

PERFORMANCE AND EMISSIONS ANALYSIS OF A DIESEL ENGINE USING THUMBA OIL BIODIESEL

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ABSTRACT

The performance and emissions analysis of the biodiesel made by non edible vegetable oil Thumba (*Citrullus Colocynths*) and its blends with diesel fuel have been performed on a CI engine (Power 3.5 k-Watt Kirlosker 4-stroke single cylinder). The performance of engine with biodiesel B20 (20% Thumba oil and 80% diesel) and B40 (40% Thumba oil and 60% diesel) performed at rated load of 3.15 kW, B40 is having the efficiency 29.87% as compared to diesel 29.49%. 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.

Keywords: Vegetable oil fuel, Thumba (*Citrullus Colocynths*), diesel blend, India

I. 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 transesterification 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%); particulate matter (47%); and hydrocarbon emissions, 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 crops in India. Therefore the concentration has been 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

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 crops. After some research proves that Thumba also have a potential to produce biodiesel. *Citrulluscolocyntis* known as **Indrayanin** 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 monoecious and have yellow round fruit .

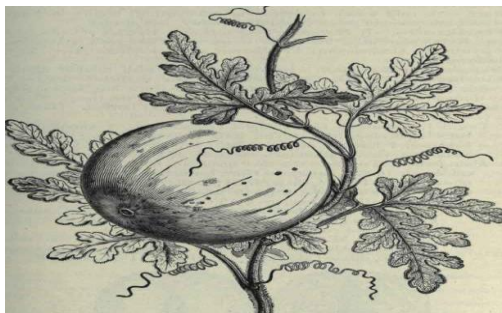


Figure 1 Thumba (Citrullus colocynthis)

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

II. EXPERIMENTAL WORK

2.1 Material and Methods

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 (CH₃OH) 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 2 Experimental data of physical and chemical properties

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

2.2 Experiment Setup

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 3 shows the experimental set up.

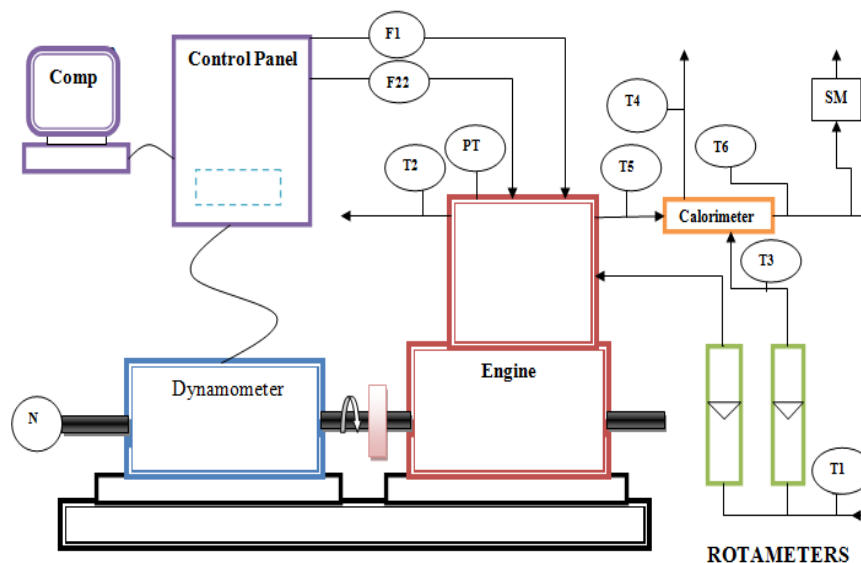


Figure 2 Schematic layout of experimental set up

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 Work

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).

III. RESULT AND DISCUSSION

3.1 Brake Thermal Efficiency

Figure 2.1 shows the variation of brake thermal efficiency with brake power for various Thumba biodiesel blends like B20, B40, compared with pure diesel. 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.

