

Performance and Experimental Analysis of Roselle oil as Bio-diesel Blend on Four Stroke, Diesel Engine

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ABSTRACT: Biodiesel is a biodegradable, environment friendly as well as suitable source, to meet the future energy crises. The main aim of this experimental analysis is to reach a tentative goal, how this fuel can be utilised with maximum effective way. This work investigates the reliability of using easily available edible vegetable seed oils to produce biodiesel. The oil has been converted to biodiesel by the well-known base catalyst transesterification process. It is found that physical and chemical properties of roselle oil and biodiesel are very close to fossil diesel. Biodiesel can be used alone (B100) or blended with petroleum diesel in any proportion blends, such as B5 are ASTM approved for safe operation in any compression-ignition engine designed to be operated on petroleum diesel. This experimental investigation is to optimise the performance of Roselle biodiesel and its blends with Diesel. Here oxygenate additive Methanol and Ethanol are used for enhancing the combustion quality. Its blends are measured and evaluated in four strokes, single cylinder diesel engine.

Parameters like speed of engine (RPM) and fuel consumption were measured at different loads for pure diesel and various combinations of biodiesel blends. This investigation gives the comparative measures of brake power (BP) and brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC), brake thermal efficiency (BTE) were calculated and also compared with ordinary diesel which is also known as petro-diesel.

KEYWORDS: Roselle oil, Transesterification, Biodiesel-Blend, Additive, Diesel Engine.

I. INTRODUCTION

The primary cause of global warming and thus greenhouse gas (GHG) emission is human activity, most significantly the burning of fossil fuels, the need for exploring renewable sources of energy has been increasing rapidly. On the other side, biomass use is becoming more popular due to its short span of life cycle which makes it a carbon-neutral source [1].

To fulfil the energy demand of the world, there is a need to find out an alternative source of fuel like as fossil fuels are depleting at a very faster rate. One of the best available sources to fulfil the energy demand of the world is Biodiesel. Biodiesel is one such renewable fuel made from biomass used for diesel engine and compression ignition engines. Biodiesel is chemically defined as the monoalkyl esters of vegetable oils or animal fats. Biodiesel is the best alternate for diesel engines because it burns like petroleum diesel with better efficiency than gasoline. Biodiesel is now mainly produced by soybean, canola, rapeseed, jatropha, karanja, mahua, and palm oils [8]. The heating values of biodiesels are relatively high. The higher heating values (HHVs) of biodiesels (39 to 41 MJ/kg) are slightly lower than those of gasoline (46 MJ/kg) or petroleum diesel (43 MJ/kg) [2]

Bio-diesel is a renewable fuel, biodegradable and non-toxic. Which consist of long chain alkyl(methyl, ethyl, or propyl) esters. Biodiesel is typically produced by a simple chemical reaction between vegetable oil (edible or non-edible) or animal fat and alcohol in the presence of an acid or base as catalyst [3]. Biodiesel contains around 10% built-

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Vol. 6, Issue 9, September 2017

in oxygen by weight and free from Sulphur, aromatics and has excellent lubricity properties. Built-in-oxygen makes it more efficient fuel than petro-diesel hence its cetane number is higher than that of petro-diesel. It can be blended with petro-diesel in any proportion and can be used in compression-ignition (diesel) engines with little or no modifications. In technical terms Biodiesel is a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM D 6751 [4].

