Investigating Emissions Profiles of a Conventional Diesel Engine Fueled by Ziziphus Oenoplia Methyl Esters

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Abstract

The current experimental work intends to briefly describe the feasibility of Wild jujube Ziziphus-Oenoplia Methyl Ester (ZOME)as an ideal substitute energy source for operating the diesel engines with native aspiration for studying the effects of emissions characteristics. Seeds were crushed to extract oil by deploying a mechanical expeller. The extracted Wild jujube seed oil is processed for purification and allowed for performing a two-stage transesterification method for transforming into biodiesel. The test fuels, such as ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100, were prepared along with baseline diesel at working ambient conditions for the experimental investigations. The observations during the experimentation indicated how CO, HC, and opacity of smoke display lower values by 5.7%, 8.1% and 4.9% respectively than baseline diesel owing to effective vaporization.

Keywords- Ziziphus Oenoplia Methyl Esters, Conventional Diesel Engine

1. Introduction

Over the last two decades, Biofuels have emerged as widely accepted with global recognition for replacing the mineral diesel as an alternative fuel substance. Eminent scientists and many other researchers have continued to investigate the various alternative sources available for the substitution of mineral diesel owing to the twin crises of atmosphere degradation and depletion of fossil fuels [1]. The promising potential substance of the myriad available sources is Biofuels, which have multiple benefits ascribed to their non-toxic, low emissions, and biodegradable nature [2]. In developing Countries like India, many challenges prevail owing to the high price value of mineral diesel due to insufficient reserve capacity. Therefore, the search for an alternative has made compulsion for the government [3]. From the myriad references, Biofuels can be predominantly extracted from edible and non-edible seeds. However, few references were available on animal fat. Many people survive with agriculture as their livelihood, and animals serve to conduct agriculture. So, the people have an emotional connection and even some ethical values associated with people leads to switching over to focus more on vegetable oils. The conflict between food and fuels has raised concern about focusing on non-edible oils as edible sources are predominantly used for domestic purposes, and exponential growth in population pressurized industries to produce more oils from edible sources [4]. The food-fuel dilemma could be resolved by using inert that are not edible.Few literatures demonstrate exactly what fatty acid ester compounds are made with non-edible sources. For instance, therefore, the work was focused on producing bio-fuels from non-edible sources.

Sandeep et al. used transformation to create edible oil renewable fuels. In a particular kind of transesterification, the reactant produces fatty acid ester. To investigate engine performances at different loading situations, renewable fuels including pongamia oil fatty acid ester (POFAE),Pongamiafatty acid ester (PAE), and neem oil fatty acid ester (NOFAEE) have been developed[5-7].5 ratios for each biodiesel pongamia oil fatty acid ester (POFAE20, POFAE40, POFAE60, POFAE80, and POFAE100); Pongamiafatty acid ester mixes (PAE20, PAE40, POEE60, PAE80, and PAE100); and neem oil fatty acid ester (NOFAEE20, NOFAEE40, NOFAEE60, NOFAEE80, and NOFAEE100) were combined using diesel fuel as well as the results were contrasted about conventional diesel.Combinations 20 and 40 of every bio-fuel have heating effectiveness marginally higher than diesel requirements. The study revealed that mixes 20 and 40 have lower discharges of hydrocarbon (HC), carbon monoxide (CO), and carbon dioxide (CO_2) in comparison to diesel fuel. For every blending with bio-diesel, there has been an increase in NO_X emissions.Blends 20 and 40 had maximum pressures plus a thermal discharge pace that was marginally lower than that of regular diesel. The ignition parameters of the remaining mixes didn't include using bio-fuels in the case of diesel engines. In contrast with POFAE and NOFAEE, POFAE 40 was deemed to have the most effective fuel out of the various mixtures evaluated.Recent literature suggests that ZOME is not yet widely established as a fuel source. However, biodiesel derived from ZOME has attracted considerable attention as a potentially sustainable and environmentally friendly fuel option. To completely understand the benefits of ZOME bio-diesel, it is essential to comprehensively examine its performance characteristics and determine its optimal application in internal combustion engines. This research attempts to deal with the current lack of scholarly investigation in this field by thoroughly evaluating the act of ZOME bio-diesel blends in intestinal burning engines. Specifically, this research will focus on assessing engine performance, burning properties, and fumes connected with ZOME bio-diesel. The primary objective is to analyze the impact of various blend ratios and the mixing of ZOME bio-diesel with conventional diesel on engines output, aiming to identify the most suitable fuel composition[6-12].

