International Journal of Future Generation Communication and Networking
Vol. 13, No. 4, (2020), pp. 4871–4883

Study of Biodiesel based on Algae and Palm Oil Properties and Jatropha Integerrima Tree Characteristics for Enhancing Performance of 4 Stroke CI Engine

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Abstract

Different biodiesels are currently being studied and used in various industries around the globe. Besides, there is a broad scope for improving the fuel economy, performance, and ignition properties of these biodiesels. These biodiesels are ideal for use in vehicles, trucks, and airplanes. Our goal in this study is to investigate the performance characteristics of non-edible oil, palm oil, and biodiesel algae oil extracted by esterification, demoisturization, oil transesterification, and to classify the properties of these hybrid blends such as calorific value, density, cetane no, flash point, fire point, etc. B9, B18, B27, B36 blends will be used in this analysis. In this research work, we also conduct, performance and analysis on 5 HP single cylinder of vertical arrangement and direct injection CI engines with rope brake dynamometer with a blending of jatropha biodiesel. The diesel engine efficiency and emission parameters were found to contain different biodiesel proportions in the current diesel fuel. The result shows that compatible efficiency parameters with reduced emissions can be achieved by using up to 20 percent biodiesel in diesel.

Key Words**:** *Biodiesel, Esterification, Demoisturization, Transesterification, calorific value, cetane number, flash point, fire point.*

1. INTRODUCTION

Biodiesel is an alternative fuel that, as a sustainable, biodegradable, and non-toxic fuel, has attracted considerable attention over the past decade [2]. It is extracted by transesterification from the various forms of vegetable oil (edible and non-edible oil) and animal fats; it is often referred to as alcoholism. Methanol, ethanol, and methanol are the widely used alcohols for transesterification, primarily due to their low cost. To substitute conventional petroleum diesel, it is a stable alternative fuel. It has high lubricity, is a clean-burning fuel, and for current, unmodified diesel engines, it can be a fuel part. Less air pollution is created by biodiesel, and it is safer for the environment. Non-edible oils such as palm oil and algae oil have also been found to be the most appropriate for this reason. An alternative to liquid fossil fuels is algae fuel, algae biofuel, or algae oil, which uses algae as the source of energy-rich oils. Algae fuels are also an alternative to widely recognized sources of biofuels, such as maize and sugarcane. The algal oil methyl ester was synthesized by methyl transesterification of algal oil feedstock using previously synthesized potassium impregnated zinc oxide. The edible vegetable oil obtained from the mesocarp (reddish pulp) of the oil palm fruit is palm oil. The differences are in color (raw palm kernel oil lacks carotenoids and is not red) and saturated fat content: palm mesocarp oil is 49 percent saturated, while 81 percent and 86 percent saturated fats are palm kernel oil and coconut oil. Due to their lower fuel consumption and lower exhaust emissions of carbon monoxide (CO) and unburned hydrocarbons (UHC) compared to gasoline engines, diesel engines are commonly used as a power source in medium and heavy-duty applications. Vegetable oil has been used as a fuel since the invention and efficient running of the CI engine when the availability of petroleum fuel was costly or difficult to procure. Later, vegetable oil was replaced with diesel for the availability and supply of petroleum products (or heavy fuel). This decreased dependency on vegetable oil as well as directed interest in research to develop diesel fuel. Less study has been aimed at improving vegetable oil used as fuel for CI engines [1].

ISSN: 2233-7857 IJFGCN

Figure 1.1: palm oil fruit

The growing concern about environmental pollution caused by traditional fossil-based fuels and the awareness that they are non-renewable has now resulted in the search for more environmentally sustainable and renewable fuels. Biodiesel derived from multiple renewable sources has been recognized as a strong contender for reducing diesel exhaust emissions and reducing the energy bill, among the numerous options explored as a new CI engine fuel.

The use of biodiesel helps to minimize the emission of carbon dioxide into the atmosphere. The reliance on fuel imports, is sustainable in nature. Safer to treat, has no aromatic compounds, virtually no sulfur content, and oxygen atoms in the fuel molecule, which can reduce CO, total hydrocarbon (THC) and particulate matter (PM) emissions [2,3,4].

However, as compared to petroleum diesel fuel, biodiesel poses some issues, such as worse low-temperature properties[5], more significant emissions of certain oxygenated hydrocarbons[6,7], and higher production costs[8]. The last of the problems listed can be partially solved through the use of waste cooking oil as the raw material in the transesterification process. In essence, the cooking oil used is a waste product [9] and thus cheaper than the unused (virgin) vegetable oil [10, 11].