I A. Roselle Seed oil: A rainfed wasteland evergreen edible oil and vegetable plant, *Hibiscus sabdariffa* is commonly known as 'Roselle' or 'Sorrel' or 'Ambadi' in Hindi. There are more than 300 species of hibiscus around the world, one of them is Roselle (*Hibiscus sabdariffa* Linn.), which is a member of the plant family Malvaceae [6]. Roselle (*Hibiscus sabdariffa* L.) is known for both its economic, horticultural and industrial importance. Roselle (*Hibiscus sabdariffa*) is a species of *Hibiscus* probably native to West Africa, used for the production of best fibre and as an infusion, in which it may be known as carcade and it is related to the species in the *Hibiscus* species, including Kenaf (*Hibiscus cannabinus* L.), are found growing widely in many countries of eastern Africa (Cheng, 2002) [5] and also now in India. Roselle (*Hibiscus sabdariffa*) calyces are commonly used for making the non-alcoholic beverage drink which is called Zobo in Nigeria. This is a refreshment drink presently in Nigeria, when the people are feeling thirsty. Some of the species like Roselle and Kenaf are economically important as a source of food and are intensively used in making rope, paper products, jelly, tea, jam, juice, wine, syrup, gelatine, pudding, cake, ice cream flavours, and medicines. [7].



Figure 1.1: Roselle Plant



Figure 1.2: Roselle seeds

Figure 1.1 and 1.2 show the Roselle plant and their seeds. It is cultivated mainly in India, Saudi Arabia, Malaysia, Indonesia, Thailand, Philippines, Vietnam, Sudan, Egypt and Mexico, and Nigeria etc. In India, it is generally cultivated in West Bengal, Assam, Bihar, Chhattisgarh, Orissa, Uttar Pradesh, Tripura, Andhra Pradesh, Karnataka, Tamil Nadu and Meghalaya etc.

I B. Aim and Objectives: The aim of this work is to establish the possibility of using Roselle (*Hibiscus sabdariffa*) methyl esters as alternative fuels in diesel engine and compared with its blend with diesel. The specific objectives are:

- To convert the roselle oil to biodiesel by the process of transesterification, and then compare their physicochemical properties with those of petroleum-based diesel.
- To test the performance of the biodiesel from these oils at various blend ratios with diesel using the Compression Ignition Engine.

II. LITERATURE SURVEY

Nadir Yilmaz, [9] in his work he takes standard diesel fuel, biodiesel (45%)-methanol (10%)-diesel (45%), biodiesel (40%)-methanol (20%)-diesel (40%), biodiesel (45%)-ethanol (10%)-diesel (45%) and biodiesel (40%)-ethanol (20%)-diesel (40%) blends are tested in a four-stroke single cylinder compression ignited engine under the same operating conditions. Performance and emission characteristics of the engine fuelled with biodiesel-methanol-diesel (BMD) and biodiesel-ethanol-diesel (BED) are compared to standard diesel fuel as the baseline. Overall, biodiesel-alcohol-diesel blends show higher brake specific fuel consumption than diesel. As alcohol concentrations in blends

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 9, September 2017

increase, CO and HC emissions increase, while NO emissions are reduced. Also, methanol blends are more effective than ethanol blends for reducing CO and HC emissions, while NO reduction is achieved by ethanol blends.

Erinc Uludamar et al., [10] in his study examine the effect of ethanol additive in diesel-soybean biodiesel fuel blend. He takes 20% (by volume) soybean biodiesel was blended with low sulphur diesel fuel, and 5%, 10%, and 15% ethanol was added in the blend. Experiments were conducted in a water cooled 4-cylinder 4 stroke diesel engine. The results showed that, compared to diesel and biodiesel, ethanol addition improved carbon monoxide (CO), nitrogen oxide (NO_x) and smoke opacity emissions, whereas engine power and torque values reduced while brake specific fuel consumption increased. Same trend observed with increasing ethanol content in the mixture.

Gopinath D, E Ganapathy Sundaram, [11] study pertaining to the use of bio fuel which is Neem Oil Methyl Ester (NOME) as an energy source for internal combustion engine. This paper investigates experimentally the performance, emission and combustion characteristics of Niger oil methyl ester and its blends with diesel as fuel in a single cylinder stationary diesel engine. The test was carried out with B20, B30 and diesel at 0%, 25%, 50%, 75% and full load conditions. The result showed that the efficiency with B20 blend is higher as compared to B30 and diesel. For NOME, the study found B20 blend gives better performance, emission and combustion characteristics as compared to B30 and diesel.

