Sustainable Biodiesel from Temple Waste Oil: A Study on Conversion Process, Engine Performance and Emission Analysis

Mr. Kishor Kumar S[1*], Mr. Hareesha M[2],

[1*]Assistant Professor, Department of Civil Engineering, Malnad College of Engineering, Hassan, Karnataka state, India.
[2]Assistant Professor, Department of Mechanical Engineering, Malnad College of Engineering, Hassan, Karnataka state, India.

***Corresponding Author:** Mr. Kishor Kumar S
*Mail id: Skk@mcehassan.ac.in

ABSTRACT

Inflation in fuel prices and unprecedented shortage of its supply has promoted the interest in development of the alternative sources for petroleum fuels. The present paper discusses with the various phases of production of bio-diesel from temple waste oil. The phases of collection of waste oil from temple, pre-treatment and transesterification are discussed. Investigations were carried out to study the performance, emission and combustion characteristics of temple waste oil. The results were compared with diesel fuel, and the selected temple waste oil fuel blends (10%, 20%, 30% and 100%). The engine performance parameters such as specific fuel consumption, Brake Thermal Efficiency and Exhaust Emission (CO, SOx, HC, and NOx) were recorded. The exhaust gas emissions are reduced with increase in biodiesel concentration. The experimental results proved that the use of biodiesel in compression ignition engine is a viable alternative to diesel. From the comparison of results, it is inferred that the engine performance is improved with significant reduction in emissions for the chosen oil without any engine modification.

Keywords: Biodiesel, Temple waste oil, Transesterification

1. Introduction

Energy is very valuable resource to the mankind and also for the sustainable development. In the present world, the energy has become the major crisis and global issue to confront us. The main source for producing energy is fuels. Thus, fuels play an important role to generate energy as they can be burned to produce a significant amount of energy. In the production process in most of industries makes use of diesel machines, 80% of the world energy requirements of the world is contributed by fossil fuel. The large amount of diesel and gasoline consumed in the transportation sector example ships, vehicles, trucks, buses and many other vehicles run by consuming a significant amount of diesel and gasoline. Thus, the today's world is very much depending on fossil fuel for the lead of day-to-day life. And also, the production of domestic crude oil is not covered the growing population of present world. Moreover, biodiesel fuel has become more attractive because of its environmental benefits due to the fact that plants and waste temple oils and animal fats are renewable biomass sources. Biodiesel represents a largely closed carbon dioxide cycle (approximately 78%), as it is derived from renewable biomass sources. Compared to petroleum diesel, biodiesel has lower emission of pollutants, it is biodegradable and enhances the engine lubricity and contributes to sustainability. Use of (unprocessed) waste temple oil in the compression ignition engines is reported to cause several problems due to its high viscosity. Biodiesel which is used as an attractive alternative fuel, is prepared by transesterification of waste temple oils with a methanol in presence of a catalyst. The use of waste temple oil as biodiesel feedstock reduces the cost of biodiesel production since the feedstock costs constitutes approximately 70-95% of the overall cost of biodiesel production. Hence, the use of waste temple oil should be given higher priority over the edible oils as biodiesel feedstock. Small amount of biodiesel can be used to add in low Sulphur formulation of diesel to increase the lubricating capacity that is lost when Sulphur is removed.In India, due to various mythological and religious reasons hundreds of devotees pour oil over the idols in Hanuman or Maruti and Shani temples. The oil poured once cannot be reutilized and was ultimately wasted. This waste oil can be used to produce biodiesel. Biodiesel production and its applications were gaining popularity in recent years due to decreased petroleum reserves. Biodiesel is defined as a fuel composed of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. The cost of Biodiesel was higher than that of fossil fuel, because of high raw material cost. To decrease the cost of bio fuel, waste temple oil was used as alternative as feedstock

1.1 Advantages of biodiesel

Renewable fuel, obtained from waste temple oils or animal fats. low toxicity, in comparison with diesel fuel degrades more rapidly than diesel fuel, minimizing the environmental consequences of biofuel spills. Lower emissions of contaminants like carbon monoxide, particulate matter, polycyclic aromatic hydrocarbons, aldehydes. It lowers health risk, due to reduced emissions of carcinogenic substances. No Sulphur Dioxide (SO_2) emissions occur. It may be blended with diesel fuel at any proportion; both fuels may be mixed during the fuel supply to vehicles. Excellent properties as a lubricant. It is the only alternative fuel that can be used in a conventional diesel engine, without modifications. Used cooking oils and fat residues from meat processing may be used as raw materials.

