# "Performance and Emission Characteristics of Biodiesel Obtained from Waste Cooking Oil used as an Alternative Fuel in Diesel Engine."

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**Abstract -***Biodiesel is becoming popular now-a- days due to high cost of petrochemical products as we know that these sources are finite in number as they are going to finish or reduce day by day. Therefore we need to find an alternate source to compensate these problems. In this project we obtained biodiesel in the laboratory by using waste cooking oil which is purchased from a nearby restaurant, illustrated its chemical properties, compared with different types of fluid which is used in engine & engine performance characteristics of biodiesel blended with different percent such as (B5%, B10% B15% and B20%) of diesel under different load condition. The experimental investigation has carried out in diesel engine at variable loads& constant RPM with respect to engine performance parameter i.e. Brake power (BP), Indicated power (IP), Brake thermal efficiency, Indicated thermal efficiency, Brake specific fuel consumption (BSFC), Indicated specific fuel consumption(IFSC) and engine effects on emission of Carbon Monoxide(CO), Carbon Dioxide(CO2),Hydrocarbons(HC), Nitrogen Oxides (NoX) Sulphur Oxides(SoX) etcand plotted different graphs.*

***KeyWords*: Waste Cooking Oil, Diesel, Engine, Blends, Biodiesel, Performance, Emission,**

## 1. INTRODUCTION

In today's world everyone uses vehicle for transportation and to run heavy machinery fuels are required in MIDC areas. The prices of petrol and diesel are high. There are uncertainties concerning about petroleum and diesel availability. It has been reported that emission of diesel and petrol responsible for global warming and environment pollution. The first engine runs on peanut oil therefore it is not new concept. In ancient days, vegetables oil were more expensive as compared to petrochemicals. Due to its easy availability and cheap cost it was dominant source at that time. But now a days it is having high cost and for its production we have to depend on other countries.

Waste cooking oil is a vegetable oil after consumption which is no longer able to use or consume. Waste cooking oil can be produced from homes, restaurants, hotel and industries etc. Biodiesel can be produced from plant (Seeds) or animal(Fatty Acids).

Biodiesel has become a subject which increasingly attracts worldwide attention because of its environmental benefits. Biodiesel is a good alternative to petroleum diesel and it can be produced in such a manner that it can be directly in present diesel engines without much engine modification. Neat biodiesel (100%) is not directly used in diesel engines as this could lead to performance issues. Usually, biodiesel is blended with petroleum diesel in some proportion for use in automobile engines[1].

## HISTORY

Biofuels is not a new concept as we know that the first engine made by Rudolph Diesel which runs on peanut oil held in World Exhibition in Paris in 1900. At that time the vegetable oil fuels were more expensive than petroleum diesel fuels and in the first starting of $20^{th}$ century there was a great development in the petrochemical industry because of its low cost and easy availability, petroleum became the dominant energy source and petroleum diesel was then developed as the primary fuel for diesel engines. The world energy needs are supplied through petrochemical sources, coal and natural gas, these sources are finite. Biodiesel, derived from vegetable oil or animal fats by transesterification with alcohol like methanol and ethanol.

### Objectives:

1) Preparing biodiesel from waste cooking oil collected.
2) Testing the chemical properties of prepared biodiesel.
3) Comparison between diesel and waste cooking oil.
4) How to Use of waste cooking oil as an alternativefuel for diesel engine.
5) To study Performance and emissions of engine byusing waste cooking oil.

### Advantages of Biodiesel over Petroleum:

- Renewable fuel, obtained from vegetable oils or animal fats
- Low toxicity, in comparison with diesel fuel.
- Oxygenated.
- Biodegradable.
- Lower emissions of contaminants: carbon monoxide, particulate matter, polycyclic aromatic hydrocarbons, aldehydes.
- Lower health risk, due to reduced emissions of carcinogenic substances.
- No sulfur dioxide (SO2) emissions.
- Higher flash point (100_C minimum).

- Environmentally friendly.

## 2. LITERATUREREVIEW

An extensive study is done on production of Biodiesel from WCO and its engine performance & emissions of different types of gases emitted from exhaust.

**Mohamed A. Ismail [1][2020],** In this research paper, they investigates the effects of blending waste cooking oil (WCO) biodiesel with gasoline and kerosene on diesel engine performance, combustion characteristics and emissions compared to fossil diesel. They prepared waste cooking oil biodiesel from transesterification process. They added Kerosene and gasoline additives to biodiesel at ratios of 5 and 10 % by volume. They took Tests on a diesel engine which is running at 1500 rpm with various loads on it. They researched that the decreases in peak cylinder pressures for kerosene blends are 2 and 1.5% for K5 and K10 respectively but for gasoline blends are 3.5 and 3% for G5 and G10, respectively about diesel oil. They concluded that the thermal efficiency at full load for diesel fuel had a value of 18.5% and reduced by 9.0, 7.0, 3.5, and 2.0% for G5, G10, K5, and K10, respectively also the CO emissions values were reduced by 24, 31, 35, 40, and 20% for G5, G10, K5, K10, and WCO biodiesel, respectively. HC emissions were declined by 26, 33, 38, 43, and 21% for G5, G10, K5, K10, and WCO biodiesel, respectively. NOx emissions were increased by 31, 25, 13 and 7.5% when using G5, G10, K5, and K10, respectively about diesel oil. The smoke emissions decreases were 30, 34, 41, and 44% when using G5, G10, K5, and K10, respectively. WCO biodiesel blended with gasoline or kerosene can be considered good alternatives for fuels in diesel engines due to their improvements in performance parameters, combustion chracteristics as well as emissions reduction.

**Hassan Abdulkadhim Abbas[3] [2019],**his team Experimentally simulated study for the effect of waste cooking oil methyl ester blended with diesel fuel on the performance and emissions of diesel engine In this research paper they had been taken methyl ester of waste cooking oil (MEWCO) which is being prepared from used waste cooking oils which collected from different restaurants nearby and they investigated experimentally and theoretically. They mixed the biodiesel with different percentages of 10%, 20% & 100% on a volume basis together with original diesel fuel and tested on a constant speed diesel engine. Their experimental work deals with the impact of the blending ratio on the performance and emission parameters at different load conditions. They experimentally verified with simulation study done by Dieselrk software and concluded that they are in good agreement. They concluded that maximum pressure reduced as a result of increasing MEWCO blends due to the reduction in the heating value of the blended fuels. Both sides are reported promising reduction in nitrogen oxides (NOx) on the behalf of carbon emissions. Mixing 20% MEWCO is the best compromise, mixing ratio and beyond that, dramatic reduction in the outcome of the performance has been observed.

