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# EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE FUELED WITH PALMYRA BIODIESEL

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***Abstract:*** The constant increase in the consumption of fossil fuels is consequent upon the ever-increasing population in the present days. The greenhouse gas emissions from these fossil fuels are constantly degrading the planet and causing global warming and other pollutant emission-related problems. As such, the situation demands an alternate source of energy that can be used to overcome the forecasted future energy crisis. In addition, if the energy source is clean and renewable, it will also reduce environmental issues. In this quest for an alternate and renewable energy resource, scientists have come up with a variety of options among which biodiesel-diesel blends as alternative fuels have become a popular option and have the attention of many researchers. In this work biodiesel production from palmyra seeds oil has been synthesized by a transesterification process with the influence of catalyst concentration, methanol is used to produce the palmyra oil methyl ester (POME) from the palmyra crude oil which is extracted from the palmyra seeds by the application of mechanical pressing operation. The extracted palmyra oil methyl ester is then blended with diesel and preliminary tests are conducted with palmyra oil methyl ester blends (POME10, POME20, POME30, POME40) on a 4-stroke single-cylinder diesel engine at constant speed by varying loads from no load to full load conditions and observe the engine 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 ($CO_2$), hydrocarbons (HC), nitrogen oxides (NOx) and plotted different graphs.

***Keywords:*** Biodiesel, Palmyra oil methyl ester (POME), Palmyra seeds, Fossil fuels, Energy.

## 1. INTRODUCTION

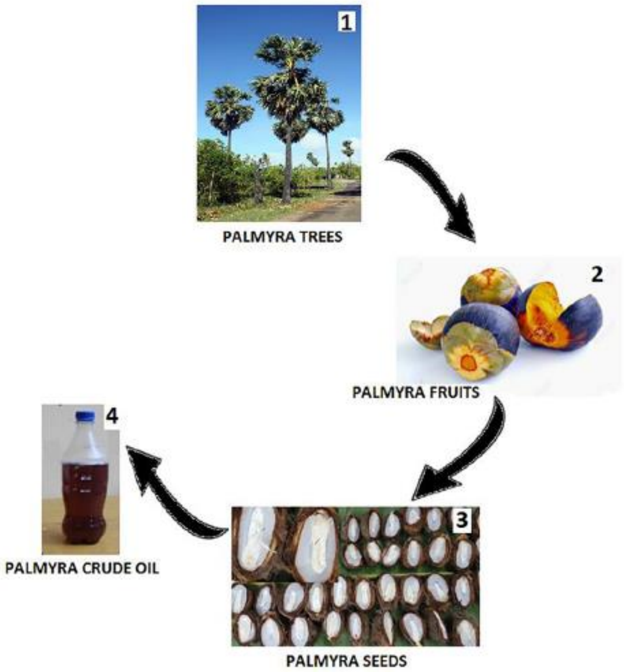
The exponential increase in energy demand in the past few decades are be due to rapid urbanization and industrialization. Urbanization of developing countries practically relies on energy (i.e., renewable and non-renewable) sources. Fossil fuels are the primary source of fulfilling such energy requirements. Industries and transport sectors are dependent primarily on fossil fuels. The exhaustion of fossil fuels in the next few decades could increase costs and the associated impact on global warming and greenhouse gas emissions are the primary reasons that require extensive research on alternate fuels for the future. Biodiesel seen be the potential alternative to diesel fuel that compensates for high energy demand. In addition, the use of biodiesel does not seek a major modification to the existing diesel engine. Biodiesel production from renewable energy sources (oils derived from plant and animal fat) possesses excellent features such as biodegradability, nontoxic, carbon neutral, and eco-friendly. In recent years, edible (soybean, sunflower, coconut, palm, pine, and so on) and non-edible (mahua, karanja, jatropha, cotton seeds, algae, etc.) oils are used as a potential source for the production of biodiesel. India has the world's second-largest population and the fulfillment of huge energy demand with edible and non-edible oils has been criticized due to its low sustainability, shortfall of agricultural land, and conflict with food and fiber production. The feedstock (raw material) price is a key factor that accounts for approximately 70- 95% of total biodiesel production cost. Edible and non-edible oils grown particularly for biodiesel production are treated as uneconomical due to their high raw material cost. fish oil (i.e., residue after extraction of omega-3 fatty acids) is used as a source for biodiesel production and is treated sustainably due to its minimal processing steps. In comparison with conventional diesel fuels, biodiesels promote more complete combustion and thus effectively reduce emissions of particulate matter (PM), carbon monoxide (CO), and smoke. However, the use of biodiesel increases the content of Nitrogen oxides (NOx) in combustion products. This higher NOx emission is due to the comparatively high temperature inside the cylinder owing to the combustion of biodiesel and the higher oxygen content of the fuel. Biodiesel is considered one of the promising alternative resources for diesel engines, especially from non-edible oil feedstock as well as its potential to be a part of a sustainable energy mix in the future. The advantages of non-edible oils as diesel fuel are liquid nature portability, ready availability, renewability, higher heat content, higher flash point, higher cetane number, lower sulfur, and aromatic content as well as biodegradability. The biodiesel produced from non-edible feedstock as well as biomass can overcome the socio-economic disadvantages of current biodiesel technology and be able to address many of the challenges of climate change and the energy crisis. So, we experiment with palmyra biodiesel on a 4-stroke diesel engine to study performance and emission characteristics. In the experiment, we test the performance and emission characteristics of palmyra biodiesel with different blends of palmyra biodiesel POME10, POME20, POME30, and POME40. The tests are conducted on a 4-stroke single-cylinder diesel engine at constant speed by varying loads from no load to full load conditions and the readings are analyzed to find which blend gives the best performance and low emissions.