Zhang et al. [9] found that feedstock oil prices are one of the most important factors influencing biodiesel manufacturing's economic viability. Moreover, using both virgin vegetable oils and waste cooking oils, they compared many methods. The acid-catalyzed process using waste cooking oil was found to be more economically viable because the lower cost of raw material was sufficient to compensate for the higher initial investment (larger sizes and stainless steel construction of the reactors and methanol distillation column). In Jordan and mostly around the world, much of the cooking oil used is poured into the cities' sewage system. This activity leads to the contamination of rivers, lakes, seas and underground water, which is very detrimental to human health and the environment [12]. But there are at least two reasons for these oil spills to be stopped. Oils and grease, on the one hand, can cause the clogging of the pipes because they stick to the inner walls and reduce the sewer pipes' effective diameter. It can cause sewage spills if this layer becomes thicker. Suppose oil enters the wastewater treatment plants, on the other hand. In that case, it interferes with regular operations and raises both the maintenance costs and the prices to be charged for water purification [13].

Only a small amount of the cooking oil used is collected and recycled properly, especially in rural areas [14]. This waste was primarily used to make animal food a few years ago. However, because there is some evidence that highly oxidized fats (oils are exposed to high temperatures during frying in the presence of atmospheric oxygen) may have carcinogenic properties [15], governments are banning animal food from the cooking oil used. Biodiesel production could be an alternative choice for the reuse of waste cooking oil in this case.

Some drawbacks, such as low volatility, high viscosity, weak fuel particle atomization, and the blending of biodiesel, require more pumping capacity. It also needs more investment in biodiesel production and requires a more generous amount of oil to restrict the use of biodiesel. However, biodiesel can still be used in many applications, such as generator sets, marine and hybrid public transport, and industrial applications [16].

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Oil extracted from Jatropha seed that grows on the jatropha plant is converted by transesterification into biodiesel and can be used up to certain proportions in diesel engines and benefit from the properties of duel fuel. The properties of jatropha biodiesel are almost equivalent to diesel fuel, but certain properties, such as ignition and viscosity, are also very high [17].

1.1 The Potential of Jatropha cultivation in India

Roughly 40 million ha in India, out of the 64 million ha., the Jatropha plantation will establish wasteland. Two years after planting in the area, the Jatropha begins fruiting and continues for 30-40 years. For planting, high oil content, seed yield, and resistance to insect-quality seeds should be used. The Novod Board has established a model plantation for parental material for Jatropha in India's various states. [18]

2. METHODOLOGY BIODIESEL PRODUCTION

A. Biodiesel based on Algae and Palm Oil Properties

Considerable efforts have been made to develop vegetable oil derivatives that approximate hydrocarbon-based diesel fuels' properties and performance. The problem with substituting triglycerides for diesel fuel is mostly associated with high viscosity, low volatility, and polyunsaturated characters. These can be changed in at least four ways: Pyrolysis, microemulsion, dilution, and Transesterification.

Biodiesel setup

The reaction was carried out in Biodiesel Redley Reactor equipped with a reflux condenser, magnetic stirrer, and thermometer. It consists of water jackets, an external heater, and a condenser. The suitable mixing and turbulence for accelerating the reaction were done by the supplementary impeller, attached mechanically to the spindle.

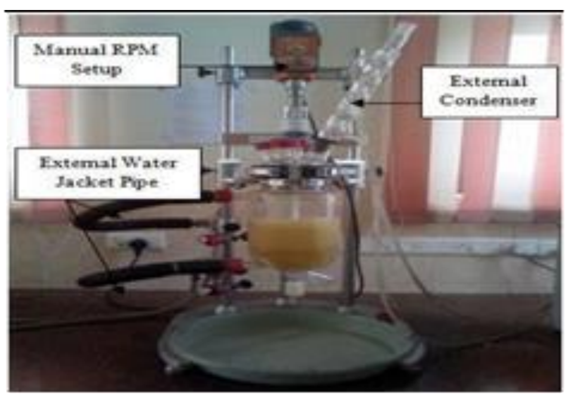

Figure 2.1 Biodiesel setup

1. Filtration: Filtration is a physical, biological, or chemical operation that separates solid matter and fluid from a mixture with a filter medium with a complex structure through which only the fluid can pass. Solid particles that cannot pass through the filter medium are described as oversize, and the fluid that passes through is called the filtrate. [1]

2. Demoisturization: It is the process that removes the water contents which are present in the biodiesel by heating the oil. After water washing, our biodiesel has an orange juice color to indicate it's full of water. To obtain the fastest drying, we heat the air over the biodiesel, where the water content will move out from oil.

3. Esterification: It is the reaction of an acid (condensation of the carboxyl group of an acid) with an alcohol (the hydroxyl group of the alcohol) in the presence of a catalyst. The chemical reaction that takes place during the formation of the ester is called esterification. Esterification is the process of combining an organic acid (RCOOH) with an alcohol (ROH) to form an ester (RCOOR) and water; or a chemical reaction resulting in the formation of at least one ester product. Ester is obtained by an esterification reaction of an alcohol and a carboxylic acid.

