# Performance Study of Diesel Engine by using Thumba oil (Citrullus Colocynths) Biodiesel and Its Blends with Diesel Fuel and results

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**Abstract-** The performance results of the biodiesel made by non edible vegetable oil Thumba (Citrullus Colocynths) and its blends with diesel fuel have been represented in this paper. The experiment has been performed on CI engine (Power 3.5 k-Watt Kirlosker 4-stroke single cylinder). The trial were conducted on the engine set up using two different blends of Thumba methyl ester oil with diesel at ratio of 20% and 40% by volume. The parameters of the engine performance studied in this paper were power and mechanical efficiency ($\eta_{m)}$, mean effective pressure (MEF) and torque (T), specific output, volumetric efficiency ($\eta_v$), fuel-air ratio, specific fuel consumption, thermal efficiency, specific weight and exhaust gas temperature (EGT). The performance of engine with biodiesel B20 (20% Thumba oil and 80% diesel) and B40 (40% Thumba oil and 60% diesel) performed in the range of compression ratio within 15 and 18. At rated load of 3.15 kW, B40 i s having the efficiency29.87% as compared to diesel29.49%. Much lesser emissions produced by Thumba oil biodiesel blends as compared to pure diesel fuel in this performance. The Thumba oil as biodiesel has a great possibility to replace fossils diesel fuel at an optimum level. Thumba may be the best alternate fuel for future in India.
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**Keywords:** Vegetable oil fuel, Thumba (Citrullus Colocynths), diesel blend, India

## 1. INTRODUCTION

India with 1.27 billion people is the second largest populous country in the world. According to figure India represents almost 17.31% of the world's population; it means one out of six people on this planet lives in India. India will be the most populous country of the world by 2030 with the population growth rate at 1.58%. In last two decades[1], Indian economy developed rapidly reducing the percentage of the population living below the poverty line from 35% in year 1994 to 29% in the late year 2010[2]. In India about 70% energy generation is from fossils fuel, with coal having 40% of India's total energy consumption and remaining by crude oil and natural gas with 24% and 6% respectively India is mostly reliant on fossils fuels imports to assure its energy demands[3].

India will be the third largest consumer of transportation fuel by 2020 after USA and China. In year 2009-10 India imported 159.26 million tons of crude oil. About 90% of the total imported oil is consumed in transportation [4]. There are limited reserves of the fossils fuels. These reserves are limited and also available in certain India is mostly reliant on fossils fuels imports to assure its energy demands. India will be the third largest consumer of transportation fuel by 2020 after USA and China[5]. Bio-fuel, Biomass energy is a type of alternative fuels for the future purpose which can full fill the demand of the fuel requirement at extent level. Biodiesel is the one of the most common bio-fuel energy option which is produce through transesterfication of non-petroleum based oil [6]. It can be used in unmodified diesel engines with conventional petro or diesel or also partially. Production of biodiesel represents a way to attain economical growth by increasing and securing energy supply for the developing countries and it can also create job opportunities and an attractive source for the farmers.

Biodiesel is very resourceful and appropriate alternate fuels for fossils fuels like diesel and petroleum. Biodiesel can be used with blend with diesel as well as separately in CI engine and having very low emissions [7] and same power. Its main advantages are its high energy yield and its drastically reduced emissions of carbon dioxide (78%); sulfur (100%); carbon monoxide (48%); which form harmful ozone (85%) – resulting in a reduction of 94% in cancer causing potential [8].

In Indian context the biodiesel produced by edible vegetable oils may not be the promising as alternate fuel for diesel because of the deficient production of vegetable oil corps in India. Therefore the concentration has been particulate matter (47%); and hydrocarbon emissions, diverted towards non edible vegetable oil sources for diesel engine [9]. In India there is a plenty of forests and trees available as non edible vegetable oil sources for biodiesel. Table [10] shows the production of non edible vegetable oil plant in India with oil percentage.