### 1.1 PALMYRA CRUDE OIL EXTRATION

The palmyra palm's name derives from the Greek words "Borasus" which means "fruit with a leather covering" and "Flabellifer" which means "fan-bearer". Female inflorescences produce spherical fruits ranging in diameter from 15 to 20 cm and averaging 1.5 kilograms. Each fruit has one to three hard-coated seeds, rarely four, surrounded by yellowish edible mesocarp pulp. The process of palmyra crude oil extraction from the palmyra fruits is shown in figure 1. When a seed is young, its gelatinous endosperm is delicious and, it becomes hard, ivory-like, and hollow as it matures. Eventually, the immature seed

Figure 1: Process of palmyra crude oil extraction

hardens and generates a fibrous kernel that aids in the extraction of oil. Palmyra palm nuts include 0.08 percent ash, 0.18 percent protein, 0.26 percent fiber, 0.09 percent lipids, and 26.18 percent amylase. Annually, 100 million Palmyra fruits are harvested worldwide; however, only around 5 to 10 million are consumed; the remaining is dried. Palmyra oil is derived from dried palmyra seed kernels




manually or mechanically. Oil extraction methods include mechanical extraction, solvent extraction, and enzymatic extraction. The various physicochemical properties are determined as per the ASTM standards and found higher viscosity for the palmyra oil. Then the extracted oil from palmyra seeds is transesterified to produce palmyra oil methyl ester'(POME).

### LITERATURE SURVEY

**Gaura Pual et, al [1]** In this work we observe that the effect of the addition of jatropha biodiesel to mineral diesel on the performance and emission characteristics of a conventional engine has been experimentally investigated and compared with simulated data using Diesel-RK software. In respect of emission characteristics, NOx emission is found to increase with the load as well as the use of biodiesel in both experimental and simulation studies. Combustion characteristics show an increase in peak cylinder pressure and a decrease in ignition delay period with the increase in fuel share in the blends, whereas the emission of NOx and $CO_2$ increases. Smoke and PM emission decreases for the same.

**L.Narsinga Rao et, al [2]** From this work we know that biodiesel obtained from various renewable sources has been recognized as one of the alternative fuels due to its biodegradability, high cetane number, no sulfur emissions, and low volatility. Biodiesel derived from non-edible feedstocks such as linseed oil is reported to be a feasible choice for developing countries including India where the consumption and cost of edible oil are very high. The present work aims to optimize biodiesel production from linseed oil through the transesterification process. The various performance and emission parameters like brake power (BP), brake specific fuel consumption (BSFC), Brake thermal efficiency (BTE), CO emissions, $CO_2$ emissions, HC emissions, NOx emissions, and smoke were evaluated at different loads in a 4 stroke, single cylinder Diesel engine. These performance and emission parameters of diesel fuel were compared with that of B25, B50, B75, and B100.

**Dr.K. Prasada Rao et, al [3]** In this work we know that the rapid depletion of petroleum fuels and their ever-increasing costs and concern for vehicular emissions have led to an intensive search for alternative fuels. Bio-diesel is an attractive alternative fuel that is renewable, non-toxic, and reduces carbon monoxide and hydrocarbon emissions due to its higher content of oxygen. At present, biodiesel is commercially produced from refined edible vegetable oils such as rice bran oil (RBO), sunflower oil, palm oil, and oil, etc. The various parameters that have been considered for the research in this direction with edible oil have yielded encouraging results with rice bran oil which is edible and has been considered as an alternative fuel. The exhaust gas emissions are reduced with an increase in biodiesel concentration. The experimental results proved that rice bran oil can be substituted for diesel without any engine modification as a fuel.

**S.C. Borse et, al [4]** In this work therefore we found that biodiesel is becoming popular nowadays due to the high cost of petrochemical products we know that these sources are finite in number as they are going to finish or reduce day by day. The experimental investigation has been carried out in a diesel engine at variable loads& constant RPM concerning engine performance parameters 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 ($CO_2$), Hydrocarbons (HC), Nitrogen Oxides (NOx) Sulphur Oxides (SOx) and plotted different graphs.

**M.M.K. Bhuiya et, al [5]** From this research paper we find that extensive use of fossil fuels is depleting its reserve and producing harmful emissions causing environmental issues. Currently, biodiesel is mainly produced from conventionally grown edible oil plants thus leading to a competition of usage of food versus fuel. The increasing criticism of the sustainability of first-generation biodiesels (those derived from edible oils) has raised attention to the use of so-called second and third-generation biodiesels. The second-generation biodiesel includes non-edible vegetable oils, waste cooking oils as well as animal fats. These aspects include different sources of biodiesel feedstocks, biodiesel conversion technology, and performance and emission characteristics of second-generation biodiesel.

**Dr.K. Prasada Rao et, al [6]** In this present work Experimentation has been carried out with the additive Diethyl Ether (DEE) and Mahua biodiesel in diesel engines to replace conventional fuels. This idea is being floated with the objective that low-temperature combustion can be maintained and thereby reducing NOx emission. Biodiesel application reduces other emissions substantially, but for NOx. This is because of the reason that transesterified vegetable oil contains oxygen in its molecular structure. In this study, DEE was mixed with the Mahua methyl ester (MME) at different proportions such as 3%, and 5%, and tested at different loads on the diesel engine. Emission levels are decreased substantially with a 15%Eblend with MME at full load.

**Manzoor Sheikh et, al [7]** In this research paper say that biodiesel is an alternative to petroleum-based fuels derived from a variety of feedstocks, including vegetable oils, animal fats, and waste cooking oil. At present, biodiesel is mainly produced from conventionally grown edible oils such as soybean, rapeseed, sunflower, and palm. The cost of biodiesel is the main obstacle to the commercialization of the product. Biodiesel produced from edible oils is currently not economically feasible. On the other hand, extensive use of edible oils for biodiesel production may lead to a food crisis. These problems can be solved by using low-cost feedstocks such as non-edible oils and waste cooking oils for biodiesel production. This paper reviews numerous options of non-edible oils as substantial feedstocks, biodiesel processing, and the effect of different parameters on the production of biodiesel.