1.2 Chemical composition of biodiesel

It consists of alkyl usually methyl esters. It has combustion properties similar to regular diesel. Chemical formula for diesel fuel is C12H26. Biodiesel is derived from waste temple oils such as triglycerides which are esters of glycerol with fatty acids.

2. Materials and Methods

2.1 Collection of waste Temple Oil

The temple waste oil was collected in the sterile plastic bottle from the Anjaneya and Marikamba temples which are located at Sirsi – Banavasi road, Uttar Kannada district. A quantity of 6 litres of temple waste oil was collected from the temple. The temple generates around 250 to 350 litres of waste oil per month, sometimes going up to 1000 litres during the month of Karthika.

Fig.2.1 Anjaneya Temple (Sirsi)

Fig.2.2 Waste temple oil

2.2 Pre-treatment

The used temple oil was first filtered to remove solid impurities. It is preheated up to 50–60 $^{\circ}$C to reduce the viscosity. The same oil was further heated up to 100 $^{\circ}$C for half an hour to remove moisture.

2.3 Determination of FFA of the Oil

Obtain 10ml of temple waste oil sample and dissolve it in 100ml of isopropyl alcohol. Prepare a titration solution by dissolving 1.0 gm of KOH in 1.0L of distilled water. Add 1 ml of the KOH titration solution to the mixture and stir.

$$\text{FFA Content} = \frac{(28.2 \text{ x Normality of NaOH x Titration value})}{\text{Weight of the oil}}$$

If the FFA content is below 4, a single stage of production of biodiesel can be carried out i.e. the Trans-esterification. If the FFA content is greater than 4, a two-stage production has to be carried out for the production of biodiesel, i.e. acid-esterification to reduce to FFA content below 4 and trans-esterification.

2.4 Acid Esterification

Acid-esterification is the general name given to the chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product. 750 ml of seed oil is heated to about 600 on a hot plate magnetic stirrer and it is transferred to a clean and dry three necked flask.70 ml of Methanol and 1.5 ml of H2SO4 is added and stirred at a constant speed of 800 rpm for 2 hours. After the completion of reaction, the solution is allowed to cool down and then transferred to a Separatory funnel and allowed to cool down for 12 hours. The formation of layers takes place, in which the top layer formed is the processed oil, which is brown in colour and the lower layer is the Free Fatty Acid which has to be drained out, separating it from the supernatant processed seed oil. The processed seed oil is then tested for Free Fatty Acid. The resulting FFA was found to be again more than 4, hence, the seed oil was again used to carry out the acid esterification process. Again, the processed seed oil is tested for Free Fatty Acid. Since resulting FFA was found to be 2 (less than 4), the seed oil was used to carry out the trans-esterification process.

2.5 Trans Esterification

FFA content of the temple waste oil is to be determined, if FFA content will be greater than 4, a two-stage production has to be carried out for the production of biodiesel, i.e acid-esterification to reduce to FFA content below 4 and trans-esterification.

For the trans esterification process the temple waste oil (below 4) is to be transferred to a three necked flask and is to be kept on a hot plate magnetic stirrer, is to be heated to 60^{0}C, at this point 120 ml of Methanol and 4 grams of NaOH are to be added and it is to be kept in a constant stirring condition at a speed of 800 rpm. The reaction is to be allowed to proceed for duration of 2 hours. After the reaction is completed, the solution is allowed to be cooled, upon cooling the biodiesel and glycerin are to be separated through a separator funnel.