Murat Ciniviz et al., [12] Considering strict restrictions on exhaust emissions of newly produced diesel engines, in this study, the effects of methanol and diesel fuel blends on compression ignition engine performance and exhaust emissions of a four cylinder, four strokes, direct injection, turbocharged diesel engine were experimentally investigated. Methanol-blended diesel fuels were ranged from 0 to 15% volumetric methanol content with an increment of 5%. The tests were performed by varying engine speed between 1000 min to 2700 min by an engine testing dynamometer. Results indicated that brake specific fuel consumption and nitrogen oxide emissions increased while brake thermal efficiency, carbon monoxide and hydrocarbons decreased relative to single diesel fuel operation with increasing amount of methanol in the fuel mixture.

III. MATERIAL AND METHODS

III A. Selection of raw material, processing, oil extraction:

Roselle seeds are selected as a material for preparation of biodiesel. The seeds were collected from local trees and dried by sun light for about 2 weeks. The sun-dried seeds are stored in normal room temperature. After removed moisture content completely it will be ready for oil processing machine. A large rotating pestle in a fixed mortar system can be powered by motor to apply friction and pressure to the oil seeds to release oil at the base of the mortar. The oil was filtered to remove small dust particles. Finally, the refined oil is used for preparation of biodiesel by transesterification process.

III B. Transesterification process: The transesterification is the process used for preparation of Biodiesel using vegetable oils. It breaks down the molecules of vegetable oils into constituent molecules forming biodiesel as the main product and glycerin as the by product. Transesterification reaction is a stage of converting oil or fat into methyl or ethyl esters of fatty acid, which constitutes to biodiesel. Biodiesel (methyl ester) is obtained through the reaction of triglycerides of vegetable oils with an active intermediary, formed by the reaction of an alcohol with a catalyst. The general reaction for obtaining biodiesel through transesterification is:



In this research work select a simple chemical reaction as base catalyzed transesterification process for the roselle seed oil for biodiesel. The production of biodiesel by transesterification of vegetable oil uses the following steps:

- Mixing of alcohol and catalyst:** Potassium hydroxide (KOH) is used as alkaline catalysts with methanol (CH₃OH) for production of biodiesel.
- Reaction:** The alcohol/catalyst mix is charged into a closed reaction vessel and the vegetable oil is heated to the boiling temperature of the alcohol (normally 50 to 60 °C). The reaction mixture is added slowly to heated roselle oil and continuously stirred by magnetic stirrer for 5 to 10 min. after this solution is rest for 24hr in separating funnel.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 9, September 2017



Fig 3.1: Heating of roselle oil Fig 3.2:Separating of Biodiesel

- c) **Separation of glycerin and biodiesel:**Once the reaction is complete, two major products are produced: glycerin and biodiesel (methyl ester). Mixture separates into an upper layer of methyl esters and a lower layer of glycerol diluted with un-reacted methanol. The quantity of produced glycerin varies according to the vegetable oil used, the process used, and the amount of excess alcohol used.
- d) **Methyl ester washing:**The methyl ester produced from the reaction is then washed with hot water and separated out buy centrifugation.
- e) **Heating of biodiesel:**After washing your biodiesel, it will usually have a slightly hazy or cloudy appearance to it, this is because there are micro droplets of water still in suspension in your just washed fuel. We must remove that water before using it in a diesel engine or risk damaging the engine.

The quantity of Biodiesel produced and by-products as glycerol from 500ml of Roselle oil is listed below.

Oil	Quantity of oil (ml)	Methanol (ml)	KOH (gram)	Biodiesel Obtained (ml)	Glycerol (ml)
Roselle	500	150	10	350	300

Table 3.1: Quantity of raw material required and quantity of final product obtained.

III C Properties of biodiesel used in test engine:CI engines are basically designed to run with Diesel as fuel, therefore it is necessary that the alternative fuel have properties close to that of diesel, because the large variation in properties of fuel may lead to erratic running of engine and may cause damage to the engine and poor performance. The below table shows the properties of Diesel, Roselle Biodiesel, Methanol and Ethanol.