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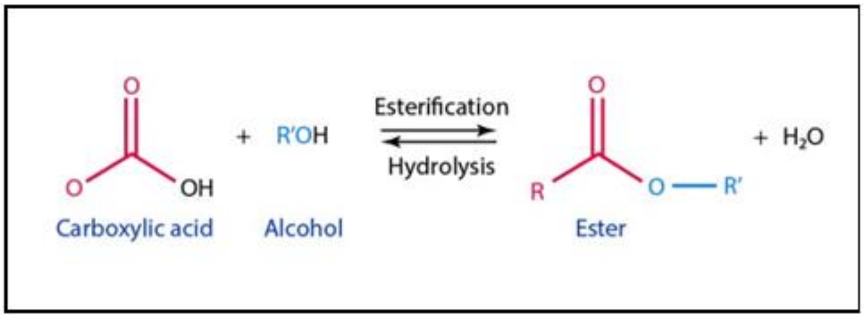

Figure 2.2: the chemical reaction of esterification

4. Transesterification: This transesterification process is like alkali transesterification, the only ratio of catalyst and solvent a stirring time different, and in this Transesterification, we have used lipase catalyst. The process is explained in the following figure.

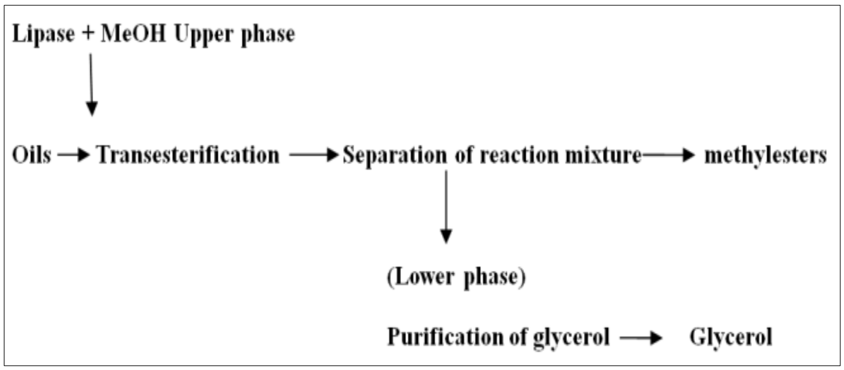

Figure 2.3 Transesterification process

Lipases are known to have a propensity to act on long-chain fatty alcohols better than on short-chain ones. Thus, in general, the efficiency of the Transesterification of triglycerides with Methanol (methanolysis) is likely to be very low compared to that with ethanol in systems with or without a solvent.

I. Transesterification method:

Biodiesel is considered a possible substitute for conventional fuel, composed of fatty acid methyl esters that can be prepared from triglycerides in vegetable oils by the transesterification process. It contains phospholipids, sterols, water, which more harmful to the diesel engine. To overcome this problem, the oil required slight chemical modification, mainly Transesterification, Pyrolysis. Transesterification, also called alcoholysis, is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except that alcohol is used instead of water. “This process has been widely used to reduce the high viscosity of triglycerides.

Transesterification is one of the reversible reactions and proceeds essentially by mixing the reactants. However, the presence of a catalyst (Base or acid) accelerates the conversion. Two major steps carry out this reaction.

II. Transesterification reaction:

The significant components of vegetable oils and animal fats are Triglycerides. To obtain biodiesel, the vegetable oil or animal fat is subjected to a chemical reaction termed Transesterification.

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CH_2OCOR'''			CH_2OH		$R'''COOR$
|			|		
CH_2OCOR''	+ 3ROH	⟶	CH_2OH	+	$R''COOR$
|			|		
CH_2OCOR'			CH_2OH		$R'COOR$
100 pounds	10 Pounds		10 Pounds		100 Pounds
Oil or Fat	Alcohol (3)		Glycerin		Biodiesel (3)

Figure 2.4 Chemical reaction of Transesterification

5. Setting up oil and separation:

After completing the above processes, we give us time to set up the biodiesel, which gives us two major products: glycerin and biodiesel.