2.1 Distillation of ZOME Bio-diesel from Wild jujube seeds

The Wild jujube seeds were collected and allowed into hot water to remove the outer(peel) surface. Finally, they dried under hot sun for around five days to remove moisture content, organic matter, and small traces of impurities The dehydrated seedlings subsequently deployed into a mechanically evaporator for extracting mineral oil. The extracted mineral oil was purified by adding 5% hexane and allowed to get heated along with stirring for a temperature around 100^{0}C with an estimated time of 30 min. The contaminants include gums fragments will settle at the base, and the purified mineral bio-diesel can be removed once ambient conditions are reached.[13-15].

2.2 Characterization of Wild jujube seed oil

The evaluation of attributes like density, viscosity, flash point, and calorific value are conducted for Wild jujube seed oil by deploying a hydrometer, Redwood Viscometer, Pensky-Martin open cup apparatus, and bomb calorimeter, respectively, which are provided in tabular column 1. The seed oil appears in light yellow. The results were compared with other oils like sterculiafoetida kernel oil. Table 1 shows the attributesof raw oil. Table 2 represents the acid’s fat composition of ZOSO.

Table 1. AttributesofZOSO

Properties	Units	ZOSO	SFKO
Kinematic Viscosity at 40^{o}C	mm^2/s	38.43	35.76
Density @ 15^{o}C	Kg/m^3	910	927.7
Acid Value	mg KOH/g	5.9	5.9
Flash Point	^{0}C	241	238
Calorific Value	MJ/kg	37.04	36.44

Table 2. Fatty acid composition of ZOSO

Fatty acid composition	ZOSO
Myristic acid (C14:0)	0.2
Arachidic acid (C20:0)	1.9
Lauric acid (C12:0)	0.1
Malvaloyl Acid (18:CE)^a	3.2
Oleic acid (C18:1)	54.1
Linolenic acid (C18:3)	2.3
Stearic acid (C18:0)	11.3
Palmitoleic acid (C16:1)	0.9
Linoleic acid (C18:2)	7.5
Palmitic acid (C16:1)	12.5
Sterculoyl acid (19:CE)	11.4

3. Fuel Preparation

3.1. Description of the production of methyl ester in a mini-biodiesel plant

The plant is fabricated for the creation of fatty acidsthrough mineral oil. The maximum capacity of the plant is around 5 litres. The plant has a speed regulator, pressure gauge, motorised stirrer, and temperature controller. Fig.1 shows the Mini Biodiesel Plant and its fittings.The generation plant of 1.5 kW power is attached on a coiled within the vessel intended forheat to the mineral oil. The oil can be allowed through a provision (inlet- valve) provided at the top of the container, and using the level indicator, the quantity of oil can be measured. [16-17]The stirrer with three blades made of stainless steel is used for the mechanical rotation of the reagent in the container and is coupled with the motor, which can function between 300 rpm and 1200 rpm. The electronic speed regulator is equipped with a digital indicator for identifying the reaction speed of mixing. The mineral oil's temperature is determined with an electronic thermometer. The base layer of the vessel is affixed within an oil of minerals collection outflow faucet. The upper layer of the vessel is fixed utilizing the intake channel valve to permit the movement of mineral oil into the container [18-19].