Property	Diesel	Roselle Biodiesel	Methanol	Ethanol
Density(kg/m ³)	840	854	796	792
Viscosity(mm ² /s)	4.4	5.21	0.6	1.1
Calorific value(KJ/kg)	43910	29314.27	19678	26795
Flash point(°c)	65	172	11.11	12.77

Table 3.2: Property test results of Diesel, Roselle Biodiesel, Methanol, Ethanol.

III D. Preparation of Blends

Total Eight different blends are produced and properties testing is done for all blend sample. The blends are;

- **Blend A** (5% Methanol + 5% Roselle biodiesel + 90% Diesel),
- **Blend B** (5% Methanol + 10% Roselle biodiesel + 85% Diesel),
- **Blend C** (5% Methanol + 20% Roselle biodiesel + 75% Diesel),
- **Blend D** (5% Methanol + 30% Roselle biodiesel + 65% Diesel),

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

- **Blend E** (5% Ethanol + 5% Roselle biodiesel + 90% Diesel),
- **Blend F** (5% Ethanol + 10% Roselle biodiesel + 85% Diesel),
- **Blend G** (5% Ethanol + 20% Roselle biodiesel + 75% Diesel),
- **Blend H** (5% Ethanol + 30% Roselle biodiesel + 65% Diesel),

The below table shows the properties of six different blends.

Type of Blend	Amount of Methanol/Ethanol over 1000 ml	Amount of Biodiesel over 1000 ml	Amount of Diesel over 1000 ml	Density (kg/m ³)	Calorific value (KJ/kg)
Diesel	-----	-----	1000	840	43910.00
Blend A	50	50	900	850.1	41968.67
Blend B	50	100	850	849.7	41238.83
Blend C	50	200	750	848.3	39779.25
Blend D	50	300	650	842	38319.70
Blend E	50	50	900	850.2	42324.46
Blend F	50	100	850	849.5	41594.67
Blend G	50	200	750	848.1	40135.10
Blend H	50	300	750	841.8	38675.53

Table 3.3: Properties of eight different blends

III E. Performance test

In this section, our point is to test the performance of the biodiesel from Roselle oil at various blend ratios with diesel using the Compression Ignition Engine. before perform the test, essential discussion is required about experimental setup, components, parts, the engine performance parameters etc, which we going to use in this thesis work are:

- **Experimental set-up**
The test set-up consists of a four-stroke diesel engine connected to a hydraulic dynamometer brakethrough a flexible coupling. The engine is water cooled type and therefore both load test aswell as heat balance sheet can be conducted. It runs at a maximum speed of 1500 rpm. Thetest rig is complete with base, air measurement system, and fuel measurement system andtemperature measurement arrangement using thermocouples to measure temperature digitally.The various components of experimental setup are described below.
- **The engine:**The engine used to carry out experimentation is a single cylinder, four strokes, vertical, watercooled, Kirloskar make CI engine.

Make	Kirloskar
Speed	1500 rpm
No. of cylinder	01
Compression ratio	16.5:1
Bore	80 mm
Stroke	110 mm
Brake Horse Power	5 H.P.
Cooling	Water cooled
Loading	Hydraulic Dynamometer

Table 3.4: Specification of Engine:

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017



Fig 3.1: Diesel Engine

Fig 3.2: Dynamometer

- **Dynamometer**

The hydraulic dynamometer is used for the experiments. Loads increased by closing the valve of dynamometer loads calculated by spring balance and the distance between dynamometer shafts centre to centre of spring balance in meters is 0.34. This distance can be used for calculation of torque.

III F. Performance parameter:

Engine performance is an indication of how well the engine performs its assigned task, i.e. the conversion of the chemical energy contained in the fuel into the useful mechanical work. The engine performance parameters, which we going to use in this thesis work are; Brake power, Brake thermal efficiency, Brake Specific fuel consumption, Brake Specific Energy Consumption.