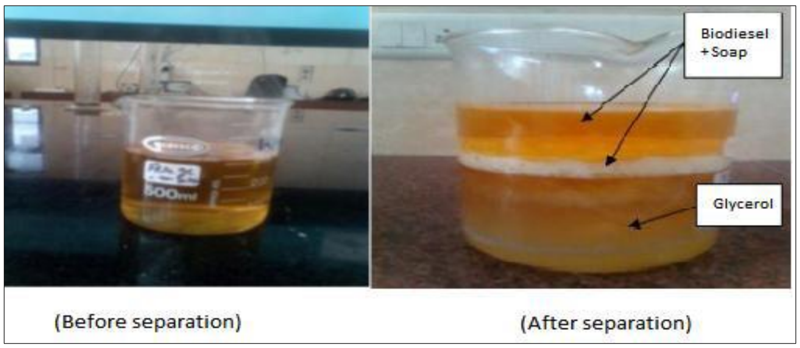

Figure 2.5 Setting up of the oil and separation

Each has a substantial amount of the excess Methanol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed. The glycerin phase is much denser than the biodiesel phase, and the two can be gravity separated with glycerin simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster. After the separation process, we get an impure form of oil, and the remaining is Glycerol.

6. Hot water washing:

Further, we mix the biodiesel obtained from the above separation and with hot water and get two layers as biodiesel and water due to the density difference between them. Water has a higher density so that it will be settled down at a lower position, and then you can remove the water. After removing the water, we can get quality as well as the clear solution of the biodiesel [3].

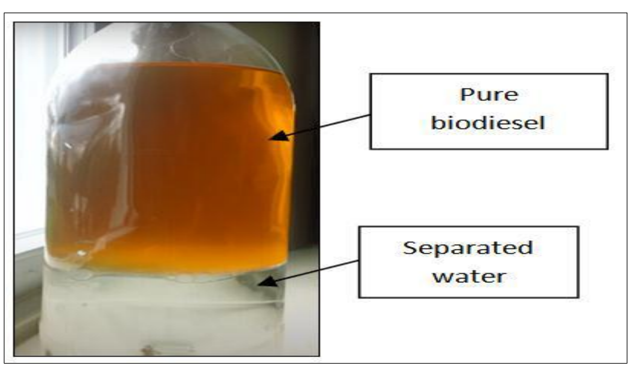

Figure 2.6 After hot water washing

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International Journal of Future Generation Communication and Networking
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B. Biodiesel based on Jatropha Integerrima Tree Characteristics

Transesterification of Jatropha oil to Biodiesel

There are different technologies to produce biodiesel [13].

a. Homogeneous Catalysts Method for Transesterification

b. Heterogeneous Catalysts Method for Transesterification

c. Enzymatic TE of Vegetable Oils

d. Non-Catalytic Super Critical Vegetable Oils to FAME

Transesterification

Transesterification is process of chemical reaction between triglycerides present in oil and alcohols like methanol and ethanol with use of catalyst to produce alkyl esters in form of methyl or ethyl ester and by product glycerol.

$$\text{Triglyceride} + \text{Alcohol} \rightleftharpoons \text{Alkyl Esters} + \text{Glycerols}$$

The use of methanol is more preferred due to its cheap and easy availability. And this reaction carried out in the presence of homogeneous catalysts like potassium hydroxide KOH, sodium hydroxide NaOH, or heterogeneous catalyst like enzymes, titanium silicates, etc and finally conversion of triglyceride-diglyceride - mono-glycerides – glycerol by one mole of ester liberated.[14]

In this project work, purchased Jatropha oil is used to reaction with methanol alcohol in the presence of NaOH to produce methyl esters and glycerol. A known amount of sodium hydroxide NaOH based on a percentage of the oil weight. This Sodium hydroxide NaOH is premixed with methanol and added to the Jatropha oil. This mixture heated at a particular temperature up to 30 min and it is controlled by electrical heating, mixed by magnetic stir for a few mins then stays this mixture to settlement about twelve hrs. The separated bio-diesel coming out at the top of mixture and part of glycerine settled at the bottom of flask. Table 2.1 shows the comparison of various properties of jetropha biodiesel and diesel.

Figure 2.7 Jatropha Seeds

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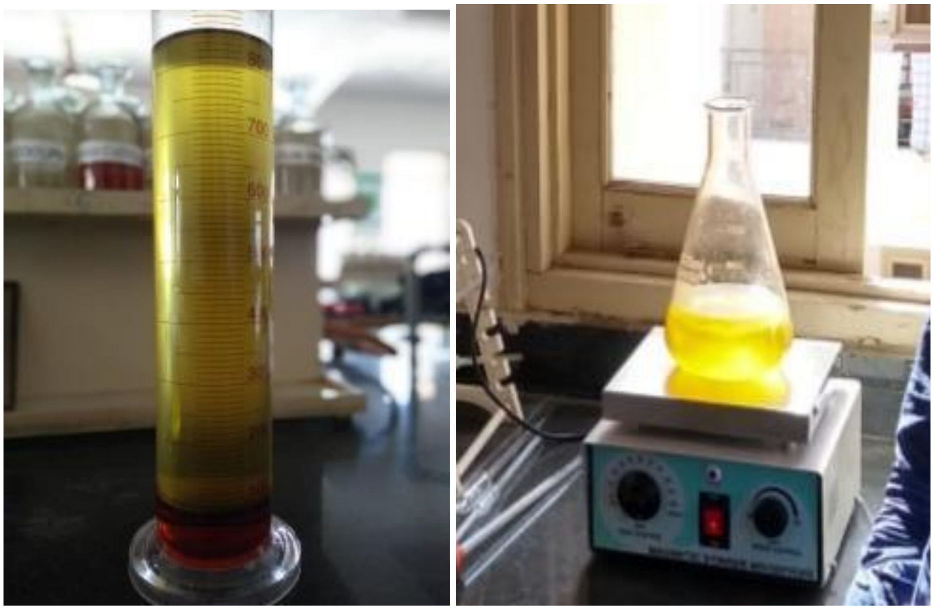