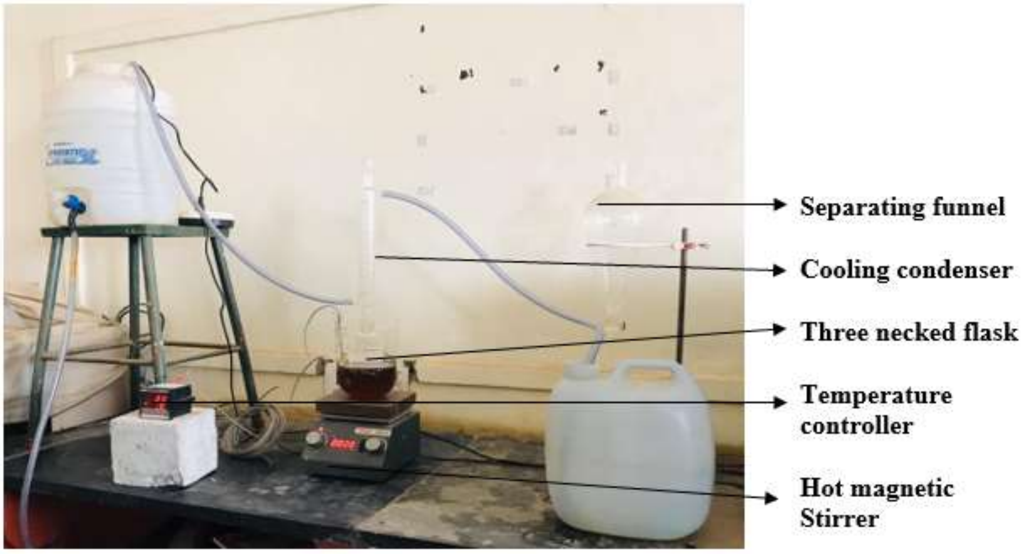


Fig.2.3 Experimental setup

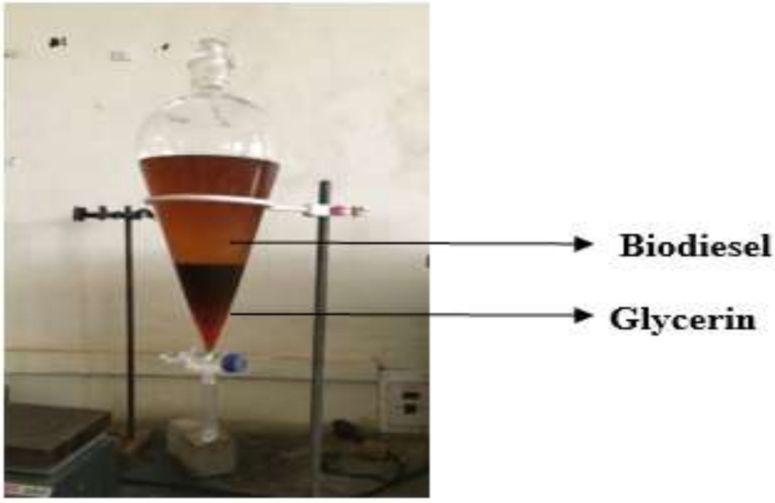


Fig.2.4 Separation of Biodiesel and Glycerin

The biodiesel is then washed with warm water (60◦) in order to remove the methanol present in the biodiesel. The biodiesel has to be washed till the water used does not change color after the wash. The biodiesel is then heated to a temperature of 1000 to remove any traces of water content present in it.

Fig.2.5 Water washing

Fig.2.6 Biodiesel and glycerin

3. **Results and Discussion**

3.1 Properties of Temple waste Biodiesel

Different properties of biodiesel like Density, Kinematic Viscosity and Calorific value were tested using hydrometer, viscometer and bomb calorimeter respectively. Temple waste biodiesel was blended with conventional diesel in the following proportions: -

B10: 10% Biodiesel + 90% Diesel

B20: 20% Biodiesel + 80% Diesel

B30: 30% Biodiesel + 70% Diesel

Table 2: Properties of Biodiesel

Properties	**density (kg/m^3)**	**viscosity (cst)**	**calorific value(kj/kg)**
Diesel	830	3.28	38315.06
B10	840	3.21	37323.80
B20	845	3.78	36720.30
B30	860	3.96	36668.01
B100	885	4.25	32050.12

3.1.1 Variation of Density for Different Biodiesel-Diesel Blends

Density of Biodiesel depends upon molecular weight. Since the density of temple waste biodiesel is more than conventional diesel fuel, the density of different blends increases with the increase in biodiesel percentage and same can be observed in table 2. Temple waste Biodiesel has maximum density of 885 kg/m^3. Among blends B10 has density close to Diesel value i.e. 840 kg/m3.

3.1.2 Variation of Kinematic Viscosity for Different Biodiesel-Diesel Blends

Viscosity is one of the most significant properties of biodiesel since it plays a vital role in fuel injection process of diesel engine. If the viscosity is high, it affects atomization process because of which effective mixing of fuel with air will not takes place and it in turn causes incomplete combustion. Viscosity will be high for those oils having longer chain length of fatty acid and is less for those oils having more amount of unsaturated fatty acid. From table 2, it can be observed that temple waste Biodiesel has highest viscosity of 4.25 cSt. Among blends B10 has viscosity nearer to diesel value i.e. 3.21 cSt.

