Experimental Investigation of Single Cylinder Diesel Engine By Diesel – Citrullus Vulgaris With n-Butanol And Its Blends

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Abstract

Everyday a need for energy sources and fossil fuel is growing high. Also that this type of fossil fuel is not an eco-friendly. So it is necessary to look forward for alternate fuel for vehicles. The best and most suitable alternate source of fuel is Biodiesel. Because Biodiesel contain long chain alkyl esters. Also that it is prepared from renewable sources and it is bio-degradable. In this project citrullus vulgaris oil is used as a biodiesel. It is used due to its low cost and high availability. This biodiesel is prepared by using the process of transesterification process. Experimental investigation of diesel engine is carried away to find out the performance characteristics and Emission analysis of the CI (compression ignition) diesel engine, when using n-Butyl alcohol (n-butanol) as an additive with neat diesel and Biodiesel blends. This experiment consists of mixing of Biodiesel and Diesel with additive n-butyl alcohol (commonly known as n-butanol) in 80% of diesel, remaining 20% of Biodiesel and additives in mass basis. The final results yields that performance and emission characteristics of the single cylinder diesel engine can be improved slightly by using Biodiesel blend than neat diesel and it is compare with standard diesel. The performance characteristics were carried out the BTE, SFC, TFC, and at the same time the emission analysis and result getting the HC, CO, CO₂ and NOx.

Keywords: Performance, Emission analysis, n-butanol, Biodiesel, Diesel Engine, Transesterification.

I. Introduction

I.i. Diesel:

In our modern world, most of the people have their own four wheeler vehicle. Because of that, usage of diesel is rapidly increasing now. In today world, Diesel plays a major role in our life. Generally, Diesel being produced from different...
sources, mostly by using petroleum. It can also be produced by some other sources like Bio-mass, animal fat, bio gas and coal liquefaction. Generally Petroleum Diesel also named as Fossil Diesel or Petro Diesel. Nowadays, most of the people use petroleum Diesel for their four wheeler vehicles. Diesel Fuel are generally used in Diesel engines only, it cannot be used in petrol Engines. Because Diesel fuel is not as volatile as compared to petrol and will not form droplets and vapour as easily as petrol, in fact Diesel fuel is fairly viscous. Generally, In Diesel Engine, Inlet air is compressed to a certain volume, then the Diesel fuel is sprayed on the compressed air, thus the combustion takes place in that engine. There is no need of spark plug in this diesel engine. Thus increasing the usage of Diesel fuel, increasing the demand for diesel fuel. But, Availability of diesel fuel in the world is going down. According to one survey, Availability of Diesel fuel in the world would last for around 80 years only [XX]. Due to that less availability and high demand for diesel fuel, rapidly increasing its cost in day-to-day. Also that, by burning of biodiesel in Diesel engine, emits the highly carbonated carbon monoxide and other some impurities to the atmosphere. Thus makes the environment as pollution, also that it increases the global warming in the world. Due to the problems like less availability, high cost and high emission in the Diesel fuel, we are looking for alternate fuel, i.e. Biodiesel. Nowadays many experiments are carried out by people all over the world for implement of biofuel as an alternate for diesel fuel [I], [XIX], [XXXVI], [XLVII].

I.ii. Biodiesel from WSO

The research of biofuel produced from citrullus vulgaris (watermelon seed oil) is made by transesterification process. Because transesterification process is a most economical way for producing Biodiesel from seed oil when compared to other process. In transesterification process, methanol (CH3-OH) plays a major role for producing biodiesel from watermelon seed oil. In this method of using CH3-OH (methanol) in the occurrence of catalyst NaOH for synthetically break the molecules from raw watermelon seed oil into ester and glycerol. Here, catalyst also plays important role for biodiesel production. Generally, for biodiesel preparation by transesterification process, a catalyst of NaOH or KOH only mostly used for biodiesel production. In our case, sodium hydroxide (NaOH) is used as catalyst for biodiesel production. Because sodium hydroxide removes the fatty acids present in the oil. The combination or mixture of alcohol and catalyst i.e. methanol and sodium hydroxide, is named as alkoxide preparation. In this transesterification process, watermelon seed oil (citrullus vulgaris) is react with methyl alcohol (commonly known as methanol) in the occurrence of catalyst, sodium hydroxide to generate glycerol and full of fat acid ester. [XXXI], [XXXV].