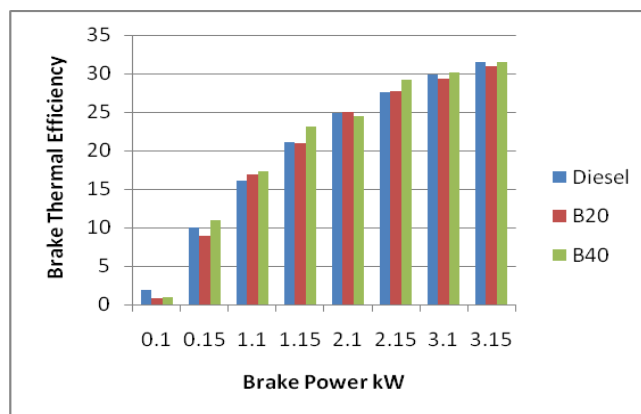


Figure 2: Variation of brake thermal efficiency w.r.t brake power at CR18

Thumba oil biodiesel has higher viscosity, density and lower calorific value than diesel. Higher viscosity leads to decreased atomization, fuel vaporization and combustion. Figure 3.1 shows the percentage change area of all biodiesel B20 and B40 blends with diesel as reference at compression ratio 18. It shows much percent change is occurs in brake thermal efficiency of pure diesel and biodiesel blends.

3.2 Brake Specific Fuel Consumption (BSFC)

The Variation in BSFC (Brake Specific Fuel Consumption) with brake power for different fuel samples and their percent change area with reference to diesel is shown in figure 3. 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.

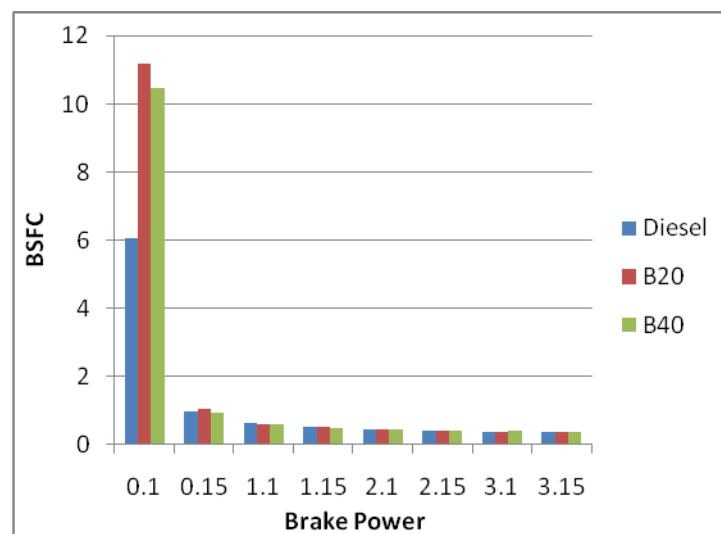


Figure 3: Variation of brake specific fuel consumption w.r.t. brake power at C18

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.

3.3 Brake Specific Energy Consumption

The variation of BSEC (Brake Specific Energy Consumption) with BP (Brake Power) for different fuels 4 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. The value of BSEC 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.

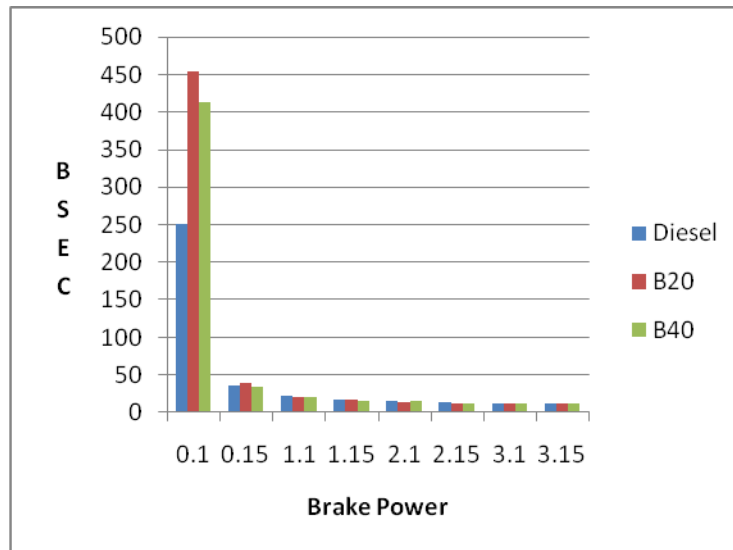


Figure 4: Variation of brake specific energy consumption w.r.t. brake power at CR 18

3.4 Exhaust Gas Temperature (EGT)

Exhaust gas temperature (EGT) for different blends with respect to brake power with their percent change graph in reference with diesel are represented in figure 5. 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.