3.1.3 Variation of Calorific Value for Different Biodiesel-Diesel Blends

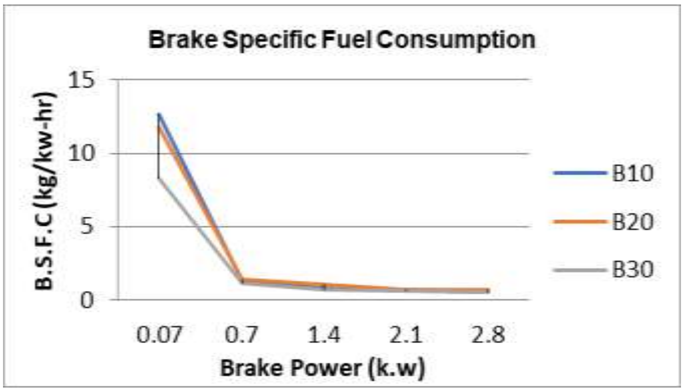
Calorific value of fuel is one of the important parameters that determines efficiency of an engine. Higher the calorific value of a fuel, larger amount of heat will be released which increases the efficiency of the engine. From table 2, it can be observed that as biodiesel percentage in blends increases there is a decrease in calorific value. It is because of the reason that since Biodiesel is an oxygenated fuel; its calorific value is less compared to diesel. Diesel has a highest calorific value 38315.06kJ/kg and among blends B10 has calorific value nearer to diesel value 37323.80 kJ/kg.

3.2 Performance Evaluation

In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber.

3.2.1 Brake Specific Fuel Consumption (B.S.F.C)

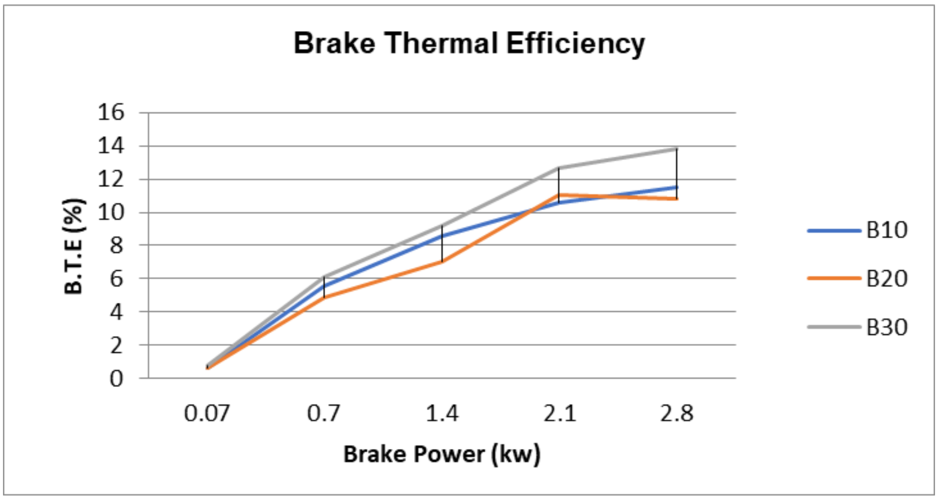
Brake Specific Fuel Consumption (B.S.F.C.) is the fuel consumed by the engine per unit of power output or produced. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work.



For fuel tested, decrease in B.S.F.C. was found with increase in brake power. It can be seen from this graph that as Brake Power increases, B.S.F.C. decreases to minimum at full load condition. By observing related results at full load engine condition, the value of B.S.F.C. for B10 blend is minimum.

3.2.2 Brake Thermal Efficiency

Brake Thermal Efficiency is the ratio of the power output of the engine to the rate of heat liberated by the fuel during the combustion.



It is observed that the brake thermal efficiency is low at low values of BP and increases with increase of BP for all blends of fuel. For a blend of 30% the brake thermal efficiency is high at low BP values when compared with other blends of fuel. Hence at the blend of 30%, the performance of the engine is good.

3.3 Emission Characteristics

Fuel	Exhaust Emission (ppm)			
	CO	HC	SO_2	NO_2
DIESEL	0.070	12	07	575
B10	0.057	11	06	787
B20	0.051	13	03	800
B30	0.023	07	02	790

The above table shows that all emissions with biodiesel are lower than diesel except NO_2. NO_2 emissions will increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. The higher of NO_2 emission could be reduced either by the use of catalytic converter.

The above analysis of biodiesel shows that the reduction in CO emission is about 18.5% with B10 and 67% with B30 use on per liter combustion basis. CO emissions reduce when using biodiesel due to the higher oxygen content and the lower carbon to hydrogen ratio in biodiesel compared to diesel.