For our process, the ratio of 1000 ml of methyl alcohol and 0.040 kilograms of NaOH has been taken. They are mixed in the bottom flask to form sodium methoxide. Then watermelon seed oil of 1 litre (5000 ml) was taken and this oil is mixed with sodium methoxide solution. The mixture was heat upto 333 K [XXI], maintain the same temperature and stirring at constant speed for two hours to form ester. After this mixture is allowed to cool down upto 12 hours or half a day without stirring in the separation flask. Then, this mixture was temperature raised upto 60°C and held at that temperature by methods for steady speed mixing for two hours to
frame the ester. At that point this blend was permitted to cool and settle in a division container for 12 hours. Following 12 hours, 2 layers were formed in the container (burette type). In that flask, the bottom layer is drained in a separate container or vessel, it consists of glycerol & the upper layer is separated in another vessel or container, it consists of methyl ester. After that glycerol can be separated from mixture by the process of solvent separation or decantation. Then methyl ester was going to under purification process. The purification process is done by methyl ester is wash down with distilled water to take away the excess methanol [XXXV]. Finally glycerol and methanol can be retrieved from the mixture and pure biodiesel can be obtained. This transesterification process plays an essential role in improving the property of biofuel are density, viscosity, flash & fire point, and heating value.

I.iii. Transesterification:

Initially, in transesterification, there are 3 fundamental routes to produce biodiesel from oils and fat. They are base catalyzed transesterification of the oil, direct corrosive catalyzed transesterification of the oil and move the oil to its unsaturated fats and after that changed to biodiesel. Almost of the Biodiesel is produced by using the method of bottom catalyzed transesterification, because it is the most inexpensive method compared to other process, it barely requiring depressed temperature and pressure and lengthen 98% renovation yield. [XXIV], [XLI].

Transesterification is a changing one or more chemicals of transform giant, come apart, three molecules of dissimilar fatty acid is related to the alcohol glycerol of vegetable oils and fats into slight, direct or rectilinear chain molecules, [XXX], [XLIV], almost correspondent in size to the molecules of the mintage available in the diesel fuel. The method happens by the response of oil with alcohol in the being there of a medium [VII].The good number of frequently used catalyst in transesterification process is NaOH or KOH [XXXIV], [XXX].
The WSO can be extracted in 3 methods are

1. **cold pressing**,
2. **oil expellers**,
3. **Solvent extractors** and etc.

In oil expeller technique the seed is squashed a turning screw in an even chamber and as a result the oil progress during a time opening. [XLI]. The cold squeezed technique is utilized to keep up the most extreme amount of nutrients.[XXII] The crisp squeezed technique is like the expeller technique yet it ought to keep up temperature less 50°C (T < 50°C). Be that as it may, the dissolvable extraction technique utilizes some dissolvable to concentrate oil from the seed at a high temperature. This strategy is utilized monetarily for high generation [IX].

**Flow chart for oil preparation**

![Flow chart](chart1.png)

**Chart. 1. Oil preparation chart**

![Watermelon seed](fig2.png)

**Fig. 2. Watermelon seed**
II. Blends or Preparation of Biodiesel of Fuel Preparation

Blending the 2 or more types of fuel is added. It was found to reduce the properties of fuel are density and viscosity of biodiesels. They are two methods are available to blending the fuels are:

1. By mass basis,
2. By volume basis.

The proportion of Citrullus vulgaris mixture is increased and directly, heating valve of citrullus vulgaris also increased [XX], [XXX]. In this research method was considered as by mass basis blending the liquids [XVIII], [VIII], [XXII], [XLIX], [XXIII].