III G. Formulation:

Formula used for calculation of various parameters is described below:

1) Quantity of fuel used,

$$m_f(\text{kg/sec}) = \frac{X(\text{ml})}{t(\text{sec})} \times \frac{S.G.}{1000}$$

Where X (ml) = Volume of fuel consumed

“t” = time taken for X(ml) of fuel consumed

S.G. = Specific gravity of fuel

2) Brake power output,

$$B.P. = \frac{2\pi NT}{60000} (\text{KW})$$

Where, T = Torque in (N-m) = $P \times r \times 9.81$

P = Net load in (kg)

r = Distance between dynamometer shaft centre of spring balance (meter)

N = Rated RPM of the engine

3) Brake specific fuel consumption,

$$B.S.F.C. = \frac{m_f \times 3600}{B.P.} (\text{kg/Kw-hr})$$

4) Heat Supplied to the engine,

$$Q_f = m_f \times C.V. (\text{KW})$$

Where, C.V. = Calorific Value of fuel (KJ/kg)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

5) Brake Thermal Efficiency,

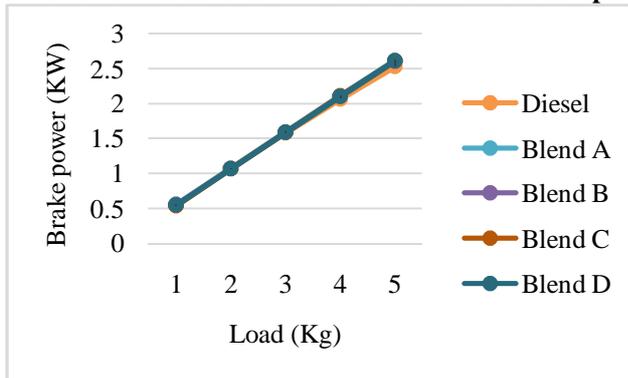
$$\eta_{BTE} = \frac{B.P.}{Q_f}$$

6) Brake specific Energy Consumption,

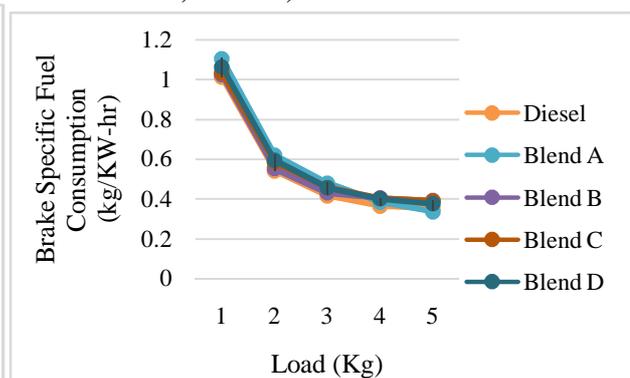
$$B.S.E.C. = \frac{B.S.F.C. \times C.V.}{1000} \text{ (MJ/Kw-hr)}$$

IV. EXPERIMENTAL RESULTS AND DISCUSSION

IV A. Performance Characteristics for Diesel as compared with Blend A, Blend B, Blend C and Blend D