Figure 2.8 Production of Biodiesel in laboratory

Table 2.1: Comparing Petroleum-Based Diesel And Jatropha Biodiesel

Parameter	Jatropha based Methyl Ester	Diesel
Density at ,kg/m3	885	830
Viscosity, mm2/s	4.84	2.6
Flash point, °C	162	70
Pour point, °C	-6	-20
Ash content,%	Nil	0.02
Carbon residue,%	0.025	0.17
Sulphur content,%	NIl	-
Iodine value	104	-
Saponification value	190	-
Calorific value, MJ/kg	37.2	42
Cetane number	51.6	46

Experimental Performance and Analysis

For this Research work, we perform experiment on single vertical cylinder, four strokes, and water-cooled, direct injection CI engine. Fig 2.9 is the Schematic diagram of the experimental setup and Table 2.2 shows details of technical specification of the engine.

Table 2.2: Specifications of The Engine

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BHP/KW	5/3.72
Compression Ratio	16.5:1
Rated Speed (rpm)	1500
Bore (mm)	80
Stroke (mm)	110
Number of stroke	4
Number of Cylinder	1
Type of ignition	Compression Ignition
Method of loading	Rope Braking
Method of starting	Crank start

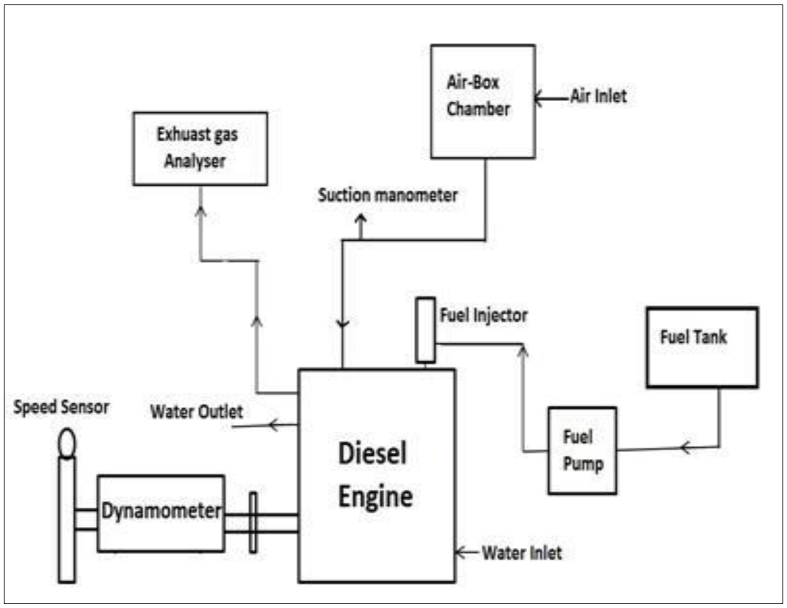

Fig 2.9 Schematic diagram of Experiment set up

Experimental Procedure

- Before starting the engine check the fuel supply line, electrical supply, and availability of cooling water.
- Set the dynamometer to zero loads and run the engine till it attains the working temperature.
- Keep the zero load, adjust the fuel supply so that the engine attains its rated speed and run the engine till the steady -state condition is achieved.
- Note down the fuel consumption rate, cooling water, and air flow rate and exhaust temperature and Emission parameter.
- Now, Set the dynamometer to 25% of full load, adjust the fuel supply so that the engine attains the desirable rate speed after steady state is reached, note down the dynamometer reading, fuel consumption rate, cooling water temperature, air flow rate, exhaust gas temperature ,and Emission Parameter.
- Repeat the experiment at 50, 75, and 100% of full load at constant speed.

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- Then do the same procedure by blending of biodiesel with diesel for different ratios.
- These different ratios are:
    1. 10% Jatropha fuel + 90% diesel
    2. 20% Jatropha fuel + 80% diesel
    3. 30% Jatropha fuel + 70% diesel

3. RESULT AND ANALYSIS

A. Biodiesel based on Algae and Palm Oil Properties

Below are few properties which have observed during the testing of biodiesels considered in this study. The properties are compared with the existing diesel in the below-mentioned results.