**Gaurav Dwivedi[4]** [2013], his team worked on emission analysis using biodiesel from various oil. . The aim of this research paper is to know review of engine performance and emissions using biodiesel from different feedstock and to compare that with the diesel sources.. They concluded that by using biodiesel which leads in reduction of particulate matters, hydrocarbon and carbon monoxide emission which results in power loss, increase in fuel consumption and increase in NO*x* emission over a conventional diesel engine with not much engine modification.**Prafulla D. Patil[5]**[2012], his team worked on WCO by using Sulfuric Acid & Microwave Irradiation Process.They comparative studied biodiesel production from waste cooking oil using sulfuric acid (Two-step) and microwave- assisted transesterification (One-step) was carried out. A two-step transesterification process was used to produce bio- diesel (alkyl ester) from high free fatty acid (FFA) waste cooking oil. Microwave-assisted catalytic transesterification using BaO and KOH was evaluated for the efficacy of microwave irradiation in biodiesel production from waste cooking oil. On the basis of energy consumptions for waste cooking oil (WCO) transesterification by both conventional heating and microwave-heating methods evaluated in this study.

**Abdul Raqeeb Mohammed[7][2017],**they produced biodiesel from WCO by lab scale catalytic production The adverse effects of fossil fuels on the environment and the rapid exhaustion of oil reserves are major concerns in the current global energy demand scenario. The purification steps, biodiesel properties and engine emissions profile are also discussed.**Nor Hazwani Abdullah[9] [2013]**, his team only produced biodiesel from Waste Cooking Oil (WCO) As we know that the use of recycled waste cooking oil is harmful to health and it is also not environmental friendly to dispose used cooking oil. To overcome this problem the best way is to use it for industrial purposes, especially to reproduce into biodiesel.Waste cooking oil is collected from chip cracker Factory in Johor. In this project they produce biodiesel from waste cooking oil using pilot plant and they tested biodiesel in the laboratory. The biodiesel was blended with diesel oil to get B5 and B10 grade biodiesel.

**Shiv Kumar Sharma[10]** [2017], his team performed evaluation of diesel engine using biodiesel fuel derived from waste cooking refined soyabean oil. According to them, Brazil is a country where people are using biodiesel to run cars or vehicles as an alternative fuel. There is a rapid growth of bio fuels around the world due to energy supply and ecological concerns, and in this market area, there is lot of efforts are need to be made to the growth of bio-fuels. In India, the main purpose of the Bio fuel Policy is to make bio-fuels which readily turn to in the dynamic marketplaces which is used to meet the requirement at a given time. **Timothy Philip Guider[11][2008],**in this research paper they Characterized Engine Performance with Biodiesel Fuels. He particularly focus on investigates the performance of four types of diesel fuels in a 6 HP single-cylinder compression ignition (CI) engine. **Ahmadreza Ansari**[12] [2019],his team performed research onProduction of biodiesel from waste cooking oil using a homogeneous catalyst This study investigated the transesterification of waste cooking oil (WCO) with methanol in the presence of potassium hydroxide as the catalyst.

### ConcludingRemarksfromLiteratureReview

**K.A. Abed[2]** in 2018, took only three blends of biodiesel from waste cooking oil with diesel such as B10, B20, & B30. In this project we took different types of blends of biodiesel from waste cooking oil mix with diesel such as B5, B10, B15& B20. Because of this we can view in detail about on which blend engine performance can increase or decrease. **Sunday O[6]** in 2019 reviwed experimentally investigated diesel fuel blends and performance on diesel engine, but they did not said anything about engine emissions. In this project we are going to calculate emission on engine also**. Majid Mohadesi [8]**in 2019 reviewed that they can produce biodiesel from waste cooking oil by using homogeneous catalyst such as KOH as a catalyst, KOH has high titration oils than NaOH. High titration oils leading in the formation of lot of soaps, which results that we can process much higher titration oils with KOH than we can do with NaOH. NaOH is a lighter molecule than KOH. NaOH have the better yield property compared with KOH. NaOH catalysts give 71.2% of biodiesel yield whereas only 68.9% of biodiesel yield obtained using KOH as catalyst. Other advantages of NaOH are that it is easily and readily available in the market and it is cheap as compared to KOH.

As from literature review it is cleared that there is not much research or study done on simultaneous engine performance and engine emission from WCO. WCO is used due to its advantages such as it is considered as a homogeneous mixture when blended with diesel.The main advantages of vegetable oils such as they are less volatile, more viscous compared to pure diesel and having poor atomization quality which results in larger droplets. The burning rate of these droplets is slow because of the shorter ignition delay. As sulphur content is responsible for acidic rain, biodiesel having zero sulphur dioxide emissions, low toxicity ,highly oxygenated, biodegradable, environment friendly-lower health risk due to reduced emissions of carcinogenic substances and it has low emissions as compared with petrochemical diesel**.**

## 3. PROBLEM STATEMENT

Waste cooking oil does not dispose and harmful to environment. They lead to soil pollution, water pollution, air pollution and many more. Also if we do not used this oil there is wastage of money and now a days the fuel resources are limited and can finished very soon. There is many methods of disposing the waste oil, but the many are spending on it is neither contributing to welfare of society and also total disposing requires many time. Therefore there is wastage of time and also money.Generally the waste oil from restaurants, homes and other places are directly thrown into the environment which leads to pollution which is the major issue which a society is facing now a day.The Major cost of producing biodiesel is of its raw material. for making the production of Biodiesel more economical waste oil can be used [4].Therefore aim of this project is to know how to use waste cooking oil as an alternative fuel to diesel engine.