Table 1 shows the biodiesel from different seed

| S. No. | Type | Production (MT) | Oil % |
|---|---|---|---|
| 1 | Neem | 500 | 30 |
| 2 | Karanja | 200 | 27-39 |
| 3 | Kusum | 80 | 34 |
| 4 | Pilu | 50 | 33 |
| 5 | Ratanjot | - | 30-40 |
| 6 | Jaoba | - | 50 |
| 7 | Bhikal | - | 37 |
| 8 | Wild Walnut | - | 60-70 |
| 9 | Undi | 04 | 50-73 |
| 10 | Thumba | 100 | 21 |

Thumba oil is a non edible vegetable oil which is mostly found in western Rajasthan and Gujarat. Thumba oil is also known as Citrullus Colocyntis scientifically.Presently work is based on the production of biodiesel with the use of Thumba oil as raw material. Thumba (***Citrullus colocyntis***) [11]. seeds contain 20-30% oil in it. In India biodiesel production is based on jatropha and other vegetable seeds corps. After some research proves that Thumba also have a potential to produce biodiesel. Citrulluscolocyntisis known as **Indrayan** in Hindi or **Bitter apple** in English. It is inhabitant of Turkey and also found in Asia and Africa. The plant is in the form of climbing plant and cultivates well in sandy soil, plant has annular and rough trunks, rough leaves which are 3 to 7 lobed, 5-10 cm long in middle. Flowers are monolecious and have yellow round fruit.

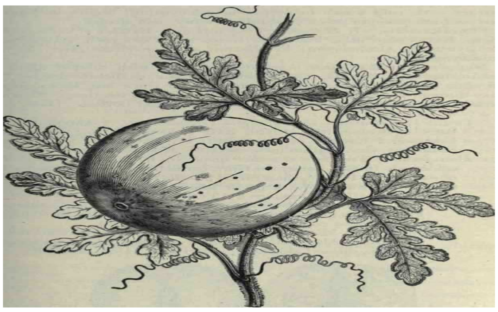

**Figure 1 Thumba (Citrullus colocynthis)**

It is found wild in the warm, arid and sandy parts throughout India, up to 1,500 m. It is most abundant in north-western plains of India, especially in the Barmer, Bikaner, Jaisalmer and Jodhpur districts of Rajasthan, and in Gujarat. Thrives on sandy loam, sub desert soils, and along sandy sea coasts. Table 2 shows the biophysical limits of thumba[12].

Table 2 Biophysical limits of Thumba

| | |
|---|---|
| **Elevation range** | lower: sea level upper: about 1,500 m (4,921 ft) |
| **Mean annual rainfall** | lower: 250 mm (10 in) upper: 4,000 mm (160 in) |
| **Rainfall pattern** | a crop adapted to arid zones |
| **Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)** | a desert plant, giving evidence of the dominion of life even in such arid regions |
| **Mean annual temperature** | lower: 15°C upper: 48°C |

## 2. EXPERIMENTAL PROCEDURE

### 2.1 *Fuel Description*

Thumba oil was collected from a private firm in Gwalior (Madhya Pradesh, India). This oil filtered after for the removal of solid impurities. Titration has been done with the addition of NaOH for the calculation of the FFA (free fatty acid). The average value of thumba oil's FFA is 2.18%. After the determination of FFA transesterification process has been performed. Methanol is used as alcohol substance and KOH as base catalyst. Methyl alcohol ($CH_3OH$) is taken with a molar ratio of (1:4.5 & 1:6) and Catalyst (KOH) is taken as (0.5%, 0.75% and 1% by weight of oil). The fuel properties of Thumba biodiesel and diesel fuel are shown in Table 2. ASTM standard procedures were adopted in this analysis.

Table 3 Experimental data of physical and chemical properties

| Sr Number | Properties of fuel withdata | Diesel fuel | Bio-diesel |
|---|---|---|---|
| 1 | Viscosity@40$^{O}$CcSt | 1.25 to 1.40 | 4.32 |
| 2 | Density@15$^{O}$CKg/L | 0.821 | 0.870 |
| 3 | Cetane number | 49 | 53 |
| 4 | Cloud point($^{O}$C) | -23 to 12.5 | 4.5 |
| 5 | Pour point($^{O}$C) | 6 to 7 | 7.2 |
| 6 | Flash point($^{O}$C) | 47 to 70 | 91 |
| 7 | Fire point ($^{O}$C) | 75 | 110 |
| 8 | Calorific Value KJ/Kg | 42000 | 37000 |
| 9 | Boiling point ($^{O}$C) | 180 to 340 | 321 |