Sr. No.	Test Description	Ref, sted. ASTM 6751	Reference		Diesel	Hybrid oil Biodiesel blend			
			Unit	Limit	B00%	B09%	B18%	B27%	B36%
1	Density	D1448	gn/cc	0.800-0.900	0.831	0.834	0.836	0.837	0.84
2	Calorific value	D6751	Mj/kg	34-35	42.5	42.41	42.38	42.11	42
3	Cetane No	D613	-	41-55	49	49.22	49.4	49.6	49.9
4	Moisture	D2709	%	0.05	NA	NA	NA	NA	NA
5	Flash point	D93	-	-	67	67	70	76	88
6	Fire point	D93	-	-	71	76	82	92	103

Table 3.1: Result analysis of the biodiesel samples with existing diesel

B. Biodiesel based Jatropha Integerrima Tree Characteristics

PERFORMANCE PARAMETERS

1. Brake Specific Fuel Consumption

The comparison of Brake thermal specific consumption (BSFC) with respect to output power for the various blends of biodiesel in diesel is plotted in Fig 3.1 The ratio of mass fuel consumption (mf) to brake power (BP) is called Brake specific fuel consumption. It is observed that BSFC is higher for all blended fuel than pure diesel under various loading condition and it is due to high viscosity, and lower heating value of biodiesel. But also found that 20% blended fuel having comparable value with diesel.

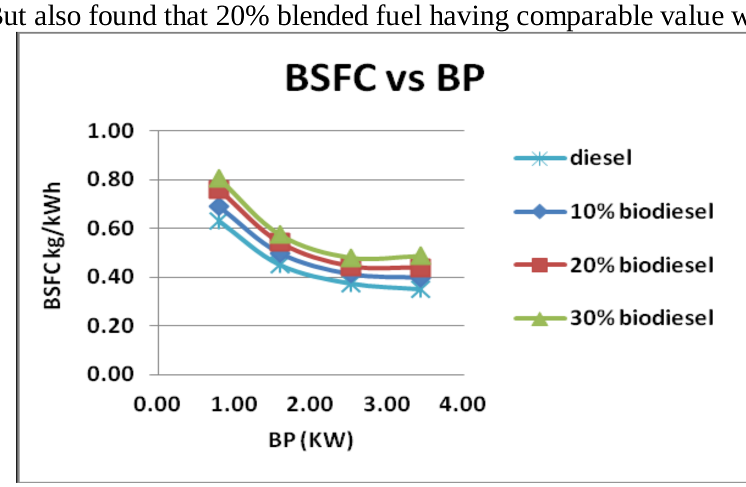

Figure 3.1 BSFC vs BP

2. Brake Thermal efficiency

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The ratio of Brake power (BP) to Heat supplied (Qs) is called Brake thermal efficiency. The Changes in brake thermal efficiency with respect to output power for different percentages of biodiesel in diesel is plotted in Fig 3.2 It was that Brake thermal efficiency with Jatropha blended biodiesel is lower than diesel fuel due to poor atomization and Vaporization. Brake thermal efficiency increases as the brake power increases for under various loading conditions.

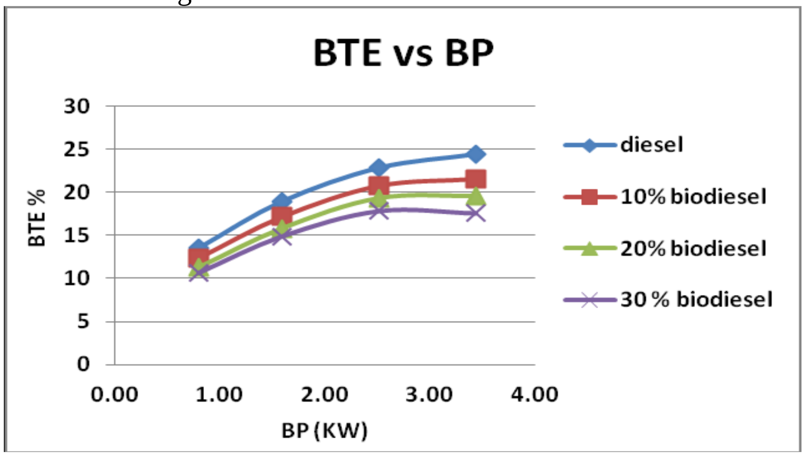

Figure 3.2 BTE vs BP

3. Brake Specific Energy Consumption

The variation of Brake specific energy consumption BSEC with respect to output power for various blends and diesel shown in fig 3.3 BSEC is a variable which independent of fuel consumption and it is energy input to produce the unit power output. It is found that BSEC of all fuels decreases with increasing the load. It was found to be a marginal difference between blended and diesel fuel and this due to lower calorific value and high kinematic viscosity of biodiesel.