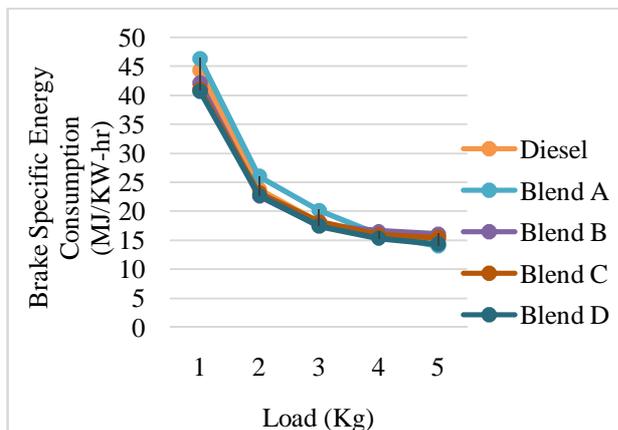
Graph 4.1 BP v/s Load



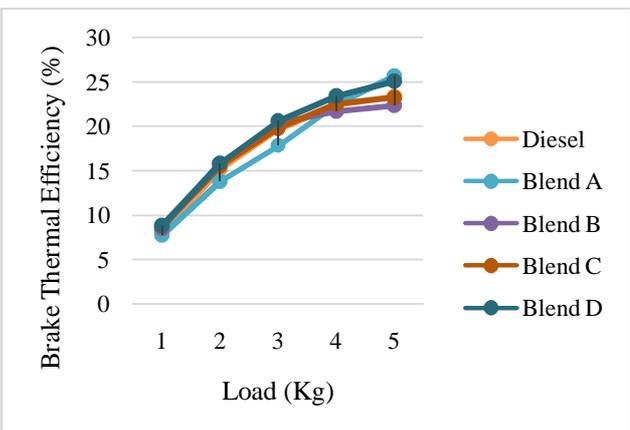
Graph 4.2 BSFC v/s Load

Graph 4.1 shows the variation of brake power with respect to load for different biodiesel blends. The results show that Brake power of biodiesel blends, Blend A, Blend B, Blend C and Blend D shows approximately same value and it is very close to diesel. But when load increased BP of all Four Blends indicates somewhat more value of BP as compare to Diesel.

Graph 4.2 shows the variation of brake specific fuel consumption with respect to load for different blends. The brake specific fuel consumption for all blends of biodiesel shows the same trend as diesel fuel whereas the BSFC for Blend B, Blend C and Blend D is more than the diesel and Blend A, but BSFC for Blend A is even less than diesel at middle load and at higher load conditions.



Graph 4.3 BSEC v/s Load



Graph 4.4 BTE v/s Load

International Journal of Innovative Research in Science, Engineering and Technology

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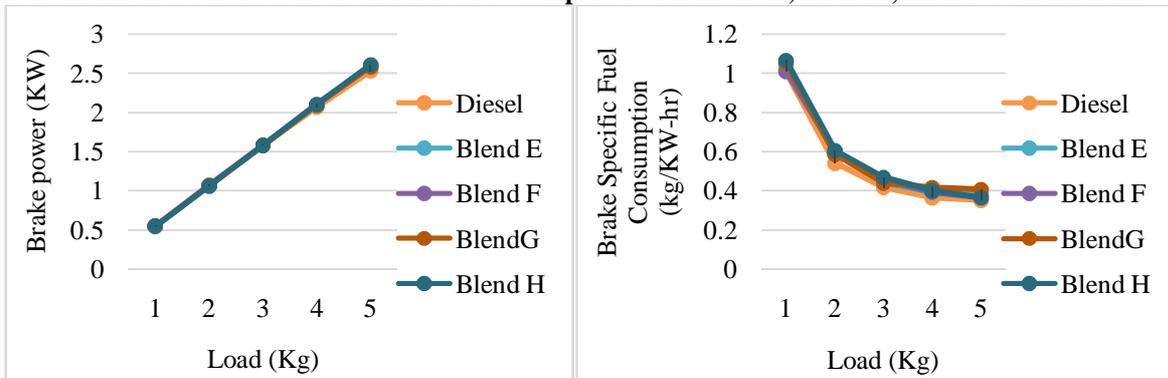
Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Graph 4.3 shows the variation of brake specific energy consumption with respect to load for different blends. The BSEC for Blend B, Blend C and Blend D is less than Diesel at low load condition. At middle loads Blend D shows the less brake specific energy consumption with respect to all but at higher loads BSEC of Blend A shows least.