**COMPARISON OF PROPERTIES**

| S. no | Properties               | Diesel | Citrullus Vulgaris | n-butanol | B20   |
|-------|--------------------------|--------|--------------------|-----------|-------|
| 1.    | DENSITY (kg/m³)          | 852    | 925                | 810       | 867   |
| 2.    | VISCOSITY @ 40°C (mm²/s) | 2.98   | 6.98               | 3.64      | 3.78  |
| 3.    | CALORIFIC VALUE (KJ/kg)  | 44800  | 38400              | 32500     | 43500 |
| 4.    | FLASH PONIT 52°C         | 94°C   | 35°C               | 62°C      |       |
| 5.    | FIRE POINT 68°C          | 123°C  | 118°C              | 86°C      |       |

Table 1. properties of fuel

|     |     |
|-----|-----|
| B20 | 80% Diesel + 20%Citrullus Vulgaris |
| TB1 | 95% B20 + 5% n Butanol |
| TB2 | 90% B20 + 10% n Butanol |
| TB3 | 85% B20 + 15% n Butanol |
III. Experimental Setup

Initially, the piston is connected to dynamometer through coupling and crank shaft. Then air filter and air flow meter is connected to the inlet of the piston through inlet manifold [III]. As like the inlet, exhaust gas analyzer and smoke analyzer is associated to outlet tube, of the piston. Here gas analyzer and smoke meter plays a main role in to find out the emissions of Engine. Here, this gas analyzer and smoke analyzer are connected to the central processing system (CPU) which is connected to the piston or Engine, so that the exhaust gas data can be processed. And also there is two important sensors can be used [XIII], [XLII]. One is pressure sensor and another one is angle sensor [XXII]. The pressure sensor is used to determine the pressure of the system and the angle sensor is used to determine he angle as well as rotation of crank shaft [XI]. From the setup, performance and emission test can be approved away for these three blends at various loading conditions and compare with standard diesel. The representation drawing of experimental setup is shown in fig 5 and the photography of engine setup is shown in fig 6. The performance characteristic is carried out BTE, SFC, and TFC. At the same time the emission parameters and result getting the HC, CO, CO₂ and NOx [XXIII], [XXXIII].
3.1 ENGINE SPECIFICATION

| S. NO | NAME OF THE SPECIFICATION | VALUE |
|-------|---------------------------|-------|
| 1     | Make                      | Kirloskar |
| 2     | Model                     | SV1   |
| 3     | Number of cylinders       | 1     |
| 4     | Swept Volume              | 0.662 litre |
| 5     | Max Power                 | 6hp (4.41kW) |
| 6     | Constant Speed            | 1500 rpm |
| 7     | Compression Ratio         | 17.5:1 |
| 8     | Constant Injection Pressure| 200 bar |
| 9     | Injection timing          | 28° bTDC |
| 10    | Constant Injection Temperature| 23°C   |

IV. Result and Discussion

Experimental investigation of single cylinder diesel engine by running by diesel – citrullus vulgaris with n-butanol and its blends were conducted in a four stroke water cooled engine & speed is constant or fixed for different or variant loading or stages are 0 %, 25 %, 50%, 75% and 100%. The graphs of performance of engine are BTE, TFC, and SFC. The emission parameters are HC, CO, CO₂.
IV.i. Engine Performance

IV.i.a. LOAD VS BTE

The dissimilarity of Brake Thermal Efficiency with regard to neat diesel and ternary blends are diesel > TB1 > TB2 > TB3 as exposed in figure 7. Here, in this graph all diesel blended and pure diesel fuels are increased, as increasing the load. The greatest BTE is 31.095% at maximum load for pure diesel and the nearest efficiency is 6.5% lesser for TB1 compare to neat diesel at maximum load. Commonly, Brake thermal efficiency is used to find out the efficiency of exchange of heat energy from biodiesel to the mechanical power. This might be due to high viscosity [VIII], & density compare to pure diesel and premixed combustion for the reason that of low calorific value or heating valve and CN of n-Butanol [XIV], [XLIIV], [IV].