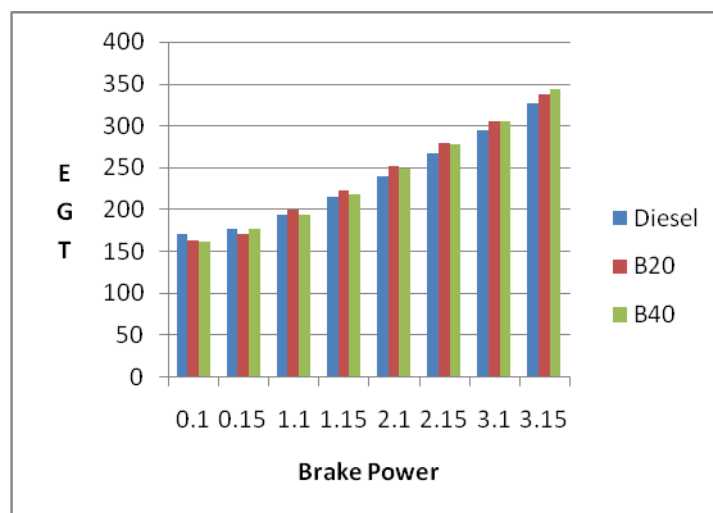


Figure 5: Variation of Exhaust gas temperature w.r.t. brake power at CR 18

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 blends like B20 and B40 at both the compression ratios. But when concentration of biodiesel increased, the exhaust gas temperature also increased.

3.5 Smoke opacity

Variation in smoke opacity with respect to brake power for different fuels is shown in figure 6. The major finding is that biodiesel and its blends with diesel produce less smoke as compared to pure diesel. This 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.

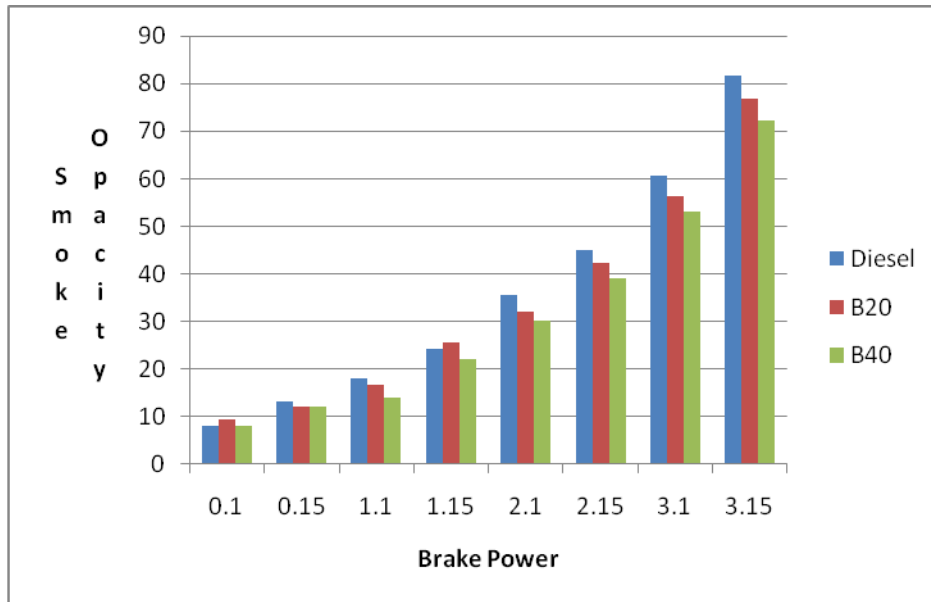


Figure 6: Variation of Smoke opacity w.r.t. brake power at CR 18

IV. CONCLUSION

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 kW 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.

- 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.
- 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.

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