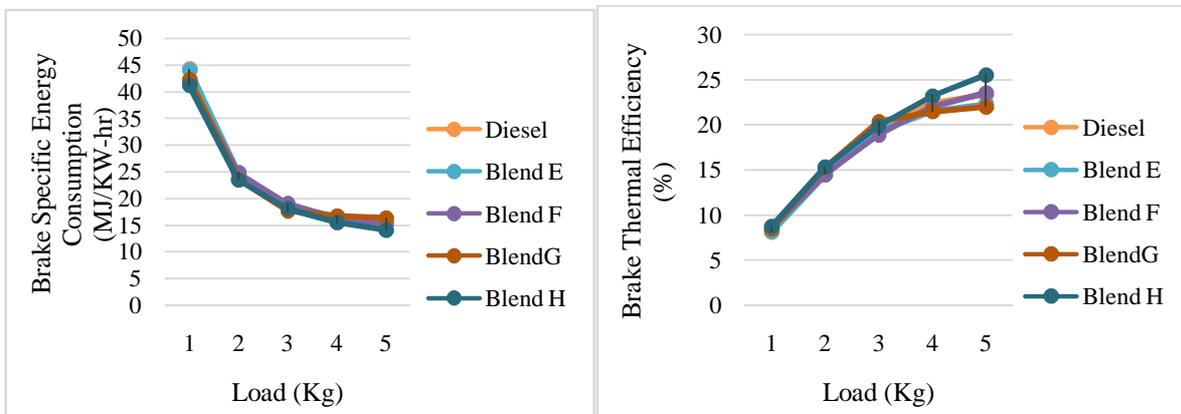
Graph 4.4 shows the variation of brake thermal efficiency with respect to load for different blends. The BTE for Blend A is less than among Blend B, Blend C and Blend D. But BTE for Blend A is even less than diesel at middle load condition but at higher loads BTE of Blend A is highest.

IV B. Performance Characteristics for Diesel as compared with Blend E, Blend F, Blend G and Blend H



Graph 4.5 shows the variation of brake power with respect to load for different blends. Brake power of all biodiesel blends follows same trend as diesel. When the load is increased brake power of Blend H shows higher value than the diesel and Blend E, Blend F and Blend G at higher loads.

Graph 4.6 shows the variation of brake specific fuel consumption with respect to load for different blends. Pure Diesel shows the least brake specific fuel consumption as compared to Blend E, Blend F, Blend G and Blend H. And BSFC for Blend H is close to diesel when compared with Blend E, Blend F and Blend G at higher loads.



Graph 4.7 shows the variation of brake specific energy consumption with respect to load for different blends. The brake specific energy consumption for all blends of biodiesel follows the same trend as diesel fuel at low load. Blend H shows the least brake specific energy consumption as compared to Diesel and Blend E, Blend F, Blend G at middle load and also at higher load.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 9, September 2017

Graph 4.8 shows the variation of brake thermal efficiency with respect to load for different blends. Blend H shows the highest brake thermal efficiency as compared to The Diesel and Blend E, Blend F, Blend G when the Load is increase.

V. CONCLUSION

Roselle seeds based biodiesels seems to be a bit superior to other biodiesels. With about 30-35% of 'oil value', roselle oil shows good conversion rate to bio diesels. A litre of Roselle seed based vegetable oil converts to approximately 700 ml of bio fuels apart from glycerine. And the most satisfactory part is that when mixed 5% of Methanol or Ethanol with Diesel, the performance of a diesel engine could be increased, especially in the high load conditions. The overall conclusions of the experiment could be summarised by the following points:

- When diesel fuel compared with Blend A, Blend B, Blend C and Blend D; Blend 'A' shows better performance than other blends (Blend B, Blend C and Blend D). Blend 'A' has the least Brake Specific Fuel Consumption, Brake Specific Energy Consumption and highest Brake Power, Brake Thermal Efficiency among all.
- When diesel fuel compared with Blend E, Blend F, Blend G and Blend H, Blend 'H' shows better performance than other blends (Blend E, Blend F and Blend G). Blend 'H' has the least Brake Specific Energy Consumption, highest Brake Power and highest Brake Thermal Efficiency among all blends when load is increases but pure Diesel shows better Brake Specific Fuel Consumption than other blends.

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