**A.M. Liaquat et, al [8]** The present work investigates the engine performance parameters and emissions characteristics for direct injection diesel engine using coconut biodiesel blends without any engine modifications. As a result of investigations, there has been a decrease in torque and brake power, while an increase in specific fuel consumption has been observed for biodiesel blended fuels over the speed range compared to net diesel fuel. Moreover, a reduction in sound level for both biodiesel blended fuels has been observed when compared to diesel fuel. Therefore, it can be concluded that CB5, CB15 can be used in diesel engines without any engine modifications and have beneficial effects both in terms of emission reductions and alternative petroleum diesel fuel.

**Swarup Chandran et, al [9]** In this work the better alternative to petroleum fuels is Karanja oils which are mono-alkyl esters of long-chain fatty acids derived from vegetable oils and animal fats. They are produced by transesterification in which oil or fat is reacted with an alcohol in presence of a catalyst. In this investigation, the viscosity of Karanja oil for the CI engine was decreased by blending with diesel. Significant improvement in engine performance was observed compared to neat Karanaja oil as a fuel.

**Dr.K. Prasada Rao et, al [10]** This research article aims to study the optimization of performance parameters to improve diesel engine efficiency. An attempt has been made to solve the correlated multiple criteria optimization problem of performance parameters of diesel engine. The process environment has been assumed to consist of four variables load, time taken for 10cc fuel consumption, type of fuel, and valve opening position. Taguchi method has been adopted to convert multiple objectives of the optimization problem into a single objective function. Taguchi's technique has been applied to determine the optimal setting, which can maximize The output parameters B.P, Break Thermal Efficiency, $CO_2$%, and can minimize CO%, HC, and O2%. The result of this optimization technique has been imported to that of the grey Taguchi technique, another approach that is widely used for solving multi-criteria optimization problems. A confirmatory test showed satisfactory results by an Artificial neural network in MATLAB.

**Arun A Suldhal et, al [11]** From this work we conclude that depletion of the energy source has become a major concern. The need for an alternate source of energy is a must to solve the problem of energy scarcity. Vegetable oils have emerged as one of the promising fuels that can be used commercially in the coming years. These oils produce less emission and are renewable in nature. A slight increase in brake thermal efficiency is observed with a 50% blend. Exhaust emissions of biodiesel are reduced compared to diesel fuel.

**Dr.K. Prasada Rao et, al [12]** In this investigation, Mahua methyl ester along with diethyl ether (DEE) is used as fuel for the single-cylinder DI-Diesel engine, and an analysis of performance and emission is presented. This paper presents an investigation into the effect of biodiesel blending on the performance and emission characteristics of diesel engines. The effect of fuel additives was to control the emission from diesel engines and to improve their performance. In this experiment, DEE was mixed with the MME at different proportions such as 3%, 5%, 10%, and 15% tested at different loads on the diesel engine. The results obtained from the engine tests have shown a significant reduction in NOx emissions, especially for DEE addition of more than 10% on a volume basis, and a little decrease in the smoke of DEE blends compared with neat MME.

**Bhupendra Singh Chauhan et, al [13]** From this work researchers and experts have concluded that biodiesel along with higher alcohol can help in improving the performance and depreciating harmful exhaust gases in a diesel engine. In the study, blends of diesel, rice bran biodiesel, and n-butanol were tested in a single-cylinder, small utility diesel engine with a rated power output of 3.73 kW to compare them with baseline diesel. The study shows that blends of these fuels can be used as fuel in a regular diesel engine without any change in the engine.

**Dr.P. Vijaya Kumar et, al [14]** In this present work we observe that diesel engines are majorly used in the transportation sector because of lower specific fuel consumption and superior efficiency compared to S.I engines. In the present work, biodiesel was produced from Palmyra oil. In this present work, investigations were carried out to study the performance, emission, and combustion characteristics of Palmyra oil. The results were compared with diesel fuel and the selected Palmyra oil fuel blends. To increase the engine performance parameters and to decrease the exhaust gas emissions with increased biodiesel concentration. The experimental results show that the use of biodiesel in compression ignition engine is a viable alternative to diesel.

**Lankapalli Sathya Vara Prasad et, al [15]** The current work investigates the influence of compression ratio and EGR on the various characteristics of diesel engine operated with a 20% Palmyra oil methyl ester (POME 20) blend at different load conditions. Preliminary tests are conducted with blends of palmyra oil methyl ester (POME 10, POME 20, and POME 30) on diesel engine working at standard conditions and it is found improved engine performance and reduce emissions for POME20. In this context, the present work focuses on the influences of distinct compression ratios (16:1, 18:1, and 20:1) on the diverse characteristics of diesel engines fuelled with the POME 20 blend. The test results revealed that the addition of 10% EGR to the POME 20 found a 23% reduction of NOx emissions when compared to POME 20 operated at standard operating conditions.

**Perumalla Vijaya Kumar et, al [16]** An experimental study has been conducted to enhance the engine characteristics of Palmyra oil methyl ester (POME) blended diesel by the approach of varying the compression ratio and different EGR rates along the amalgamation of Nano additives in the fuel. While the added 6% and 12% of EGR to POME20-CR20 results showed a reduction in the NOx emission compared to diesel. However, the result of amalgamating the fuel with alumina and ceria nanoparticles has given encouraging BSFC results, compared to diesel fuel POME20 at CR20 and 6% of EGR added with 100 ppm of Al2O3. Overall it can be highlighted that with an aid of combined engine design (CR), control (EGR rate) and fuel reformulation approach the efficient utilization of POME biodiesel blended diesel fuel in the CI engines has been facilitated.