4. CONCLUSION

The temple waste oil was successfully extracted from the seeds. The oil thus extracted was made to undergo the transesterification process and conditioned. Bio-diesel properties are then compared with neat diesel. The blend B10 properties were close to diesel properties. Calorific value of B10 is more compared to B20 and B30. Reduced viscosity which in turn increases the fuel atomization resulting in good combustion. From the performance evaluation, it is observed that the performance of C.I engine has increased by using blended biodiesel in comparison with pure diesel. From this study it is observed that the blended biodiesel can be used as an alternate fuel for the C.I engine without any engine modification. It is inferred, from the results that the brake thermal efficiency is higher for B30 and less fuel consumption for B10.
From the emission characteristics, it is concluded that biodiesel and its blends as a fuel for diesel engine have better emission characteristics compared with diesel as follows:
(1) CO emissions are less compared with diesel
(2) NO_2 emissions for biodiesel and blended fuel are slightly higher than that of diesel
(3) From this analysis it can be concluded that B30 gives better performance with reduced pollution.

REFERENCES

1. A.S.Ramadhas, S.Jayaraj, C.Muraleedharan, (2004),"Biodiesel production from high FFA rubber seed oil", Vol.84335-340.
2. A.U.Ofoefule, C.N.Ibeto, U.C.Okoro and O.D.Onukwuli, (2013), "Biodiesel Production from Tigernut (Cyperus esculentus) Oil and Characterization of its Blend with Petro-diesel", Physical Review &Research International. Vol. 3(2): 145-153.
3. Baljinder Singh, Jagdeep Kaur, Kashmir Singh, (2010). "Production of Biodiesel From Used Mustard Oil and Its Performance Analysis in Internal Combustion Engine", Journal of Energy Resources Technology. Vol.132.
4. Bobade S.N. and Khyade V.B., (2012). "Detail study on the properties of pongamia pinnata (karanja) for the production of biofuel", Research Journal of Chemical Sciences.Vol.2 (7), 16-20.
5. C.L.Butts, R.B.Sorensen, R.C.Nuti, M.C.Lamb, W.H.Faircloth, (2009). "Performance Of Equipment For In-Field Shelling Of Peanut For Biodiesel Production", Transactions of the ASABE. Vol.52 (5): 1461-1469.
6. Chauhan B.S, Kumar N, Cho H.M. (2010)"Performance and emission studies on an agriculture engine on neat Jatropha oil", Journal of Mechanical Science and Technology, Vol529-535.
7. Chavan S.B., Kumbhar R.R. and Deshmukh R.B. (2013)"Callophyllum Inophyllum Linn ("honne") Oil, A source for Biodiesel Production", Research Journal of Chemical Sciences, vol:3, pp:24-31.
8. Doddabasawa, Ravikumar Patil, (2014). "Biodiesel Production Cost Analysis from the Pongamia Pinnata :A Case Study in Yadagiri District Of Karnataka-India", International Journal of Science and Research. Volume 3.
9. Ebenaza Godson T and Vinoth E, (2015), "Biodiesel Production from Waste Cooking Oil", International Journal of Students' Research In Technology & Management. Vol 3(8).
10. Ganesha T, N Jagadeesh, Basavaraja K, Basavaraj Betur, (2017), "Biodiesel Production from Calophyllum Inophyllum Oil using Ultrasonication Method and Investigation of its Properties with Diesel and Kerosene Blends", International Journal for Research in Applied Science & Engineering Technology,vol:5.
11. Gaurav Dwivedi, Siddharth Jain, M.P.Sharma (2013) "Diesel engine performance and emission analysis using biodiesel from various oil sources- Review", J.Mater.Environ. Sci.vol:4, pp:4434-447.
12. Hadi Jabbari, (2018), "Production of methyl ester biofuel from sunflower oil via transesterification reaction", Asian Journal of Nanoscience and Materials. Vol. 1(2), 52-55.
13. Hithashree M N, Kishor kumar S, Dr.K S Jayantha (2019). "Biodiesel production and evaluation of performance and emission characteristics of sal seed", JETIR May 2019,Volume 6, Issue 5.
14. J.S.gitay, Dr.G.R.Selokar,(2017) "critical analysis & performance evaluation of diesel engine using biodiesel", International Research Journal of Engineering and Technology, Vol:4.
15. Kaniz Ferdous, M.Rakib Uddin, Maksudur R.Khan, and M.A.Islam (2013), "Preparation and Optimization of Biodiesel Production from Mixed Feedstock Oil", Chemical Engineering and Science. Vol.1, No.4, 62-66.

16. Kishor Kumar S, Dr.K S Jayantha, Subhash Kalki D and Kavya T R (2018). “Biodiesel production and evaluation of performance and emission characteristics of Calophyllum inophyllum”, International conference of infrastructure development.
17. Kumar Deepak, Garg Rajnish, Tripathi R.K,(2014), "Optimization of biodiesel production process from low cost high FFA Polanga oil", International Journal of Scientific & Engineering Research, vol:5.