### Economic aspects of biodiesels

Economic aspect of biodiesel depends on the availability of low-cost feed stocks. The major barrier for producing biodiesel in large scale applications is of its cost of feedstock oils as compared to diesel fuel from both edible and non edible oils are limited. In general approximately 70-80% of biodiesel production cost is related with the cost of raw materials. This problem can be compensated by using waste cooking oil as a raw material for the production of biodiesel so it can be reduced major cost of biodiesel. Similarly cost of catalyst also play important role in the biodiesel production cost. Different research is done to use low cost catalyst for the preparation of suitable production of biodiesel. As we are producing biodiesel from waste cooking oil due to its disadvantages such as it is harmful to environment and it is having disposal issues which leads to different types of pollution and wastage of money and time for disposal. The best way to use waste cooking in the production of biodiesel [3].

**Table 1: Comparison with other Biodiesels**

| Sr. No. | Properties | WCO | Biodiesel | Jatropha | Diesel |
|---|---|---|---|---|---|
| 1 | Density(kg/m$^3$) | 880.6 | 878.5 | 860 | 876.9 |
| 2 | Viscosity(mm$^2$/sec) @ 40$^o$c | 4.75 | 4.27 | 4.08 | 4.16 |
| 3 | Flash Point ($^o$c) | 161.7 | 168.5 | 160.5 | 156.5 |
| 4 | Cetane Number | 56.2 | 59.6 | 58.2 | 57.2 |
| 5 | Calorific Value(MJ/kg) | 37.880 | 40.1 | 40.22 | 40.49 |

## 4. Experimental work:

### General procedure to purify the oil:

- Collection of used cooking oil from restaurant
- Separation of heaver impurities
- Heating the oil at 95ºF temperature
- Filtering the heated oil

**Figure1: Separation of Heavier Impurities**

**Figure 2: Heating of Oil**

**Figure 3: Filtering of oil by coffee filter**

### Transesterification Process:

Transesterification is most commonly used for the production of biodiesel from waste cooking oil. In transesterification process an ester compound is exchanged by an alcohol in the alkyl group. In this reaction, the triglyceride component of oil reacts with the alcohol in the presence of NaOH or any other catalyst to give ester and glycerol as shown below. Biodiesel is nothing but the fatty acid methyl esters (FAME) derived from the Transesterification of triglycerides (vegetable oils or animal fats) with alcohol and suitable catalyst.

After this process biodiesel is mixed with different percentage of diesel so that it can run in diesel engine without any engine issues as neat biodiesel has some engine issues and not much modification in the diesel ngine.

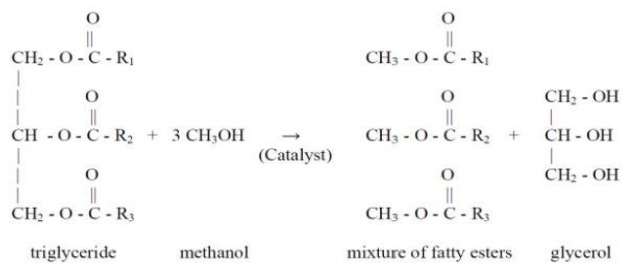



**Figure 4: Transesterification Process**

Biodiesel is obtained from different types of triglyceride sources such as vegetable oils (e.g. edible oil, non-edible or waste oils), animal fats (e.g. mostly edible fats or waste fats). The crops identified for biodiesel are corn, sunflower, palm, olive, canola, soybean and peanut soils, and animal-based lipid (e.g. butter).Waste animal fat is also is identified to be a good feedstock for biodiesel. Alcohol such as methanol, ethanol and isopropyl alcohol can be used in transesterification process for production of biodiesel. In most of the cases methanol is used because of better efficiency and also methanol is less sensitive to water in the alkali procedure as compared to ethanol. Ethanol is used for animal fats It has been reported that, transesterification process depends upon different types of parameters such as reaction temperature and pressure, reaction time, rate of agitation, type of alcohol used and molar ratio of alcohol to oil, type and concentration of catalyst used and concentration of moisture and FFA in the feed oil. The optimal values of these parameters effectively affects on the physical and chemical properties of the feedstock oil [5].

### Procedure for Transesterification Process:

1) Test the acidity of oil
2) Dissolve 0.1% of lye (NaoH) into distilled water
3) Addition of methanol into reheated and filtered oil(10ml methanol + 1ml filtered oil )
4) Add 2 or 3 phenolphthalein droplets into the mixture to check acidity or basicity
5) Add 0.1% lye solution to oil and alcohol mixture
6) Separate the biodiesel from glycerol byproduct
7) Wash biodiesel with water to remove the impurities
8) Prepare the different types of blends

### Preparation of blends:

Biodiesel is a domestically produced, renewable fuel that can be manufactured from new and used vegetable oils, animal fats, and recycled restaurant grease. Biodiesel's physical properties are similar to those of petroleum diesel, but the fuel significantly reduces greenhouse gas emissions and toxic air pollutants. It is a biodegradable and cleaner-burning alternative to petroleum diesel. Biodiesel can be blended and used in many different concentrations. They include B100 (pure biodiesel), B20 (20% biodiesel, 80% petroleum diesel), B5 (5% biodiesel, 95% petroleum diesel), and B2 (2% biodiesel, 98% petroleum diesel). The most common biodiesel blend is B20, which qualifies for fleet compliance under the Energy Policy Act (EPAct) of1992.

**B5**: B5 is a low level biodiesel blend consisting of 5% biodiesel & 95% petroleum diesel.

**B10**: B10 is a biodiesel blend consisting of 10% biodiesel & 90% petroleum diesel.

**B15**: B15 is a biodiesel blend consisting of 15% biodiesel & 85% petroleum diesel.

**B20**: B20 is a biodiesel blend consisting of 20% biodiesel & 80% petroleum diesel.


Figure 5: 5% Blend


Figure 6: 10% Blend


**Figure 7: 15% Blend**


**Figure 8: 20% Blend**

### Engine setup and its specification

The experimental setup consists of single cylinder four stroke diesel engines. The pressure sensor is mounted on cylinder head which is exposed to combustion chamber for measurement of in-cylinder combustion pressure with respect to crank angle. The crank angle encoder was mounted on crank shaft to measure the crank angle. The eddy current dynamometer was used for loading the engine. The data acquisition system was used for acquiring the pressure-crank angle data and for further analysis. The engine speed (1500 rpm) and static injection timing were maintained as constant throughout tests.