**Dr.K. Prasada Rao et, al [17]** The present work aims to suppress the crankcase oil dilution (Choice proposed: rapid swirl in pre and main combustion chambers prevent leakage of fuel in liquid form into crankcase in the case of IDI engine) and exhaust gas component reduction like NO and HC by limiting the combustion temperatures. Methanol encourages low-temperature combustion due to its higher latent heat and lower Cetane number and dilutes the biodiesel because of its lower viscosity and density. But it is being tested oil esters in the present study with an additive to create low-temperature combustion and to reduce emissions that form at higher temperatures. 1%,2%,3%,4%, and 5% and tested at different loads on IDI Diesel engine. The performance of the engine is compared with neat diesel as reference fuel keeping in view engine efficiency and exhaust emissions.

**R. Sam Sukumar et, al [18]** In This work say that Diesel is the major source of transportation and power generation but the burning of diesel causes the production of dangerous emissions which results in causes of air pollution and also diesel becoming abundant. In the present work, the neat cotton seed oil is converted into their respective methyl ester of cotton seed transesterification process. An experimental investigation was carried out to compare performance and emission analysis for several blends such as (CBD20, CBD40, CBD60, CBD80, and CBD100) with diesel on single cylinder four stroke variable compression ratios diesel engine. The performance and emission results are compared with baseline test results. For standard compression ratio at full load of the engine cotton biodiesel with 20% blend (CBD20) shows optimum results.

**Pilli Uday Kumar et, al [19]** Due to low specific fuel consumption and supreme power efficiency, it has vast applications compared to other fuels but NOx and smoke have seriously caused a problem to the environment. For this Palmyra, oil has the same properties as diesel with varying compression ratios that affect the performance, and emission characteristics are evaluated. Then increases EGRs of 0%,5%, and 10% and studied performance and emission characteristics. The influence of Palmyra oil like compression ratio on fuel consumption, brake thermal efficiency, and exhaust gas emissions like NOx and HC has been investigated. The configuration which achieved the highest Break thermal efficiency is compared to the common diesel engine configuration used.

**K. Sivakumar et, al [20]** Biodiesel is an alternative fuel to conventional petroleum diesel fuel and it`s derived from renewable resources, such as non-edible vegetable oils. The non-edible vegetable oil from seeds such as jatropha and Karanja (Pongamia) should be converted to a fuel commonly referred to as “Biodiesel”. Without an engine, modifications are required to use biodiesel in place of traditional petroleum-based diesel fuel. This interest is based on the number of properties of biodiesel including the fact that it is produced from renewable domestic resources, is biodegradable, and mainly reduces exhaust emissions. The physicochemical properties of Karanja oil were assessed for their potential in biodiesel. And also the properties of Karanja biodiesel and petroleum diesel were compared.

According to the journals we studied, we perform an Experimental Investigation on the Performance and Emission Characteristics of a Diesel Engine Fueled with Palmyra Biodiesel. To get a bio-diesel with good performance and less emission. In the experiment, we test the performance and emission characteristics of Palmyra Bio-Diesel with different blends of POME10, POME20, POME30, and POME40. The tests are conducted on a 4-stroke single-cylinder diesel engine at constant speed by varying loads from no load to full load conditions and the readings are analyzed to find which blend gives the best performance and low emissions.

## 2. METHODOLOGY

### 2.1 TRANSESTERIFICATION

Transesterification is most commonly used for the production of biodiesel from raw crude oil. In the transesterification process, an ester compound is exchanged for 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 in figure 2. Biodiesel is nothing but the fatty acid methyl esters (FAME) derived from the. Transesterification of triglycerides (vegetable oils or animal fats) with alcohol and a suitable catalyst. After this process biodiesel is mixed with different percentages of diesel so that it can run in a diesel engine without any engine issues as neat biodiesel has some engine issues and not much modification in the diesel engine. Biodiesel is obtained from different types of triglyceride sources such as palmyra crude oils (e.g., edible oil, non-edible or waste oils), and 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 identified to be a good feedstock for biodiesel. Alcohol such as methanol, ethanol, and isopropyl alcohol can be used in the transesterification process for the production of biodiesel. In most 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 the transesterification process depends upon different types of parameters such as reaction temperature and pressure, reaction time, rate of agitation, type of alcohol used, and a 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 affect the physical and chemical properties of the feedstock oil.