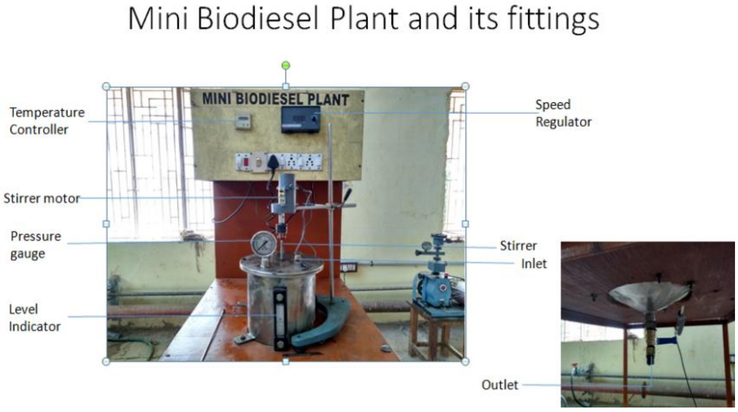


Fig.1Small Bio-Diesel Station

Fig: 2 Wild Jujube Methyl Ester

3.2 Fuel Production and Characterization

Three litters of wild jujube seed oil were transferred to a vessel heated, after which methanol and a solution of H_2SO_4 were added. Using the normal method, a mole concentration at five to one (methanol to oil) with catalysis of 0.3 per cent (wt/wt to oil) was employed in the transformation process. The vessel was operated at 60°C temperature, and the whole response was conducted for around 90 minutes at a rapid tempo of 600 rpm. By the end of the stipulated experimental duration, the whole reaction could shift into a funnel for phase separation and be kept undisturbed for an hour. Two distinct phases are noticed after the separation of the reaction. The reduced half is separated from the tophalf, which is amenable to conducting an alkali-catalyzedetherification process [20].The minor moiety was again permitted into the container for conversion, followed by employing NaOH and methanol reactant as a catalyst-producing substance. The solution was warmed to the necessary degree with a stipulated experimental duration. For better enhancement in yield, the reaction is allowed to stir for 600 rpm. After the process, the reaction was moved into the funnel again for separation and kept for 8 hours without disturbing it. [21-22].Using gravity, two distinct phases are noticed and shown in Figure 2. The lower phase is glycerin, and the upper phase is methyl ester which was separated and refined for engine testing.

3.3 Test Fuels Preparation

The Wild jujube methyl ester and standard diesel were made into 6 samples for testing in the unmodified engine. They were depicted in Table 3 for conducting investigations on various performance characteristics, emission analysis, and combustion rate. The samples were allowed to blend properly to obtain the results with maximum accuracy before injecting into the engine's fuel tank and were prepared as follows.

ZOME20 – 20% of methyl ester + 80% Standard diesel
ZOME40- 40% of methyl ester + 60% Standard diesel
ZOME60- 60% of methyl ester + 40% Standard diesel
ZOME80- 80% of methyl ester + 20% Standard diesel
ZOME100- 100% of methyl ester

Table 3.Properties of fuels

Properties	Zome100	Zome20	Zome40	Zome60	Zome80	Baseline Diesel	ASTM Standard
Density @ 15ºC (Kg/M^3)	898	852	864	875	886	840	D4052
Kinematic Viscosity At 40°C (Mm^2/S)	4.98	3.6	4	4.4	4.8	3.2	D445
Calorific Value (kJ/Kg)	40200	42000	41500	41000	40500	42400	D240
Flashpoint (°C)	171	-	-	-	-	-	D93
Fire Point (°C)	211	-	-	-	-	-	D92
Cloud Point (°C)	-5	-	-	-	-	-	D2500

Pour Point (°C)	-2	-	-	-	-	-	D97
Acid Value	0.32	-	-	-	-	-	D664

3.4. Experimental Setup

Considering standard diesel as a baseline fuel, the experiment was conducted by making the engine run for about 30 min to attain stable conditions. After fulfilling the steady condition, the engine is operated with ZOME-diesel blends. Using a stopwatch, the time taken is calculated for every 10 cc of consumption. The existing fuel traces were removed completely in the fuel tank, and even further, small proportions of fuel surfaced in the filter pump and the line remained cleared earlier to run the engine with ZOME. Fig 3shows the schematic layout, and Table 4 shows the Specifications of the Engine experimental Setup. Combustion ambient gases are analyzed using an AVL DiGas 444-type exhaust fume meter. The energy source needed for the detector must have an energy capacity of 25 W and fall between 110 and 220 V. There is a 6 to 8-minute practice time for the analyzer.Given a T95 rating, the analyzer's reaction latency is in the range of one to fifteen seconds. To track the engine's greenhouse gases, a gas detector with a maximal reaction period of eight seconds is attached to the outflow line of the cylinder. A computerized displaying device with a chrome-alumel K-type thermocouple was used to determine the engine stream temperatures. While CO releases are measured as a proportion of quantity, HC and NOx releases are measured in particles/millions (PPM). The amount being measured of emissions is then converted to grams per kilowatt-hour (g/kWh). The amount of smoky released is measured using Bosch Breath equivalents using a Bosch smoke meter.[23-25]

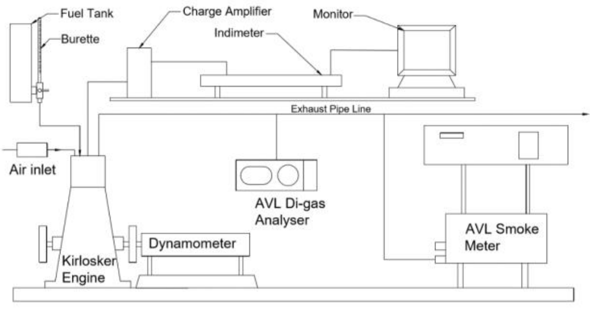


Figure 3.Engines concept illustration

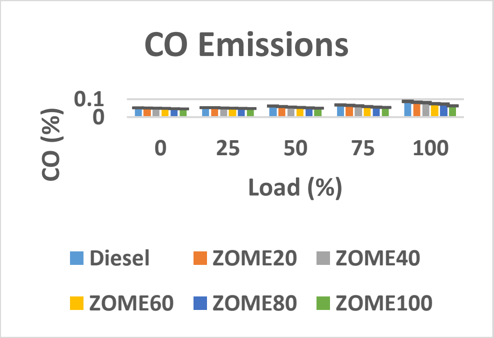
Table 4.Specifications ofMaterials for an Investigation