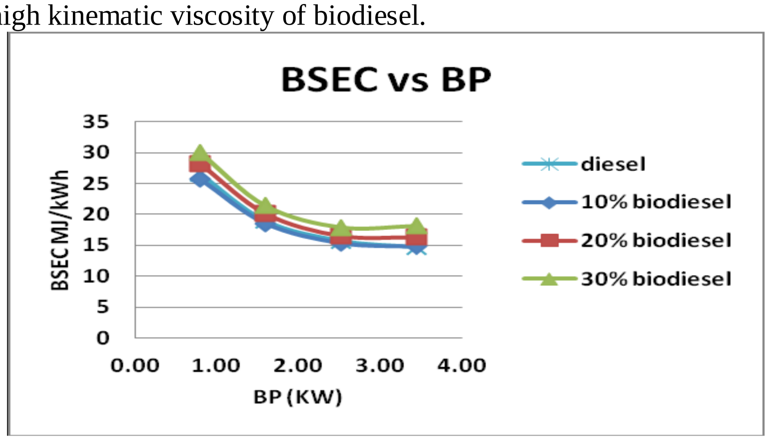

Figure 3.3 BSEC vs BP

EMISSION CHARACTERISTICS

1. Unburned hydrocarbon emission (UBHC)

Fig. 3.4 show that unburned hydrocarbon emissions for all blended biodiesel and diesel fuel. It is shown that UBHC emissions decrease with Jatropha biodiesel blending percentage than diesel. It was also seen that UBHC emission increased with increasing load on the engine. The reason was that Jatropha biodiesel has high ignition quality and high oxygen which doing complete reaction.

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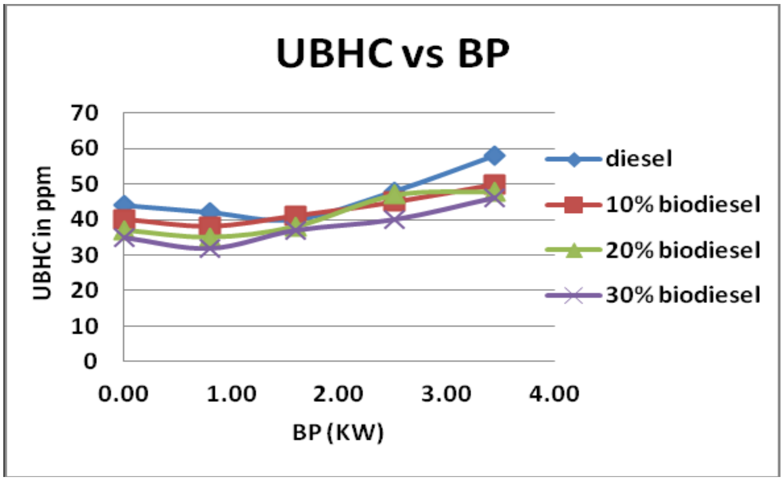

Figure 3.4 Unburned Hydrocarbon Emission

2. Carbon monoxide emission (CO)

Fig 3.5 shows that, Carbon monoxide emission for blended and diesel fuel alone. We observed that for different fuels, the carbon monoxide (CO) emission levels were increased with power output because of increase in volumetric fuel consumption. The physical properties of fuel and chemical reaction with air in the cylinder affect the formation of CO emission. It can be seen that the Carbon monoxide pollution contain with blended of Jatropha biodiesel is less compare to diesel fuel. The reason for decreseing of CO with use of Jatropha biodiesel is to converts carbon monoxide to carbon dioxide with more oxygen present it.

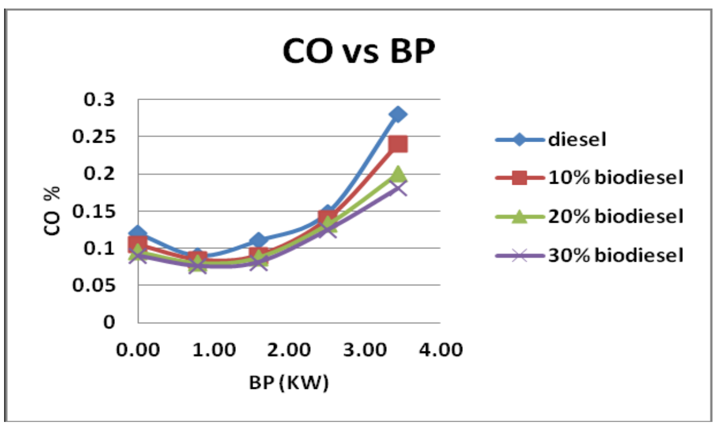

Figure 3.5 Carbon Monoxide Emission

Carbon Di-oxide Emission (CO2)

Fig. 3.6 shows that carbon dioxide (CO2) pollutant levels for diesel fuel and with blended jatropha biodiesel with power output. The CO2 emissions were increased due to increase in volumetric efficiency. It also found that the CO2 pollution with blended Jatropha biodiesel is less compare to diesel. This is due to the more oxygen contain of jatropha biodiesel.