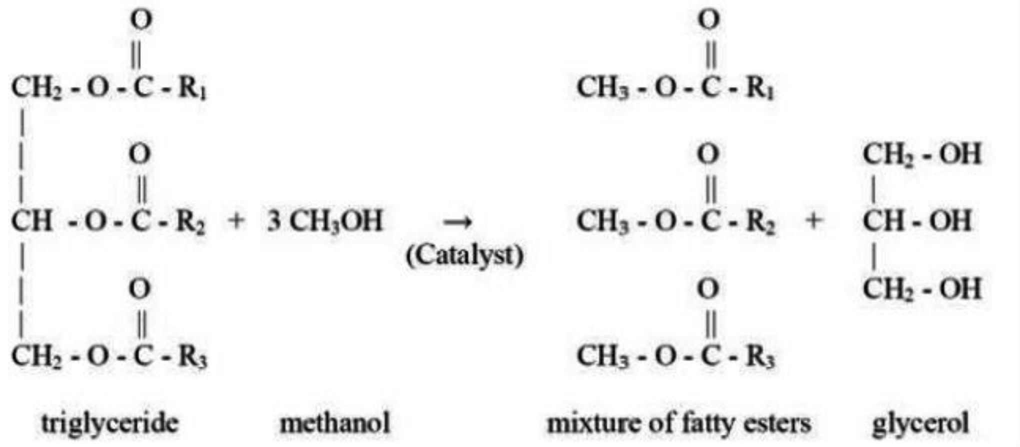


Figure 2: Transesterification reaction

### 2.2 PALMYRA BIODIESEL PREPRATION

The palmyra crude oil is extracted from the palmyra seeds by the application of mechanical pressing operation. Crude oils derived from palmyra seeds have high viscosity, hence transesterification process is used to reduce the viscosity and palmyra biodiesel is obtained by the technique. Then the palmyra crude oil is heated to a temperature of 60°C to prepare the crude oil for the transesterification process. After the pre-treatment of crude oil, the catalyst concentration and methanol are used to produce the palmyra oil methyl ester. The mixture is stirred on a magnetic stirrer until the crude oil perfectly mixes with the catalyst concentration and methanol. The mixture is allowed to settle for 24 hours to form layers of glycerin and biodiesel to develop. During gravity separation, the glycerin forms a lower layer is settle down at the bottom of the beaker and the biodiesel stays at the top of the beaker. The biodiesel above the glycerin is separated from the glycerin and washed with distilled water to clean any impurities in the oil or glycerin left over. Now the oil is heated to a temperature of $100^0$C to dehydrate the oil the distilled water gets evaporated and pure biodiesel is available. After the preparation of biodiesel, the biodiesel is blended with diesel at different percentages to get different blends of POME10, POME20, POME30, and POME40. These blends are used for performance and emission tests on the diesel engine. The Framework for biodiesel conversion from palmyra crude oil is shown in figure 3. Also, the different properties of palmyra biodiesel and different blends of palmyra biodiesel are in table 1.

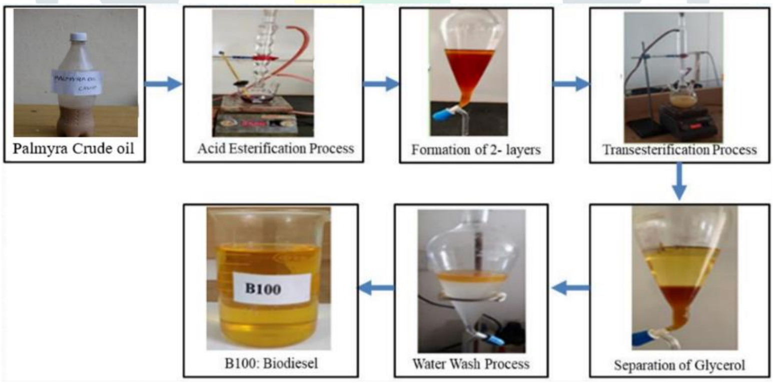



Figure 3: Framework for biodiesel conversion from palmyra crude oil

### 2.3 PREPARATION OF BIODIESEL BLENDS

- **POME 10:** It is prepared by taking 90% of Diesel + 10% of palmyra biodiesel.
- **POME 20:** It is prepared by taking 80% of Diesel + 20% of palmyra biodiesel.
- **POME 30:** It is prepared by taking 70% of Diesel + 30% of palmyra biodiesel.
- **POME 40:** It is prepared by taking 60% of Diesel + 40% of palmyra biodiesel.

The prepared palmyra biodiesel blends are POME10, POME20, POME30, and POME40 as shown in figure 4. The fuel properties of the diesel, palmyra biodiesel, and blends are determined experimentally using the various fuel apparatus in the fuels engineering lab, and the results obtained are tabulated in table 1. The following properties are determined.

**Flash point:** It is the lowest temperature at which a liquid can form an ignitable mixture in air near the surface of the liquid. The lower the flash point, the easier it is to ignite the material.

**Fire point:** The fire point of a fuel is the lowest temperature at which the vapor of that fuel will continue to burn for at least 5 seconds after ignition by an open flame. At the flash point, at a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire.

**Specific gravity:** It is the ratio of the density of any substance to the density of some other substance taken as standard, with water being the standard for liquids and solids, and hydrogen or air being the standard for gases.

**Calorific value:** The amount of energy produced by the complete combustion of a material or fuel. Measured in units of energy per amount of material, e.g., kJ/kg.

**Viscosity**: It is a measure of a fluid's resistance to flow.

Table 1: Properties of Diesel, Palmyra Biodiesel, and their Blends

| **Properties** | **Tests Procedure** | **Diesel** | **Palmyra Biodiesel** | **POME10** | **POME20** | **POME30** | **POME40** |
|---|---|---|---|---|---|---|---|
| Density ($kg/m^3$) @ $15^0$ C | ASTM D 1298 | 833 | 876 | 832 | 837 | 842 | 847 |
| Viscosity (cSt) @ $40^0$ C | ASTM D 445 | 3.3 | 7.8 | 3.75 | 4.2 | 4.65 | 5.92 |
| Calorific Value (kJ/kg) | ASTM D 4809 | 42500 | 37,710 | 42276 | 41652 | 41028 | 40584 |
| Flashpoint ($^0$C) | ASTM D 93 | 54 | 172 | 75 | 86 | 93 | 98 |
| Fire point ($^0$C) | ASTM D 93 | 59 | 177 | 81 | 91 | 97 | 104 |