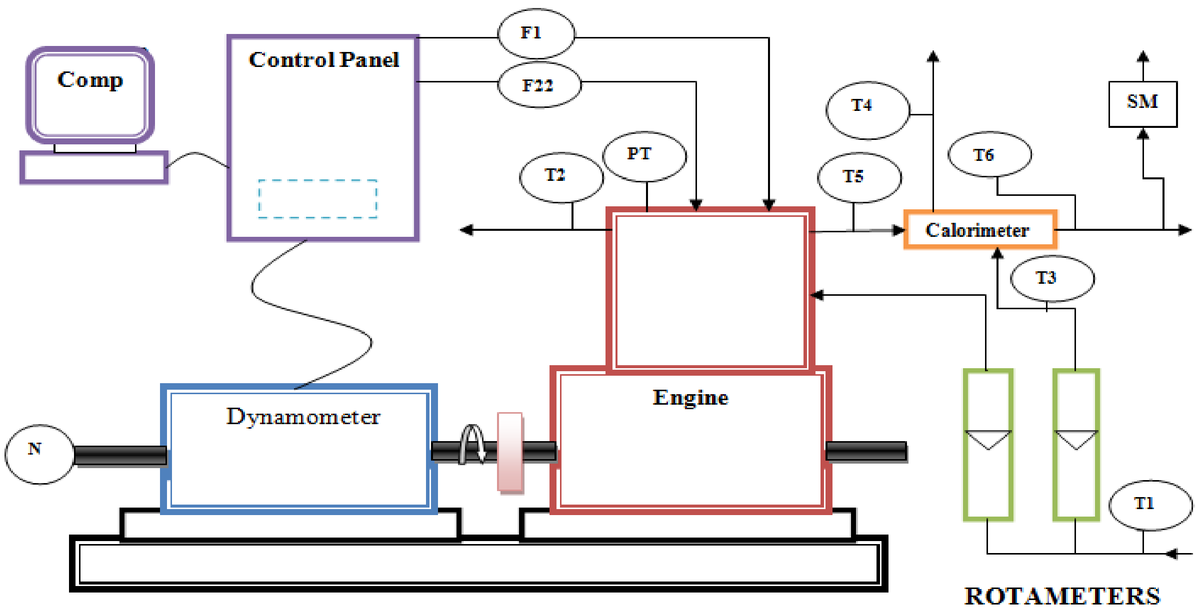


Figure 2 Schematic layout of experimental set up

**2.2 *Experiment Setup Description***

Experiment has been performed at Delhi Technical University, New Delhi India. The setup consists of a cylinder, 4 strokes, and VCR (Variable Compression Ratio) Diesel engine connected to the dynamometer for loading which eddy current type. By the special designed arrangement 'tilting cylinder block' the compression ratio of the engine can be changed without stopping the engine and also without changing the combustion chamber geometry. Setup is attached with a piezo sensor angle encoder instruments for combustion pressure and crank-angle measurements. These signals are interfaced to the computer through engine indicator for obtaining PΘ−PV diagrams. . Figure 2 shows the experimental set up.

Setup is also capable for interfacing airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rota meters are provided for the measurement of cooling water and calorimeter water flow. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance.

It consists of a stator on which are fitted a number of electromagnets and a rotor disc and coupled to the output shaft of the engine. When rotor rotates eddy currents are produced in the stator due to magnetic flux set up by the passage of field current in the electromagnets. These eddy currents oppose the rotor motion, thus loading the engine. These eddy currents are dissipated in producing heat so that this type of dynamometer needs cooling arrangement. A moment arm measures the torque. Regulating the current in electromagnets controls the load.

Technical specifications of experimental set up's engine and dynamometer are given follows:

| | |
|---|---|
| **Model** | VCR Diesel Engine test setup (Computerized) |
| **Manufacturer** | Kirloskar Engines Ltd India |
| **Software** | "EnginesoftLV" engine performance analysis software |
| **No of cylinder** | One |
| **No of strokes** | Four |
| **Power** | 3.5 k watt |
| **RPM** | 1500 |
| **Dynamometer** | Type eddy current, water cooled, with loading unit |
| **Smoke meter** | Make AVL, for opacity measurement |

**2.3 *Experimental Procedure***

A single cylinder diesel engine was used for the experimental analysis. Fuel was supplied to the engine from an outside tank. All runs started with a 5-min warm-up period prior to data collection. The gap of 3 to 4 minutes was provided between the two consecutive runs. The data measured during the tests included engine speed, brake power, torque, and fuel consumption. During the test engine load was varied from 0 to 12 kg by adjusting the load knob provided on the control panel of the test rig while maintaining a constant engine speed of about 1550 rpm. The tests were performed with pure diesel fuel and biodiesel blends (B20, B40).

