methanol (CH3OH) whose hydrocarbon chain having quicker burning capacity increases the calorific value of the Biodiesel. The transesterification process done with the larger hydrocarbon chain might result from even higher calorific value but that might decrease the rate of combustion.
- The Kinematic viscosity of the diesel having 2.638 cSt is higher than B100 having 2.31 cSt. Hence on blending biodiesel with diesel on increasing ratios decreases the values of Blend fuels from 2.609 cSt at B20 to 2.384 cSt at B80. The kinematic viscosity decides the atomization of the fuel in the combustion chamber when injected. Lower kinematic viscosity values enable higher atomization leading to efficient combustion.
- The higher flash point and fire point of the Tamarind seed biodiesel which is 42°C and 58°C make the biodiesel safest fuel with optimal maintenance charges.
- When tamarind biodiesel is blended with diesel, the blended fuel has the maximum fire point of 57.75°C at B80 and a minimum of 57°C at B20 which shows the increase in the value of the blended fuel on increasing the biodiesel concentration in the blend.
- The flashpoint is 119.2°C at B80 and 71.8°C at B20. The flashpoint value increases as in the fire point where the biodiesel ratio increment increases the fire point value.
Acknowledgment:
The authors would like to thank sincerely to the CRD (Centre for Research and Development), Vinayaka Mission’s Kirupananda Varkey Engineering College, Vinayaka Mission’s Research Foundation, (Deemed to be University) for extending the facilities to carry out the investigation.

5. References
[1] Bahar D, Kirti G, Mounika R and Rajesham S 2018 Study of performance and emission characteristics of a compression ignition engine using tamarind biodiesel International Journal of Advanced Technology and Engineering Exploration 5 134-139
[2] Venu H, Subramani L and Dhana Raju V 2019 Emission reduction in a DI diesel engine using exhaust gas recirculation (EGR) of palm biodiesel blended with TiO2 nano additives Renewable Energy 140 245-263
[3] Bolonio D, Garcia-Martinez M J, Ortega M F, Lapuerta M, Fernandez J R and Canoria L 2019 Fatty acid ethyl esters (FAEEs) obtained from grapeseed oil: a fully renewable biofuel Renewable Energy 132 278-283
[4] Chavan D B and Khobragade C N 2018 Evaluation of Fatty Acid Profile and Biodiesel Characterisation obtained from Novel Algae Scenedesmus Vaculatus X56104 International Journal of Agriculture, Environment and Biotechnology 11 195-202
[5] Pandian A K, Munuswamy D B, Radhakrishnan S, Devarajan Y, Ramakrishnan R B B and Nagappan B 2018 Emission and performance analysis of a diesel engine burning cashew nut oil biodiesel mixed with hexanol Petroleum Science 15 176-184
[6] Kader M A, Islam M R, Praveen M, Haniu H and Takai K Pyrolysis 2013 Decomposition of Tamarind seed for alternative fuel Bioresource Technology 149 1-7
[7] Zannis T C, Hountalas D T and Papagiannakis R G 2007 Experimental study of diesel fuel effects on direct injection (DI) diesel engine performance and pollutant emissions Energy Fuels 21 2642–2654
[8] Sahoo P K and Das L M 2009 Combustion analysis of Jatropha, Karanja, and Polanga based biodiesels as fuel in a diesel engine Fuel 88 994-999
[9] Ozdogan S and Yucel H G 2001 Correlations towards prediction of petroleum fraction viscosities: an empirical approach Fuel 80 447-449
[10] Hoseini S S, Najafi G, Ghobadian B, Mamat R, Sidik N A C and Azmi W H 2017 The effect of combustion management on diesel engine emission fuelled with biodiesel diesel blends Renewable and Sustainable Energy Reviews 73 307-331
[11] Nayan N K, Kumar S, and Singh R K 2013 Production of the liquid fuel by thermal pyrolysis of neem seed Fuel 103 437-443
[12] Yarkasuewa C I, Wilson D and Michael E 2013 Production of Biodiesel from yellow oleander (Thevetia Peruvian) oil and its biodegradability Journal of the Korean Chemical Society 57 377-381
[13] Yoosaf P P, Gopu C and Sunil Kumar C P 2018 Properties of biodiesel and blends: An investigative and comparative study Engineering Trends in Engineering, Science and Technology for Society, Energy and Environment 459-465
[14] Sirvio K, Niemi S, Heikkila S and Hiltunen E 2018 Kinematic Viscosity studies for medium-speed CI engine fuel blends Agronomy Research 16 1247-1256
[15] Ali O M, Mamat R, Abdullah N R and Abdullah A A 2016 Analysis of blended fuel properties and engine performance with palm biodiesel-diesel blended fuel Renewable Energy 86 59-67
[16] Devarajan Y, Munuswamy D B, Nagappan B and Pandian K 2018 Performance, combustion and emission analysis of mustard oil biodiesel and octanol blends in diesel engine Heat and Mass Transfer 54 1803-1811
[17] Vidal M, Rogers W J, Holste J C and Mannan S 2004 A review of estimation methods for flash points and flammability limits Process Safety Progress 23 47-55
[18] Rosha P, Mohapatra S K, Mahla S K, Cho H M, Chauhan B S and Dhir A 2019 Effect of compression ratio on combustion, performance and emission characteristics of compression ignition engine fuelled with palm (B20) biodiesel blend Energy 178 676-684
[19] Arun S B, Suresh R and Yatish K V 2019 jan 1 Biodiesel production and investigation of fuel properties Materialstoday: Proceedings 17 186-190

[20] Mairizal AQ, Awad S, Priadi CR, Hartono DM, Moersidik SS, Tazerout M, Andres Y 2020 jan 1 Experimental study on the effects of feed stock on the properties of biodiesel using multiple linear regressions Renewable Energy 145 375-81

[21] Brandão L F P and Suarez P A Z 2018 Study of Kinematic Viscosity, Volatility and Ignition quality properties of Butanol/Diesel Blends Brazilian Journal of Chemical Engineering 35 1405-1414