IV.i.b. LOAD VS TFC

The dissimilarity of Total fuel consumption with regard to neat diesel and ternary blends are diesel < TB1 < TB2 < TB3 as exposed in figure 8. Here, in this graph all diesel blended and pure diesel fuels are increased, as increasing the load. The least TFC is 1.18 kJ/hr at maximum load condition and the nearest efficiency is 10.55% higher for TB1 compare to pure diesel at maximum load condition. Commonly, Total fuel consumption (TFC) can be defined, the quantity of biodiesel consumed by the engine per unit time while a certain power is developed by engine [XIV]. Here, in this graph all diesel blended and pure diesel fuels are increased, as increasing the load. This might be due to poor atomization and ignition delay and compare to neat diesel [XLIX], [XXXVI]. Total fuel consumption is generally measured in kg/hr.
IV.i.c. LOAD VS SFC

The dissimilarity of SFC with regard to neat diesel and ternary blends are diesel $<$ TB1 $<$ TB2 $<$ TB3 as exposed in figure. 9. Here, in this graph all diesel blended and pure diesel fuels are decreased, as increasing the load. The least SFC is 290 g / kW hr at maximum load condition for diesel & the nearest efficiency is 4.67% higher for TB3 compare to pure diesel at maximum load condition. SFC can be defined as the ratio of fuel consumed per unit time to the power produced. The unit for the SFC is g/kw.hr. This might be due to low calorific valve [II], [XVII] and high latent of evaporation of n-Butanol by means of increasing the availability of n-Butanol, [XXXIX], [XLIV], [XLI] leads to lesser increase of SFC compare to neat diesel [V].

Fig. 8. Load Vs Total Fuel Consumption
IV.ii. Emission characteristics

IV.ii.a LOAD VS HC

The dissimilarity of Hydrocarbon (HC) Emission with regard to pure diesel and ternary blends are diesel < TB1 < TB2 < TB3 as exposed in figure 10. Here, in this graph all diesel blended and pure diesel fuels are decreased, as increasing the load and compare with pure diesel. The least HC is 49 PPM at maximum load condition for pure diesel and the nearest HC is 8.78 % higher for TB1 compare to pure diesel at maximum load.
condition. Commonly, Hydrocarbon (HC) is measured in units of ppm. This might be due to larger size of droplets of the fuel sprays plays a major role in temperature increasing, [V], [XI], combustion in the combustion chamber and fuel atomization [XXVI], [XXVII], [XVI], [XXIX], [II].

IV.ii.b. LOAD VS CO

The dissimilarity of (CO) Carbon monoxide Emission with regard to pure diesel & ternary blends are diesel < TB1 < TB2 < TB3 as exposed in figure 11. Here, in this graph all diesel blended and pure diesel fuels are decreased, as increasing the load and compare with pure diesel. The least CO is 0.04 % at maximum load condition for diesel and the nearest CO is 10.82 % higher for TB3 compare to pure diesel at maximum load condition. Commonly, Carbon monoxide (CO) is measured in percentage of volume. This might be due to oxygen content of ternary blends which makes the higher complete combustion at higher loads [XVII], [XXXV], [XLVIII]. Temperature of the diesel engine increments will get increments with the goal that ignition will be fairly great and CO becomes CO$_2$ [XXXV].

![Fig. 11. Load Vs carbon mono oxide](image)

IV.ii.c. LOAD VS CO$_2$

The dissimilarity of Carbon Dioxide (CO$_2$) Emission with regard to pure diesel and ternary blends are diesel < TB1 < TB2 < TB3 as exposed in figure 12. Here, in this graph all diesel blended and pure diesel fuels are increased, as increasing the load and compare with pure diesel. The least CO$_2$ is 8.2 % at maximum load condition for pure diesel and the nearest CO$_2$ is 13.2 % higher for TB1 compare to pure diesel at maximum load condition. Commonly, Carbon Dioxide (CO$_2$) is measured in percentage of volume.

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This might be due to Temperature rise because of the high temperature CO is converted into CO$_2$ [XXXV], A/F Ratio, Incomplete combustion [XLV], premixed combustion and high viscosity [XXXIII], [XXXVII].