## 3. RESULT AND DISCUSSION

**3.1 *Brake Thermal Efficiency***

Figure 3.1 shows the variation of brake thermal efficiency with brake power for various Thumba biodiesel blends like B20, B40, compared with pure diesel at compression ratio15 and 18. Brake thermal efficiency is increasing with increasing loads for all blends of biodiesel and diesel.

It may be due to reduction in heat loss and increase in power with increase in load.

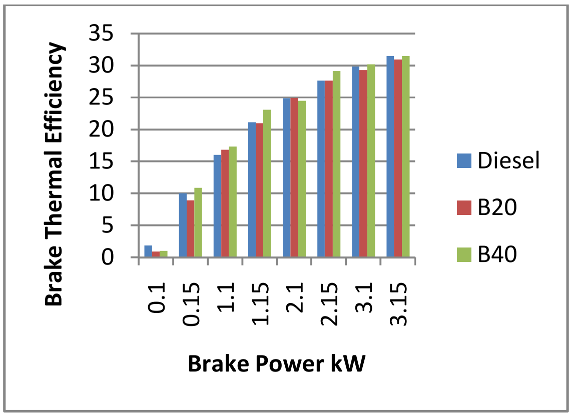


Figure 3.1: Variation of brake thermal efficiency w.r.t brake power at CR18

Thumba oil biodiesel has higher viscosity, density and lower calorific value than diesel. Higher viscosity leads to decreased atomization, fuel vaporization and combustion. Figure3.1shows the percentage change area of all biodiesel B20 and B40 blends with diesel as reference at compression ratio18. It shows much percent change is occurs in brake thermal efficiency of pure diesel and biodiesel blends. Figure 3.2 shows the variation of brake thermal efficiency with brake power at compression ratio 15. It has been observed that at starting up to 3.15kW of BP the thermal efficiency of diesel is higher as compared to all Thumba biodiesel blends At 15 compression ratio B40 has higher brake thermal efficiency as compared to all Biodiesel blends and very close to diesel. At rated load of 3.15 kW, B40 is having the efficiency 29.87% as compared to diesel 29.49%. Figure 3.2 shows percent change area of brake thermal efficiency with brake power with diesel as baseline. As figure 3.1 and 3.2 shows the brake thermal efficiency variation, at CR 15 the brake thermal efficiency of the diesel fuel is at rpm 1450 is 29.59% while the brake thermal efficiency of B20 and B40 is 28.14% and 29.87% respectively. It shows that the B40 having much efficiency than the diesel at CR of 15.

### *3.2. Brake Specific Fuel Consumption(BSFC)*

The Variation in BSFC (Brake Specific Fuel Consumption) with brake power for different fuel samples at different compression ratios of 18 and 15 and their percent change area with reference to diesel is shown in figure 3.3 and 3.4 respectively. Diesel has higher bsfc at power 1.1 and 1.5 It may be due to reduction in heat loss and increase in power with increase in load.

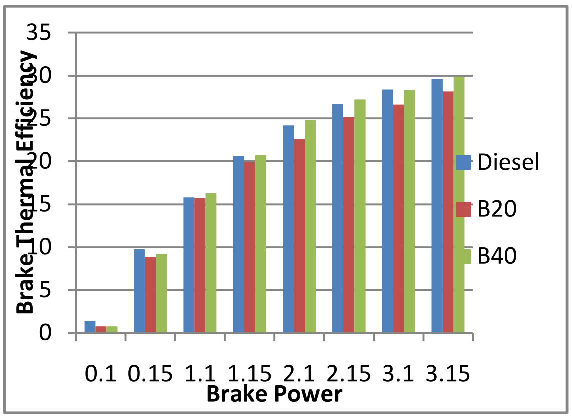


Figure 3.2: Variation of brake thermal efficiency w.r.to brake power at CR15

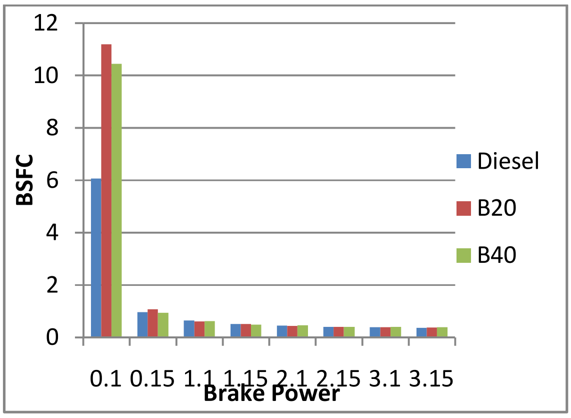


Figure 3.3: Variation of brake specific fuel consumption w.r.t. brake power at C18