**Figure 9: Engine setup used for experimentation**

**Table 2: Engine specifications**

| | |
|---|---|
| No. of cylinders | 1 |
| No. of strokes | 4 |
| Fuel | Diesel |
| Rated power | 3.5 KW @ 1500 RPM |
| Cylinder diameter | 87.5mm |
| Stroke length | 110mm |
| Connecting rod length | 234mm |
| Compression ratio very | 12:1 to 18:1 |
| Orifice diameter | 20mm |
| Dynamometer arm length | 185mm |

## Properties of oil:

By using bomb calorimeter, redwood viscometer, hydrometer, flash point etc we calculated the following parameters which are shown in table

**Table 3 : Properties of Oil**

| Fuel Property | Waste Vegetable Oil | Biodiesel from Waste Vegetable Oil | Commercial Diesel Fuel |
|---|---|---|---|
| Kinematic Viscosity(mm^2/s at 313K) | 36.4 | 5.3 | 1.9-4.1 |
| Density(Kg/L at 288K) | 0.924 | 0.897 | 0.075-0.840 |
| Flash Point(K) | 485 | 469 | 340-358 |
| Pour Point(K) | 284 | 262 | 254-260 |
| Cetane Number | 49 | 54 | 40-46 |
| Ash Content (%) | 0.006 | 0.004 | 0.008-0.010 |

## 5. Mechanical testing of experimentally formed biodiesel:

As discussed earlier we have used CI engine setup as shown in fig .Now firstly we have taken trails for commercially available diesel. During this process engine speed is constant at 1500 Rpm and load on engine varies by means of pulley arrangement form 3 Kg to 12 Kg as shown in table given below. Now time required for consuming 10 CC of oil is taken by means of stopwatch which used for calculating specific fuel consumption

### (a) observation taken for commercial diesel :

**Table 4: Readings for diesel**

| Sr No | Net Load | | Speed | Time to drop 10cc fuel |
|---|---|---|---|---|
| | W | S | | |
| 1 | 3 | 0.5 | 1500 | 83.15 |
| 2 | 6 | 0.5 | 1500 | 52.83 |
| 3 | 9 | 0.75 | 1500 | 47.80 |
| 4 | 12 | 1.25 | 1500 | 34.94 |

Form the observation table it is cleared that as the load on engine increases time required to consume 10CC of oil decreases that is as load increases mass fuel consumption also increases.

### (b) Observation taken for 5% BLEND:

Now we have taken trails for 5% blend. During this process engine speed is constant at 1500 Rpm and load on engine varies by means of pulley arrangement form 3 Kg to 12 Kg as shown in table give bellow. Now time required for consuming 10 CC of oil is taken by means of stop watch which used for calculating specific fuel consumption.

**Table 5 : Readings for 5% Blend**

| Sr No | Net Load | | Speed | Time to drop 10cc fuel |
|---|---|---|---|---|
| | W | S | | |
| 1 | 3 | 0.5 | 1500 | 69.36 |
| 2 | 6 | 0.5 | 1500 | 57.32 |
| 3 | 9 | 0.8 | 1500 | 38.37 |
| 4 | 12 | 1.25 | 1500 | 37.38 |

Form the observation table it is cleared that as the load on engine increases time required to consume 10CC of oil decreases that is as load increases mass fuel consumption also increases.

### (c) Observation taken for 10% BLEND:

Now we have taken trails for 10% blend. During this process engine speed is constant at 1500 Rpm and load on engine varies by means of pulley arrangement form 3 Kg to 12 Kg as shown in table give bellow. Now time required for consuming 10 CC of oil is taken by means of stop watch which used for calculating specific fuel consumption.

Form the observation table it is cleared that as the load on engine increases time required to consume 10CC of oil decreases that is as load increases mass fuel consumption also increases.

**Table 6: Readings for 10% Blend**

| Sr No | Net Load | | Speed | Time to drop 10cc fuel |
|---|---|---|---|---|
| | W | S | | |
| 1 | 3 | 0.5 | 1500 | 70.52 |
| 2 | 6 | 0.5 | 1500 | 61.03 |
| 3 | 9 | 1.25 | 1500 | 50.87 |
| 4 | 12 | 1.75 | 1500 | 34.35 |

### (d) Observation taken for 15% BLEND:

Now we have taken trails for 15% blend. During this process engine speed is constant at 1500 Rpm and load on engine varies by means of pulley arrangement form 3 Kg to 12 Kg as shown in table give bellow. Now time required for consuming 10 CC of oil is taken by means of stop watch which used for calculating specific fuel consumption.

**Table 7 : Readings for 15% Blend**

| Sr No | Net Load | | Speed | Time to drop 10cc fuel |
|---|---|---|---|---|
| | W | S | | |
| 1 | 3 | 0.5 | 1500 | 62.29 |
| 2 | 6 | 0.5 | 1500 | 60.33 |
| 3 | 9 | 1.5 | 1500 | 55.54 |
| 4 | 12 | 2 | 1500 | 42.32 |

Form the observation table it is cleared that as the load on engine increases time required to consume 10CC of oil decreases that is as load increases mass fuel consumption also increases.

### (e) Observation taken for 20% BLEND:

Now we have taken trails for 20% blend. During this process engine speed is constant at 1500 Rpm and load on engine varies by means of pulley arrangement form 3 Kg to 12 Kg as shown in table give bellow. Now time required for consuming 10 CC of oil is taken by means of stop watch which used for calculating specific fuel consumption.

**Table 8: Readings for 20% Blend**

| Sr No | Net Load | | Speed | Time to drop 10cc fuel |
|---|---|---|---|---|
| | W | S | | |
| 1 | 3 | 0.5 | 1500 | 69.15 |
| 2 | 6 | 0.5 | 1500 | 66.51 |
| 3 | 9 | 0.75 | 1500 | 49.71 |
| 4 | 12 | 1.25 | 1500 | 42.29 |

Form the observation table it is cleared that as the load on engine increases time required to consume 10CC of oil decreases that is as load increases mass fuel consumption also increases.