Figure 4: Diesel, Biodiesel, and Blends

### 3. EXPERIMENTAL SETUP

The experimental setup consists of a single-cylinder diesel engine with a dynamometer, exhaust gas analyzer, and smock analyzer. The engine test rig is directly coupled with a brake drum and a rope brake around the drum. One end of the rope is connected to a spring balance and the other end is to a weight platform. The engine load can be varied by adding slotted weights on the rope's end. The engine test rig is shown in figure 5. The fuels used are diesel fuel in neat condition and rice bran biodiesel with POME10, POME20, POME30, and POME40 blends as shown in figure 4. These blends are tested at five different load conditions, namely 0%, 25%, 50%, 75%, and,100% loads by maintaining a constant engine speed at 1500rpm. The diesel engine specifications are in table 2. The configuration allows for the analysis of engine performance in terms of brake power, indicated power, frictional power, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, indicated specific fuel consumption, brake-specific fuel consumption. Sample readings can be tabulated by the specifications of the experiment being studied, and the results can then be compared. Also note down the different emissions of CO, $CO_2$, HC, $NO_X$, and $O_2$ parameters of diesel and biodiesel blends with AVL 5 gas analyzer as shown in figure 6, and specifications of AVL 5 gas analyzer as shown in table 3. The smoke values in percentage are obtained from the AVL smoke analyzer as shown in figure 7 and the specifications of the AVL smoke analyzer as shown in table 4. The values are calculated and compared with diesel to know which blend gives good performance and low emission.

Figure 5: Engine test rig

Figure 6: AVL 5 gas analyzer

Figure 7: AVL smock analyzer

Table 2: Specifications of diesel engine

| | |
|---|---|
| Manufacture | Kirloskar |
| Brake Power | 5 HP |
| Speed | 1500 RPM |
| No. of Cylinders | 1 |
| Compression Ratio | 16.5: 1 |
| Bore Diameter | 80 mm |
| Stroke Length | 110 mm |
| Orifice Diameter | 20 mm |
| Type of Ignition | Compression-Ignition |
| Method of Loading | Rope Brake |
| Method of Starting | Crank Shaft |
| Method of Cooling | Water Cooling |

Table 3: Specifications of AVL 5 gas analyzer

| | |
|---|---|
| Display | LCD |
| Interface | USB |
| Operating Voltage | 100... 300 VAC, 50-60 Hz |
| Power Consumption | Max. 10W |
| Dimensions (w x h x l) | 270 x 85 x 320 mm |
| Weight | 4.5 kg |

Table 4: Specifications of AVL smock analyzer

| | |
|---|---|
| Display | LCD |
| Interface | USB |
| Operating Voltage | 100... 300 VAC, 50-60 Hz |
| Smock Inlet | Through a control valve |
| Dimensions (w x h x l) | 600 x 260 x 370 mm |
| Weight | 8 kg |

## 4. RESULTS AND DISCUSSION

### 4.1 PERFORMANCE ANALYSIS

**Brake-Specific Fuel Consumption (BSFC)**

The variation of brake-specific fuel consumption with load is shown in figure 8. The plot it is revealed that as the load increases brake specific fuel consumption decreases. At no load to full load conditions, the brake-specific fuel consumption obtained from POME10, POME20, POME30, POME40, and pure diesel are represented. The brake-specific fuel consumption of palmyra oil blend POME20 slightly decreased when compared to the diesel at full load condition.

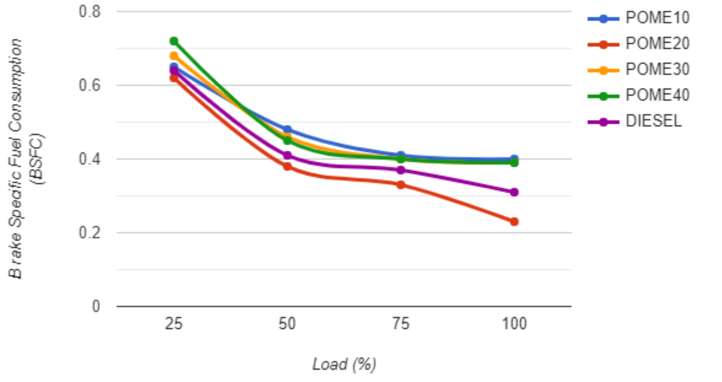



Figure 8: Load vs Brake-Specific Fuel Consumption

**Indicated Specific Fuel Consumption (ISFC)**

The variation of indicated specific fuel consumption with load is shown in figure 9. The plot it is revealed that as the load increases indicated specific fuel consumption decreases. At no load to full load conditions, the indicated specific fuel consumption obtained from POME10, POME 20, POME30, POME40, and pure diesel are represented. The indicated specific fuel consumption of palmyra oil blend POME20 slightly decreased when compared to the diesel at full load condition.

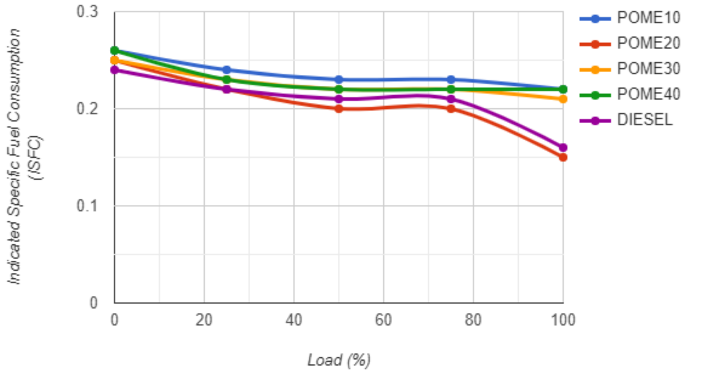



Figure 9: Load vs Indicated Specific Fuel Consumption

**Brake Thermal Efficiency ($\eta_{bte}$)**

The variation of brake thermal efficiency with load is shown in figure 10. The plot it is revealed that as the load increases brake thermal efficiency increases. At no load to full load conditions, the brake thermal efficiency obtained from POME10, POME20, POME30, POME40, and pure diesel are represented. The brake thermal efficiency of palmyra oil blend POME20 increased when compared to the diesel at full load condition.