The specific fuel consumption when using biodiesel fuel is expected to increase as compared to the consumption of diesel fuel. BSFC decreased sharply with increase in load for all fuel samples at both the compression ratio. At CR 15 the BSFC of the pure diesel is 0.37 kg/kw hr while the thumba biodiesel blends B20 and B40 having 0.38 and 0.39 kg/kw hr which little greater than diesel fuel. The main reason percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the at losses at higher loads.

As the BSFC is calculated on weight basis, so higher densities resulted in higher values of BSFC. BSFC for all the thumba biodiesel blends is higher compared to diesel but among them B20 has lower values of BSFC at both the compression ratios of 18 and 15.

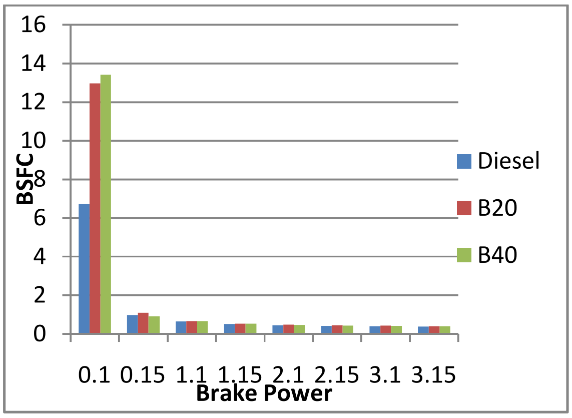


Figure 3.4: Variation of brake specific Fuel consumption w.r.t. brake power at CR 15

### *3.3. Brake Specific Energy Consumption*

The variation of BSEC (Brake Specific Energy Consumption) with BP (Brake Power) for different fuels at 18 and 15 compression ratios are shown in figure 3.5 and 3.6 and 3.6 respectively. BSEC decreases with increase in load which is because of higher percentage in brake power with load as compared to fuel consumption. It has been also observed that BSEC for B20 is high for all load conditions at compression ratio 18. The value of BSEC at CR 18 of the diesel fuel is 12.28 MJ/kE-h while the value of BSEC of B20 and B40 is 12.79 and 12.08 respectively.

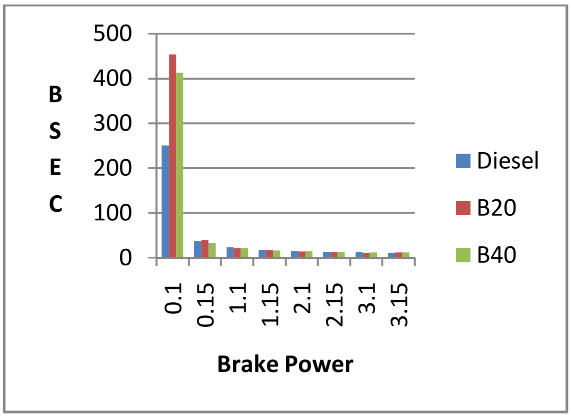


Figure 3.5: Variation of brake specific energy consumption w.r.t. brake power at CR 18

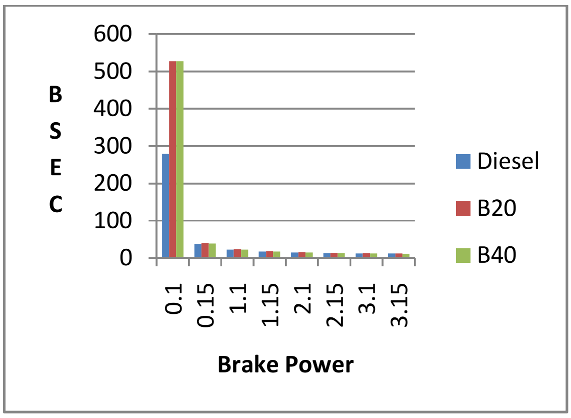


Figure 3.6: Variation of brake specific energy consumption w.r.t. brake power at CR 15

### *3.4. Exhaust Gas Temperature (EGT)*

Exhaust gas temperature (EGT) for different blends with respect to brake power at 18 and15 compression ratios with their percent change graph in reference with diesel are represented in figure 3.7,3.8 respectively. The exhaust gas temperature for all fuel samples increase with increase in the load. It is because of increase in the amount of fuel injected with increase in engine load and in order to maintain increased power output, exhaust temperature increases.