## 6. Result and Disscussion

### (a) Test results obtained For commercial diesel

From our experimental analysis we have calculated brake power in kilowatts, specific fuel consumption in Kg/hr ,brake specific fuel consumption and brake thermal efficiency for various loads ranging from 3kg to 12kg firstly on commercial diesel.

**Table 9: Result for diesel.**

| Sr No | Load (Kg) | BP (KW) | $m_f$ (Kg/hr) | BSFC (Kg/KWhr) | $\eta$bth (%) |
|---|---|---|---|---|---|
| 1 | 3 | 0.654 | 0.36 | 0.55 | 15.22 |
| 2 | 6 | 1.4407 | 0.654 | 0.454 | 21.87 |
| 3 | 9 | 2.161 | 0.621 | 0.287 | 29.16 |
| 4 | 12 | 2.816 | 0.828 | 0.294 | 28.49 |
| 5 | Avg. | 1.76 | 0.473 | 0.2687 | 31.11 |

From the above table it is cleared that as the load on engine increase

- Brake power increase as BP is directly proportional to torque generated by the engine at higher load more torque is required thus BP increase.
- Specific fuel consumption also increase as it is directly proportional to brake power.
- However brake specific fuel consumption decreases because increase in brake power percentage is higher than the increase in fuel consumption.
- Brake thermal efficiency increase as increase in percentage of brake power is higher than that of increase in fuel consumption.

### (b) Test results obtained For 5%BLEND:

From our experimental analysis we have calculated brake power in kilowatts, specific fuel consumption in Kg/hr ,brake specific fuel consumption and brake thermal efficiency for various loads ranging from 3kg to 12kg firstly on 5% blended fuel, it is clearly noted that the variations in parameter is approximately same as the amount of bio diesel present is only 5%.

**Table 10: Result for 5% Blend**

| Sr No | Load (Kg) | BP (KW) | $m_f$ (Kg/hr) | BSFC (Kg/KWhr) | ηbth (%) |
|---|---|---|---|---|---|
| 1 | 3 | 0.648 | 0.44 | 0.672 | 12.36 |
| 2 | 6 | 1.423 | 0.515 | 0.35 | 23.45 |
| 3 | 9 | 2.14 | 0.786 | 0.36 | 22.8 |
| 4 | 12 | 2.785 | 0.83 | 0.294 | 22.13 |
| 5 | Avg. | 1.76 | 0.60 | 0.34 | 24.69 |

From the above table it is cleared that as the load on engine increase

- Brake power increase as BP is directly proportional to torque generated by the engine at higher load more torque is required thus BP increase.
- Specific fuel consumption also increase as it is directly proportional to brake power.
- However brake specific fuel consumption decreases because increase in brake power percentage is higher than the increase in fuel consumption.
- Brake thermal efficiency increase as increase in percentage of brake power is higher than that of increase in fuel consumption.

### (c) Test results obtained for 10%BLEND:

From our experimental analysis we have calculated brake power in kilowatts, specific fuel consumption in Kg/hr, brake specific fuel consumption and brake thermal efficiency for various loads ranging from 3kg to 12kg firstly on 10% blend.

**Table 11: Result for 10% Blend**

| Sr No | Load (Kg) | BP (KW) | $m_f$ (Kg/hr) | BSFC (Kg/KW hr) | ηbth (%) |
|---|---|---|---|---|---|
| 1 | 3 | 0.605 | 0.427 | 0.653 | 12.8 |
| 2 | 6 | 1.405 | 0.499 | 0.346 | 24.2 |
| 3 | 9 | 2.030 | 0.599 | 0.295 | 28.4 |
| 4 | 12 | 2.685 | 0.880 | 0.328 | 25.6 |
| 5 | Avg. | 1.702 | 0.559 | 0.328 | 25.58 |

From the above table it is cleared that as the load on engine increase

- Brake power increase as BP is directly proportional to torque generated by the engine at higher load more torque is required thus BP increase.
- Specific fuel consumption also increase as it is directly proportional to brake power.
- However brake specific fuel consumption decreases because increase in brake power percentage is higher than the increase in fuel consumption.
- Brake thermal efficiency increase as increase in percentage of brake power is higher than that of increase in fuel consumption.

### (d)Test results obtained for 15%BLEND:

From our experimental analysis we have calculated brake power in kilowatts, specific fuel consumption in Kg/hr, brake specific fuel consumption and brake thermal efficiency for various loads ranging from 3kg to 12kg firstly on 15% blend.

**Table 12 Result for 15% Blend**

| Sr No | Load (Kg) | BP (KW) | $m_f$ (Kg/hr) | BSFC (Kg/KWhr) | ηbth (%) |
|---|---|---|---|---|---|
| 1 | 3 | 0.601 | 0.483 | 0.7455 | 11.26 |
| 2 | 6 | 1.214 | 0.49 | 0.342 | 24.48 |
| 3 | 9 | 1.963 | 0.547 | 0.28 | 28.95 |
| 4 | 12 | 2.618 | 0.748 | 0.2865 | 30.25 |
| 5 | Avg. | 1.635 | 0.557 | 0.34 | 24.53 |

From the above table it is cleared that as the load on engine increase

- Brake power increase as BP is directly proportional to torque generated by the engine at higher load more torque is required thus BP increase.
- Specific fuel consumption also increase as it is directly proportional to brake power.
- However brake specific fuel consumption decreases because increase in brake power percentage is higher than the increase in fuel consumption.
- Brake thermal efficiency increase as increase in percentage of brake power is higher than that of increase in fuel consumption

### (e) Test results obtained for 20%BLEND:

From our experimental analysis we have calculated brake power in kilowatts, specific fuel consumption in Kg/hr, brake specific fuel consumption and brake thermal efficiency for various loads ranging from 3kg to 12kg firstly on 20% blended fuel