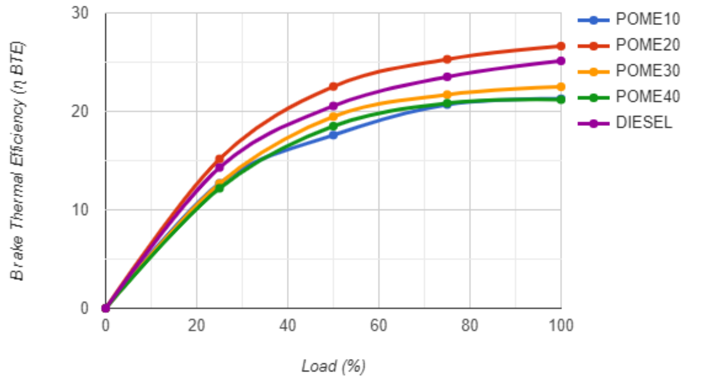



Figure 10: Load vs Brake Thermal Efficiency

**Indicated Thermal Efficiency ($\eta_{ite}$)**

The variation of indicated thermal efficiency with load is shown in figure 11. The plot it is revealed that as the load increases indicated thermal efficiency increases. At no load to full load conditions, the indicated thermal efficiency obtained from POME10, POME20, POME30, POME40, and pure diesel are represented. The indicated thermal efficiency of Palmyra oil blend POME20 increased when compared to the diesel at full load condition.

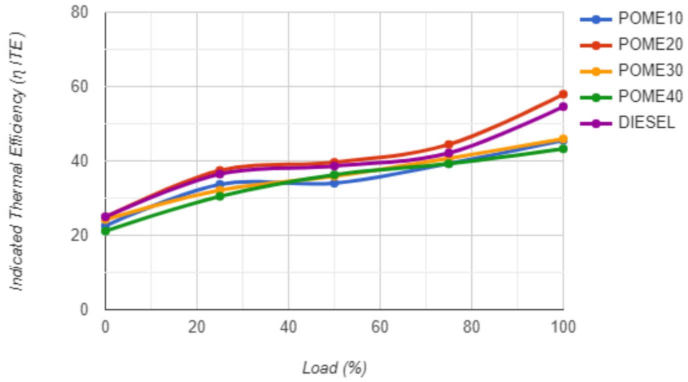



Figure 11: Load vs Indicated Thermal Efficiency

**Mechanical Efficiency ($\eta_m$)**

The variation in mechanical efficiency with load is shown in figure 12. The plot it is revealed that as the load increases mechanical efficiency increases. At no load to full load conditions, the mechanical efficiency obtained from POME10, POME20, POME30, POME40, and pure diesel are represented. The mechanical efficiency of Palmyra oil blend POME20 increased when compared to the diesel at full load condition.

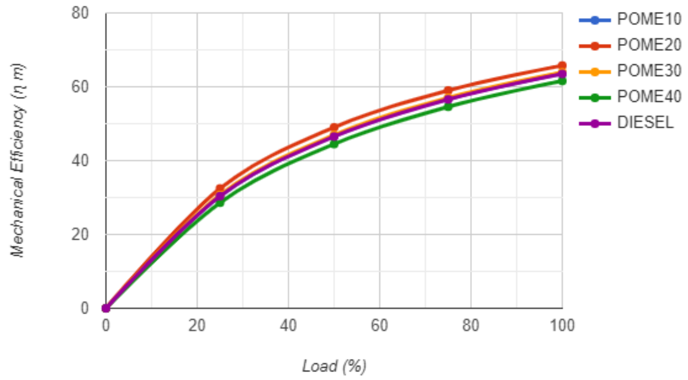



Figure 12: Load vs Mechanical Efficiency

## 4.2 EMISSION ANALYSIS

**Nitrogen Oxide (NOx)**

The variation of NOx with load is shown in figure 13. The plot it is revealed that as the load increases NOx decreases. At no load to full load conditions, the NOx was obtained for POME10, POME20, POME30, POME40, and pure diesel are represented. The NOx of palmyra oil blend POME20 slightly decreased when compared to the diesel at full load condition.

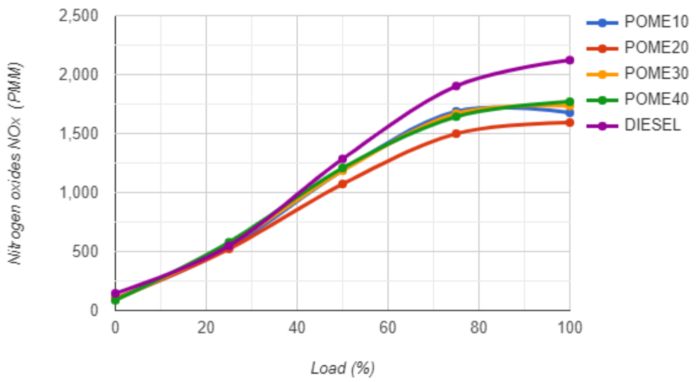



Figure 13: Load vs Nitrogen Oxide

**Carbon dioxide** ($CO_2$)

The variation of $CO_2$ with load is shown in figure 14. The plot it is revealed that as the load increases $CO_2$ decreases. At no load to full load conditions, the $CO_2$ are obtained for POME10, POME20, POME30, POME40, and pure diesel are represented. The $CO_2$ of palmyra oil blend POME20 slightly decreased when compared to the diesel at full load condition.