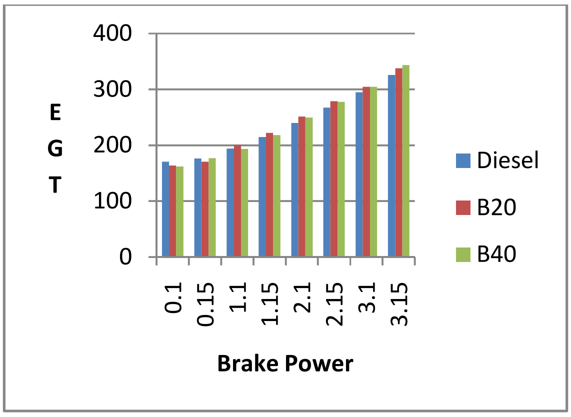


Figure 3.7: Variation of Exhaust gas temperature w.r.t. brake power at CR 18

Exhausted gas temperature is an indication of good combustion in the combustion chamber. It has been observed that the value of exhaust gas temperature is low for diesel than small blendslikeB20and B40 at both the compression ratios. But when concentration of biodiesel increased, the exhaust gas temperature also increased. It has also observed that at lower compression ratio of 15 the exhaust gas temperature of biodiesel blends is less as compared to diesel. As EGT at CR15 is less which can be leads to reduction in NOx emissions as they are highly dependent on temperature. It can be recommended that is better to run engine at lower compression ratio in order to have low emissions, but it should be further investigated properly at various engine.

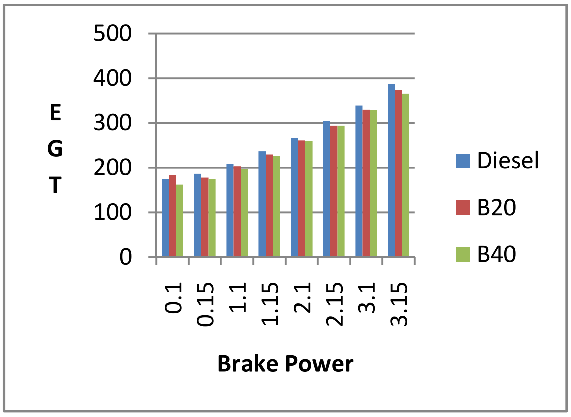


Figure 3.8: Variation of Exhaust gas temperature w.r.t. brake power at CR 15

### *3.5. Smoke opacity*

Variation in smoke opacity with respect to brake power for different fuels at 18 and15 compression ratios is shown in figure 3.9 and 3.10 respectively. The major finding is that biodiesel and its blends with diesel produce less smoke as compared to pure diesel. This is may be due to basic difference in chemical structure of biodiesel and diesel and the presence of oxygen in the molecule of the biodiesel, which enhance its complete burning as compared to diesel. It can also be observed from the graph that smoke level increased sharply with increase in load for all fuels tested at both the compression ratios. It was mainly due to the decreased air-fuel as such higher loads when larger quantities of fuel are injected in to the combustion chamber. It has been also observed that at lower compression ratio of 15 the smoke opacity in higher as compression ratio of 18.

Thumba (Citrullus colocyntis) has huge capability for biodiesel production. The most important feature of this Thumba is that it grows in the form of climbing plant in sandy soil with in a six month crop cycle. A 3.5 k watt single cylinder four stroke engine set up has been used to test Thumba (Citrullus colocyntis) seeds biodiesel and its blends and also compared with conventional fossils diesel fuel. During investigation found that the fuel properties of the Thumba biodiesel is similar to the diesel fuel. The emissions produced by Thumba biodiesel are much lesser than that of diesel.