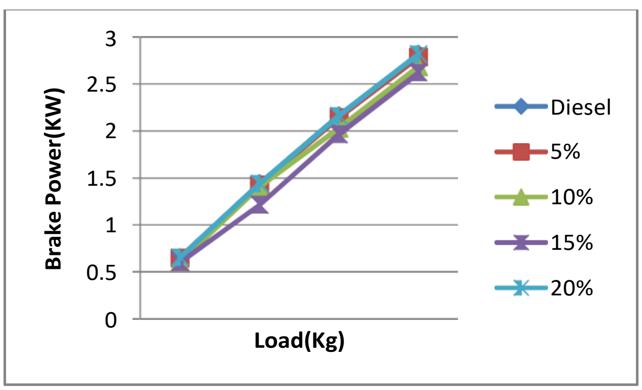
**Table 13 Result for 20% Blend**

| Sr No | Load (Kg) | BP (KW) | $m_f$ (Kg/hr) | BSFC (Kg/KW hr) | ηbth (%) |
|---|---|---|---|---|---|
| 1 | 3 | 0.654 | 0.439 | 0.671 | 12.49 |
| 2 | 6 | 1.440 | 0.459 | 0.318 | 26.43 |
| 3 | 9 | 2.161 | 0.618 | 0.285 | 29.32 |
| 4 | 12 | 2.816 | 0.721 | 0.256 | 32.75 |
| 5 | Avg. | 1.768 | 0.536 | 0.190 | 27.65 |

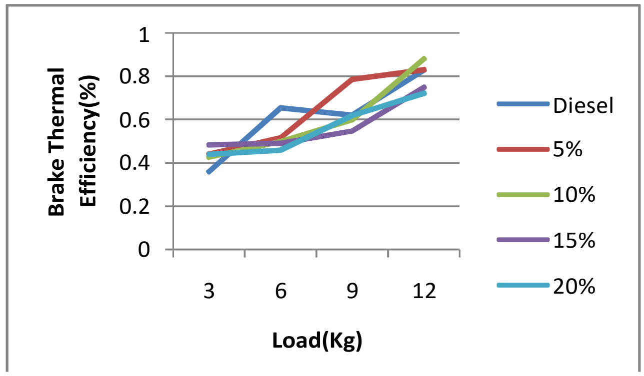
From the above table it is cleared that as the load on engine increase

- Brake power increase as BP is directly proportional to torque generated by the engine at higher load more torque is required thus BP increase.
- Specific fuel consumption also increase as it is directly proportional to brake power.
- However brake specific fuel consumption decreases because increase in brake power percentage is higher than the increase in fuel consumption.
- Brake thermal efficiency increase as increase in percentage of brake power is higher than that of increase in fuel consumption.

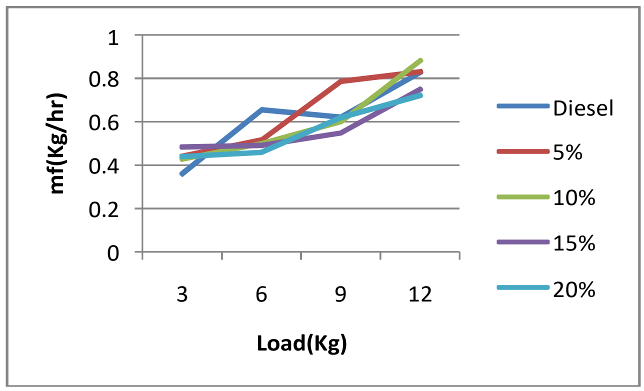
**Graphical Representation:**




**Graph No1: Load VS Brake Power**




Graph No2: Load VS Brake thermal Efficiency




**Graph No3: Load VS Mf**

## 7. Emissions

In automobile, engine emits different types of gases from exhaust after its combustion in engine. This gases is the byproduct of combustion of fuel in the engine. Biodiesel has some great benefits over petroleum diesel, such as it produces 4.5 units of energy against every unit of fossil energy and also it has some environment-friendly properties such as it is non-toxic, biodegradable and safer to breathe. Biodiesel is also a clean-burning and stable fuel .These gases are mainly such as hydrocarbons, carbon monoxide, carbon dioxide, nitrous oxides, sulphur content etc, which results in the air pollution of environment. These emissions can harm the environment.

Engine performance and emissions depend on the properties of biodiesels. Biodiesel is a highly oxygenated fuel that can improve combustion efficiency and can reduce unburnt hydrocarbons (HCs), carbon dioxide ($CO_2$), carbon monoxide (CO), sulphur dioxides ($SO_2$), nitric oxide ($NO_x$) and polycyclic aromatic HC emissions

**Emissions of diesel and biodiesel:**

**Table 14: Emissions of Diesel & Biodiesel**

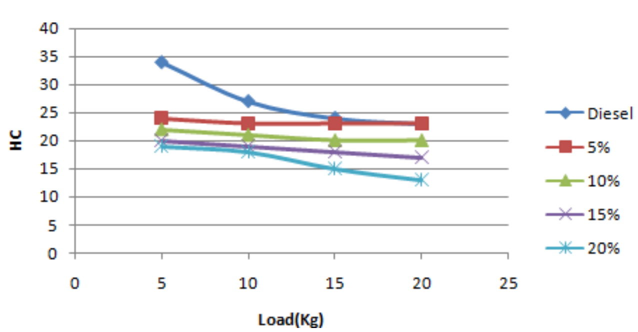
| Emission content | Diesel | Biodiesel |
|---|---|---|
| HC ppm | 11 | 9 |
| O2(%) | 18.64 | 18.75 |
| CO2(%) | 1.42 | 1.35 |
| CO(%) | 0.021 | 0.015 |
| NOx ppm | 278 | 217 |
| Cylinder tempt.(F) | 135 | 135 |

Above table we concluded that biodiesel has less emission as compared to diesel. The main advantage From of biodiesel is that it has zero sulphur content in the emissions whereas diesel has some percentage of sulphur emissions. Biodiesel can reduce $CO_2$ emissions by 15%,

**Load vs HC (ppm):**

**Table 15: load vs Hc (ppm)**

| Load(kg) | Diesel | 5% | 10% | 15% | 20% |
|---|---|---|---|---|---|
| 5 | 34 | 24 | 22 | 20 | 19 |
| 10 | 27 | 23 | 21 | 19 | 18 |
| 15 | 24 | 23 | 20 | 18 | 15 |
| 20 | 23 | 23 | 20 | 17 | 13 |