**IV.ii.d. LOAD VS NO$_X$**

Fig. 12. Load Vs carbon di oxide

Fig. 13. Load Vs oxide of nitrogen
The dissimilarity of (NOx) oxides of nitrogen or nitrogen oxides with regard to pure diesel and ternary blends are diesel < TB1 < TB2 < TB3 as exposed in figure 13. Here, in this graph all diesel blended and pure diesel fuels are increased, as increasing the load and compare with pure diesel. The least NO\textsubscript{x} is 233PPM at maximum load condition for diesel and the nearest efficiency is 11.62 % higher for TB1 compare to pure diesel at maximum load condition. Commonly, NOx is measured in percentage of PPM. The NOx emission is mainly based on high temperature[XXXIV], [XXXIII], high oxygen concentration of chemical structure, lower heating value, latent heat of vaporization and ignition delay [XXIX], [IX], [XI], [XXVIII], [XXXI].

V. Conclusions

In the present investigation was studied, 4 different fuels (diesel – citrullus vulgaris – n-Butanol) are ternary blends. The special effects of fuel properties of TB on engine performance and emission parameters is discuss in details

✓ Diesel engine can be run utilizing blend without any alteration of setup.
✓ TB valuated in this examination can be utilized at room temperature without any changes on the blends
✓ Heating valve of citrullus vulgaris is lesser compare to diesel
✓ Density and viscosity of citrullus vulgaris is higher compare to diesel
✓ CV of citrullus vulgaris is lesser than diesel.
✓ Density of citrullus vulgaris is higher than diesel.
✓ The expected brake power reduction is due to low calorific value of citrullus vulgaris.
✓ Increasing the presence of n-Butanol in the blends is affecting the BTE. The excepted BTE is obtained in TB1 due to viscosity; exhaust temperature of ternary blend is more comparing to diesel. If increasing the blends of diesel- citrullus vulgaris and decreasing the calorific value and viscosity.
✓ Total fuel consumption (TFC) found to be more for blends when compare to diesel. The needed output is obtained in TB1, might be reason for the drop is poor atomization
✓ Specific fuel consumption (SFC) found to be more for blends when compare to diesel the better outcome is obtained in TB3, drop reason is increasing of n-Butanol
✓ HC is better for TB1, comparing to diesel may be due to larger size of droplet & increasing the temperature in CC
✓ CO is well again TB3, reason for the drop is higher oxygen content of n-Butanol
✓ CO\textsubscript{2} is improved TB1, reason for the drop is temperature rise b’coz of high temperature, CO is converted into CO\textsubscript{2}
✓ The excepted NO\textsubscript{x} is reduced in TB1, is mainly based on temperature and heating value.
✓ Presence of higher n-Butanol concentration in the blends is affecting the engine performance and Emission.
✓ Study (or) Research reveals performance and emission analysis of TBI (95% B20 + 5% n Butanol) is very real to that of diesel could be successfully used as an alternative fuel.

Abbreviations

- **BP**: Brake Power in kW
- **CO**: Carbon Monoxide
- **NOₓ**: Nitric oxides
- **CO₂**: Carbon di oxide
- **CV**: Heating Value of fuel
- **HC**: Hydro carbon
- **T**: Torque
- **BTE**: Brake Thermal Efficiency
- **SFC**: Specific Fuel consumption
- **ρ**: Density of fuel kg/m³
- **PPM**: Parts Per Million
- **NaOH**: Sodium Hydroxide
- **CI**: Compression Ignition
- **B20**: 80% Diesel + 20% Citrullus Vulgaris
- **TB**: Ternary Blend
- **TB1**: Ternary Blend 1
- **TB2**: Ternary Blend 2
- **TB3**: Ternary Blend 3
- **TB1**: 95% B20 + 5% n Butanol
- **TB2**: 90% B20 + 10% n Butanol
- **TB3**: 85% B20 + 15% n Butanol
- **KOH**: Potassium hydroxide
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