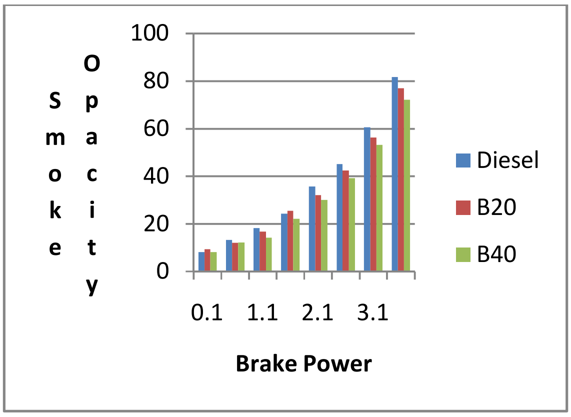


Figure 3.9: Variation of Smoke opacity w.r.t. brake power at CR 18

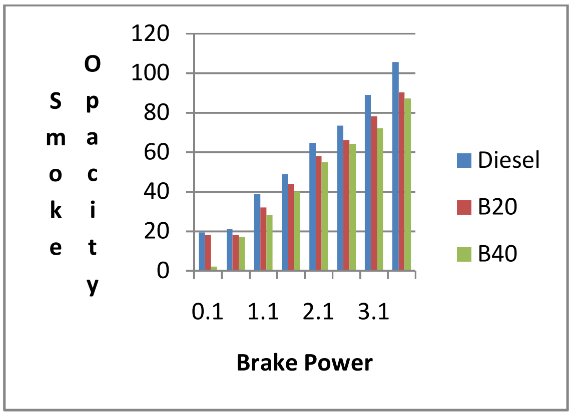


Figure 3.10: Variation of Smoke opacity w.r.t. brake power at CR 15

## 4. Conclusion

- The calorific value of the blends decreases as the percentage of biodiesel is increased, which affects the performance of high percentage blends.
- The performance parameter like brake thermal efficiency, brake specific fuel consumption, brake specific energy consumption, torque have similar result at wide range of power output.
- It is observed that the Exhaust gas temperature for biodiesel blends is low for CR15 as compared to CR18 than diesel.

- The smoke emissions of biodiesel blends are considerably less as compare to diesel due to complete combustion of the fuel.

The results confirm the potential of these blends have in reducing the overburdening imports of diesel fuel. Biodiesel acts like petroleum diesel, but produces less air pollution, comes from renewable sources, is biodegradable and is safer for the environment. Producing biodiesel fuels can help create local economic revitalization and local environmental benefits. Government may consider providing support to the activities related to collection of seeds, production of oil from non-edible sources, production of bio-fuels and its utilization for cleaner environment.

**REFERENCES**

[1] Ramesh D. and Sampathrajan A., "Investigations on Performance and Emission Characteristics of Diesel Engine with Jatropha Biodiesel and Its Blends." Agricultural Engineering International: the CIGR Ejournal, Manuscript EE 07 013. 10, March 2008,1-13
[2] http://www.wikipedia.org/wiki/Demographics_of_India
[3] Lalwani Mahendra, Singh Mool, "Conventional and Renewable Energy Scenario of India: Present and Future", Canadian Journal on Electrical and Electronics Engineering Vol. 1, No. 6, October 2010.
[4] http://www.thehindu.com/business/Industry/oil-import-from-iran-slashed-by-27/article4522020.ece March 2013.
[5] Kachhwaha SS, Pal Amit, Maji S, Babu MKG. "Thumba (citrullus colocyntis) seed oil: A sustainable source of renewable energy for biodiesel production." Journal of Scientific & Industrial Research Vol. 69 May 2010. pp. 384-389.
[6] Stavarache C, Vintaoru M, Nishimura R and Maeda Y, Fatty acids methyl ester from vegetable oil by means of ultrasonic energy, Ultrason Sonchem 12 (2005) 367-372.
[7] Performance and emission evaluation of a compression ignition engine using a biodiesel (apricot seed kernel oil methyl ester) and its blends with diesel fuel, M. Gumus, S. Kasifoglu.
[8] Narayan, C.M., (2002), "Vegetable oil as engine fuels—prospect and retrospect", Proceedings on Recent Trends in Automotive Fuels, Nagpur, India.
[9] Bhatt, Y. C. 1987. Use of some non-edible vegetable oils as a source of energy for CI engines. Unpublished Ph.D. Thesis, IIT, Kharagpur, Nov 1987.
[10]AutoFuePolicy,http://cpcbenvis.nic.in/newsletter/dieselsept2002/ch70902.htm
[11] Kachhwaha SS, Pal Amit, Maji S, Babu MKG. "Thumba (citrullus colocyntis) seed oil: A sustainable source of renewable energy for biodieselproduction." Journal of Scientific & Industrial Research Vol. 69 May 2010. pp. 384-389.
[12]http://www.jatrophabiodiesel.org/citrullucolocynthis/citrullus-colocynthis.php