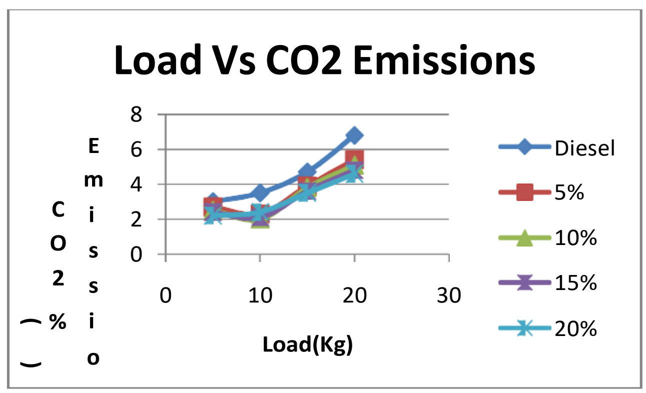

**Graph No4: Load VS HC**

The above table and graph shows the load verses hydrocarbon emissions. Diesel has high emissions as compared to biodiesels. For the different blends of biodiesel, as percentage of biodiesel increases in the mixtures the reduction in hydrocarbons takes place. For 5% blend it have less emissions than that of diesel, similarly as percentage of biodiesel increases HC goes on decreasing, For 10% it has less emissions as compared to 5% and so on. The results prove that the higher percentage of biodiesel in the blends provides lower hydrocarbon emissions.

**Load vs CO2 Emission**

**Table 16 Load vs CO2 Emission**

| Load(kg) | Diesel | 5% | 10% | 15% | 20% |
|---|---|---|---|---|---|
| 5 | 3 | 2.7 | 2.7 | 2.4 | 2.2 |
| 10 | 3.5 | 2.3 | 2.3 | 2.1 | 2.4 |
| 15 | 4.7 | 3.9 | 3.9 | 3.6 | 3.5 |
| 20 | 6.8 | 5.4 | 5.4 | 4.8 | 4.6 |



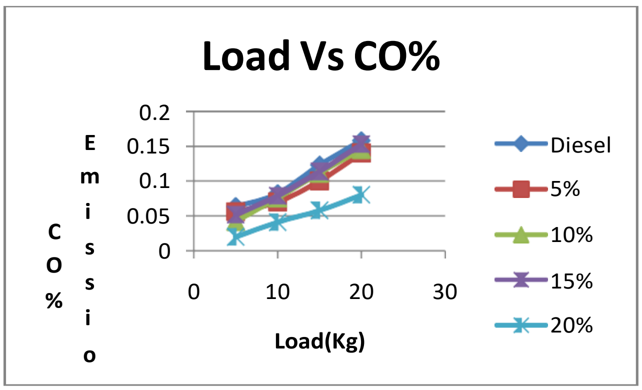

**Graph No 5: Load vs CO2 Emission**

The above table and graph shows the load verses carbon dioxide emissions. Diesel has higher emissions as compared to biodiesels. For the different blends of biodiesel, as percentage of biodiesel increases in the mixtures the reduction in carbon dioxide takes place. For 5% blend it have less $CO_2$ emissions than that of diesel, similarly as percentage of biodiesel increases $CO_2$ goes on decreasing, For 10% it has less emissions as compared to 5% and so on. The engine load increased, $CO_2$ emission increased due to higher fuel consumption associated with load increase. Over $CO_2$ emissions noticed for all examine biodiesel blends as compared to diesel oil. Reduction in $CO_2$ the mission was explained in terms of higher oxygen content in biodiesel blends as compared to diesel oil. The increase in $CO_2$ emission was due to higher oxygen content in waste cooking oil biodiesel blends compared to diesel oil

**Load vs CO%:**

Table 17: **Load vs CO%:**

| Load(kg) | Diesel | 5% | 10% | 15% | 20% |
|---|---|---|---|---|---|
| 5 | 0.063 | 0.056 | 0.042 | 0.051 | 0.019 |
| 10 | 0.082 | 0.07 | 0.076 | 0.079 | 0.041 |
| 15 | 0.123 | 0.1 | 0.111 | 0.113 | 0.058 |
| 20 | 0.158 | 0.140 | 0.145 | 0.152 | 0.08 |



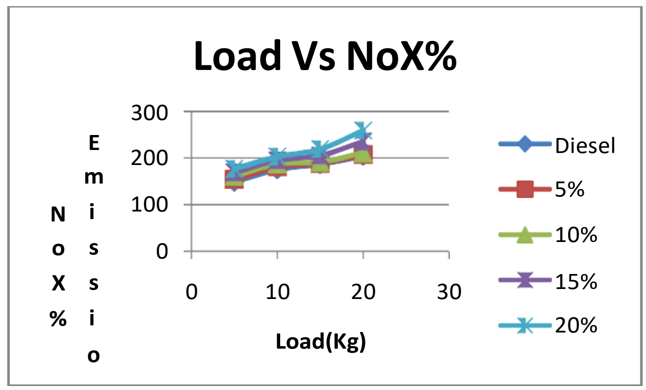

**Graph No 6; Load vs CO%:**

The above table and graph shows the load verses carbon monoxide emissions. Diesel has high emissions as compared to biodiesels. For the different blends of biodiesel, as percentage of biodiesel increases in the mixtures the reduction in carbon monoxide takes place. For 5% blend it have less CO emissions than that of diesel, similarly as percentage of biodiesel increases CO goes on decreasing, For 10% it has less emissions as compared to 5% and so on. As load goes on increasing the percentage of CO emission goes on increasing. For all tested fuels, it was observed that CO emission decreased with the increase of engine load at part load then it returned to increase up at full load. This was due to increase of fuel consumption which led to rich air fuel mixture. Comparing with "pure diesel fuel", a significant reduction in CO emission throughout the engine load range had been observed when biodiesel and its blends were used. This was due to more oxygen content in biodiesel than diesel fuel that gave more complete combustion.