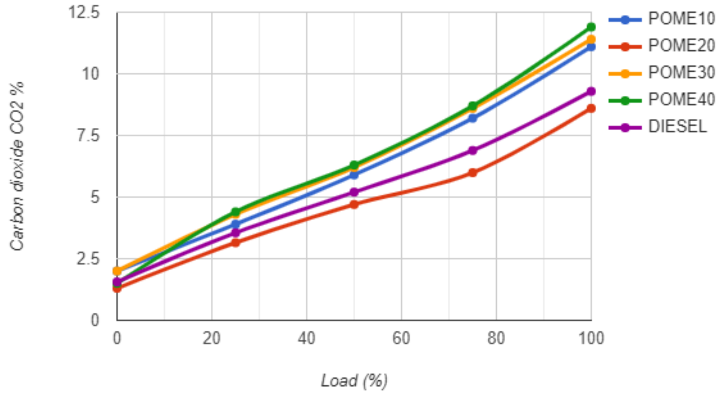



Figure 14: Load vs Carbon dioxide

**Hydrocarbon (HC)**

The variation of HC with load is shown in figure 15. The plot it is revealed that as the load increases HC decreases. At no load to full load conditions, the HC was obtained for POME10, POME20, POME30, POME40, and pure diesel are represented. The HC of palmyra oil blend POME20 slightly decreased when compared to the diesel at full load condition.

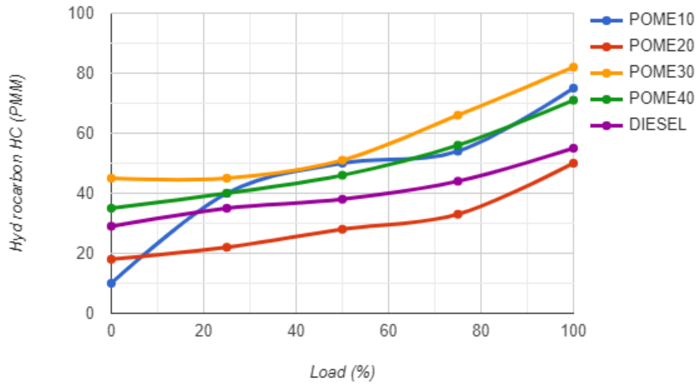



Figure 15: Load vs Hydrocarbon

**Smock Opacity**

The variation of smoke opacity with load is shown in figure 16. The plot is revealed that as the load increases smoke density decreases. At no load to full load conditions, the smoke obtained from POME10, POME20, POME30, POME40, and pure diesel are represented. The smoke density of palmyra oil blend POME20 slightly decreased when compared to the diesel at full load condition.

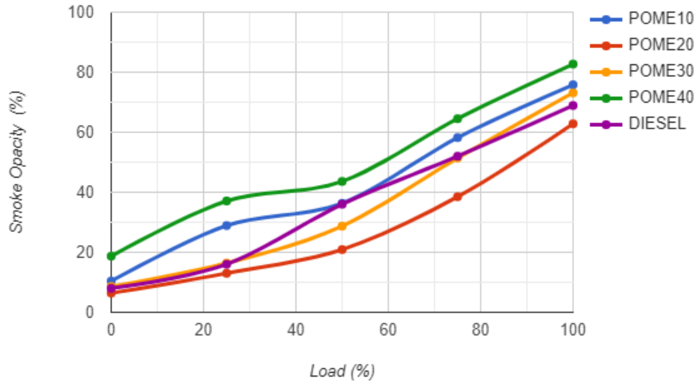



Figure 16: Load vs Smoke Opacity

## 5. CONCLUSION

The comprehensive experimental investigation has discussed the influence on the performance, combustion, and emission characteristics of a diesel engine fueled with the POME10, POME20, POME30, and POME40 blends. The key experimental findings from the current work as presented below.

- It is found higher brake thermal efficiency for the POME 20 blend operated at full load and is 26.63%. Compared to other blends and diesel i.e., POME10, POME30, POME40, and diesel with 21.28%, 22.50%, 21.19%, and 25.13% respectively. However, the BTE of POME 20 operated at different load conditions shows a slightly higher value than diesel at all load conditions.
- It is observed that BSFC is reduced by 0.23Kg/Kw-hr for POME20 operated full load condition. Whereas POME10, POME30, POME40, and diesel by 0.4Kg/Kw-hr, 0.39Kg/Kw-hr, 0.39Kg/Kw-hr, and 0.31Kg/Kw-hr.
- It is also found that the higher indicated thermal efficiency for the POME 20 blend operated at full load is 57.92%. Compared to other blends and diesel i.e., POME10, POME30, POME40, and diesel with 45.52%, 45.92%, 43.24%, and 54.59% respectively and it also observed that ISFC reduced by 0.15 Kg/Kw-hr of POME20 operated at full load condition compared

to other blends and diesel is 0.22Kg/Kw-hr, 0.21Kg/Kw-hr, 0.22Kg/Kw-hr, 0.16Kg/Kw-hr.

- It is noticed that the higher mechanical efficiency of the POME20 blend operated at full load condition and is 65.75%. Compared with other blends and diesel i.e., POME10, POME30, POME40, and diesel is 63.57%, 63.89%, 61.58%, and 63.47% respectively.
- The current experimental investigation reveals significant reductions of NOx, $CO_2$, HC, and smoke emissions of the POME20 biodiesel blend operated at full load condition. The NOx, $CO_2$, HC, and smoke emissions decreased by 1593PMM, 8.6%, 50%, and 62.8% respectively in contrast with other blends (POME10, POME30, POME40) and diesel at peak load.

From the analysis above, the blend POME20 performs better than other blends (POME10, POME30, POME40) in terms of performance metrics like brake thermal efficiency, mechanical efficiency, indicated thermal efficiency, brake-specific fuel consumption, indicated specific fuel consumption, and emission metrics like nitrogen oxide, carbon dioxide, hydrocarbon, smoke opacity. POME20 is therefore considered to be the ideal blend due to its improved performance. Overall, biodiesel showed increased engine performance with reduced emissions, and this has the potential to use as an alternative fuel for diesel.

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