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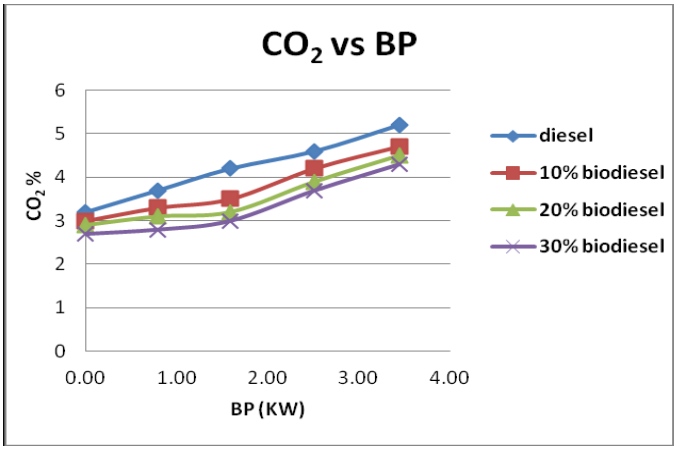

Figure 3.6 Unburned Hydrocarbon Emission

Oxides of Nitrogen Emission (NOx)

It was shown that NOx emission increase with blended biodiesel and diesel fuel with increasing load. The NOx emissions of diesel and Jatropha biodiesel fuels are plotted in fig 3.7. The formation of NOx depends on cylinder temperature so with the usage of biodiesel oxygen contain augment high peak cylinder temperature to lead NOx. It was seen that with blend of Jatropha biodiesel, peak temperature getting after combustion process.

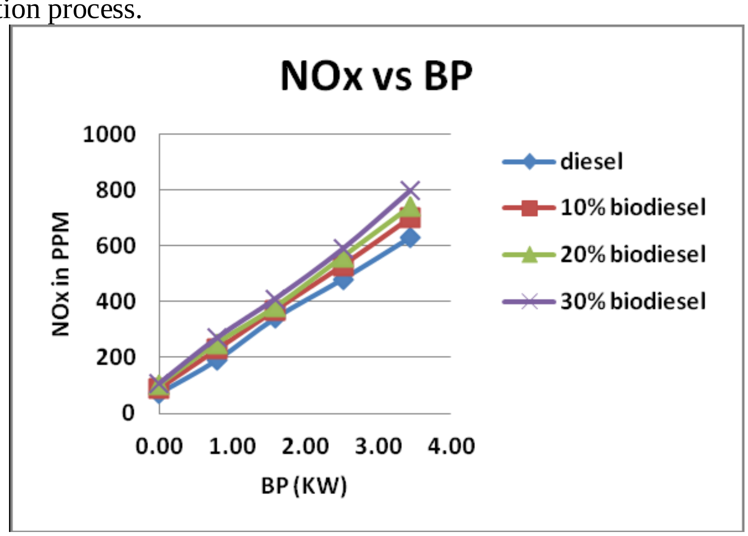

Figure 3.7 Nitro-Oxide Emission

4. CONCLUSION

Results obtained after conducting several property tests confirmed that all biodiesel categories have better properties compared with that of the existing diesel. This will improve the overall engine performance. Biodiesel derived from palm and algae oil is a potential renewable and minimum carbon content alternative to petroleum fuels. However, it faces issues such as limited supply and higher processing cost, which prevents it from becoming a good replacement for petroleum fuels. As petroleum fuel rises in its cost day by day and its supplies decrease, biodiesel will surely fulfill its requirement.

From the Jatropha biodiesel Analysis, we can suggest that Jatropha biodiesel is an alternative fuel for the economic running of compression ignition engines and reduced environmental pollution to some extent.

The following observation made from experimental work and summarized as follows:

1. The engine performance characteristics with blended biodiesel are compatible with diesel fuel.
2. There is a noticeable reduction in emissions characteristics except NOx for blended Biodiesel compared to diesel fuel.
3. NOx emission with Jatropha biodiesel blend is higher than diesel due to high peak temperature.

ISSN: 2233-7857 IJFGCN

Finally, we conclude that biodiesel from Jatropha oil could help to reduce energy security or resources to some extent without losing engine performance. And also help to control air pollution by using some percentage of biodiesel with diesel fuel.

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ISSN: 2233-7857 IJFGCN