## Load vs NOx%:

**Table 18: Load vs NOx%:**

| Load(kg) | Diesel | 5% | 10% | 15% | 20% |
|---|---|---|---|---|---|
| 5 | 148 | 154 | 161 | 169 | 177 |
| 10 | 175 | 181 | 187 | 195 | 203 |
| 15 | 186 | 188 | 191 | 205 | 219 |
| 20 | 204 | 207 | 211 | 235 | 259 |




**Graph No 7; Load vs NoX%:**

The above table and graph shows the load verses NOx%. Diesel has lower emissions as compared to biodiesels. For the different blends of biodiesel, as percentage of biodiesel increases in the mixtures the increase in NOx takes place. For 5% blend it have high emissions than that of diesel, similarly as percentage of biodiesel increases Nox goes on increasing, For 10% it has high emissions as compared to 5% and so on. The results prove that the higher percentage of biodiesel in the blends provides higher NOx emissions. NOx emissions for all biodiesel blends were higher than diesel oil. The increase of NOx emission with increase of engine load resulted from higher cylinder combustion temperature and higher adiabatic flame temperatures. The formation of NOx was favored by higher cylinder combustion temperature and availability of oxygen. The combustion of biodiesel produced more NOx compared to diesel oil.

## Conclusions

In this way we have made biodiesel from waste cooking oil (Palm oil) and also carried out various load testing on a single cylinder diesel engine. We plotted various graphs from test reading and we concluded that the performance of engine of our biodiesel has better performance between blending of 10-15% as compared to diesel.

The Biodiesel Blend of B10 gives the lowest emission when compared to other blends even though performance is slightly lower than the diesel.

## References:

1- Prafulla D. Patil, Veera Gnaneswar Gude, Harvind K. Reddy,"Biodiesel Production from Waste Cooking Oil Using Sulfuric Acid and Microwave Irradiation Processes"buplish at Journal of Environmental Protection, 2012.
2- Mohammed Abdul Raqeeb and Bhargavi R,paper name Biodiesel production from waste cooking oil, publish at general of chemical and pharmaceutical reaserch,2013.
3- Timothy Philip Guider, "Characterization of Engine Performance with Biodiesel Fuels", Publish at Lehigh University December 2008.
4- Nor Hazwani Abdullah, Sulaiman Haji Hasan, and Nurrul Rahmah Mohd Yusoff, Biodiesel Production Based on Waste Cooking Oil (WCO), publish at International Journal of Materials Science and Engineering Vol. 1, No. 2 December 2013.
5- Gaurav Dwivedi,Siddharth Jain,M.P. Sharma, "Diesel engine performance and emission analysis using biodiesel from various oil sources", publish at J.M.E.S 22 Sept 2012.
6- D.A.G. Aranda, R.T.P.Santos, N.C.O.Tapanes, A.L.D. Ramos, O.A.C. Antunes, 2008, Acid- Catalyzed Homogeneous Etherification Reaction for Biodiesel Production from Palm Fatty Acids, aug 2008.
7- Kocak MS, Ileri E, Utlu Z. Experimental study of emission parameters of biodiesel fuels obtained from Canola, Hazelnut, and waste cooking oils. Energy Fuels 2007;21:3622–6.
8- Zheng Y, Kates MM, Dube A, McLean DD. Acid-catalyzed production of biodiesel from waste cooking oil. Biomass Bioenergy 2006;30:267–72.
9- Shimada Y, Watanabe Y, Sugihara A, Tominaga Y. Enzymatic alcoholysis for biodiesel fuel production and application of the reaction to oil processing. J Mol Catal – B Enzym 2002;17:133–42
10- Sahin Z, Durgun O, Bayram C, Experimental investigation of gasoline fumigation in a single cylinder direct injection (DI) diesel engine, Energy 2008; 33: 1298-1310.
11- F. Ma, L. D. Clements and M. A. Hanna, "The Effects of Catalysts, Free Fatty Acids, and Water on *American Society of Agricultural and Engineers*, Vol. 41, No. 5, 1998, pp. 1261-1264.
12- M. Canakci and J. Van Gerpen, "Biodiesel Production via Acid Catalysis," *Transactions of American Society of Ag-ricultural and Engineers*, Vol. 42, No. 5, 1999, pp. 1203- 1210.
13- I. Roy and M. N. Gupta, "Applications of Microwaves in Biological Sciences," *Current Science*, Vol. 85, No. 12, 2003, pp. 1685-1693.
14- M. Canakci and J. Van Gerpen, "Biodiesel Production from Oils and Fats with High Free Fatty Acids," *American Society of Agricultural and Engineers*, Vol. 44, No. 6, 2001, pp. 1429-1436.
15- Enweremadu CC, Rutto HI, Combustion, emission and engine performance characteristics of used cooking oil biodiesel -A review, Renewable and Sustainable Energy Reviews 2010; 14: 2863-2873.
16- Hawi M, Elwardany A, Ismail M, and Ahmed M, Experimental Investigation on Performance of a Compression Ignition Engine Fueled with Waste Cooking Oil Biodiesel–Diesel Blend Enhanced with Iron-Doped Cerium Oxide Nanoparticles, Energies 2019; 12: 798.
17- Tanikawa N, Imai T, Urano K. Characteristics of continuous analyzers for nitrous oxide (N2O) in flue gas from municipal incinerators. Sci Total Environ 1995;175:199–205.
18- Sher E. Environmental aspects of air pollution. In: Sher E, editor. Handbook of air pollution from internal combustion engines—pollutant formation and control. London, UK: Academic Press; 1998. p. 27–41.
19- Dorado MP, Ballesteros E, Arnal JM, Gomez J, Lopez FJ. Exhaust emissions from a diesel engine fueled with transesterified waste olive oil. Fuel 2003;82:1311–5.
20- Graboski MS, McCormick R. Combustion of fat and vegetable oil derived fuels in diesel engines. Progr Energy Combust Sci 1998;24:
21- Alcantara R, Amores J, Canoira L, Fidalgo E, Franco MJ, Navarro A. Catalytic production of biodiesel from soybean oil, used frying oil and tallow. Biomass Bioenergy2000;18:515–2