Make	Kirloskar
Injection Timing	23°bTDC
Dia. of injector nozzle	0.32 mm
Stroke	4
No. of the injector	4
Cylinder	Single
Rated Power	5.2 KW
Rated speed	1500 rpm
Bore diameter (D)	87.5 mm
Stroke(L)	110 mm
Compression ratio	17.5:1
Injection pressure	210 bar
Load	Eddy Current

4. Results and discussions

4.1. Carbon monoxide (CO) emissions

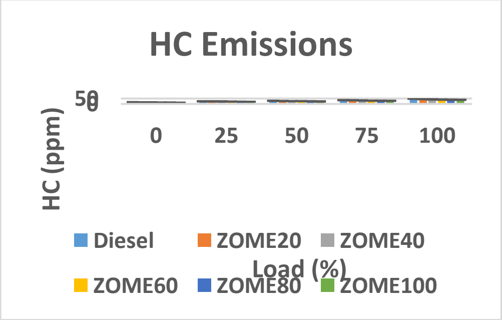
The percentage of CO emissions is inversely proportional to the ZOME biodiesel blends owing to lower IDP. The CO emissions for ZOME20, baseline diesel, ZOME40, ZOME 60, ZOME 80, and ZOME100 are represented in Supplementary Figure 10. CO emissions of ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100 are lower than diesel. The CO emissions record inferior values for ZOME blends under all steady-state conditions relative to baseline diesel [21]. The CO at the peak was 0.088 % for baseline diesel, 0.063 % for ZOME100, 0.083 % for ZOME20, 0.081% for ZOME40, 0.075% for ZOME60, and 0.073 % for ZOME80. The emissions of CO for ZOME20 were recorded as 5.7% lower than baseline diesel.Due to inadequate oxygenation, confined air, improper combination planning, or inefficient burning, carbon monoxide was produced after ignition, generally speaking, fuel in general produces more CO outputs than ZOME/diesel mixtures. Multiple variables, such as insufficient burning, fluctuations in fuel characteristics, fluctuating levels of oxygen, and other engine layout adjustments, are responsible for this. Additionally, bio-diesel emits less CO than traditional diesel engine fuels because of its better ignition qualities plus its lighter consumption behavior.



Supplementary Figure 10.Variation of CO with Load for ZOME blends

4.2. Hydro Carbon (HC) emissions

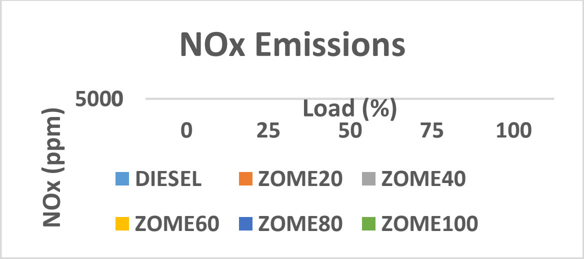
The innate availability of oxygen and fuel composition in ZOME-diesel blends resulted in lesser HC emission [24].HC with load for ZOME20, baseline diesel, ZOME40, ZOME60, ZOME80, and ZOME100, are depicted in supplementary figure 11. The HC emissions at the crest load registered 49 ppm for baseline diesel, 38 for ZOME100, 45 for ZOME20, 42 for ZOME40, 40 for ZOME 60, and 39 ppm for ZOME80. HC emissions of ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100 registered lower values baseline diesel due to substandard IDP and substantial combustion of ZOME. The emission of HC for ZOME20 is 8.1 % lower than with baseline diesel.Biodiesel typically emits more hydrocarbons (HC) into the atmosphere than ZOME/diesel mixes because of partial burning, variations in the characteristics of the fuel, different oxygen concentration stages, or engine layout improvements. When opposed to diesel combustibility, ZOME usually produces fewer greenhouse gas outputs due to its clearer consumption behavior and better ignition properties. Many research using different kinds of bio-fuel demonstrated accurate findings. Furthermore, these research studies reveal how diesel produces higher levels of hydrocarbon (HC) particles than bio-diesel, regardless of the type of bio-diesel used.



Supplementary Figure 11.Variation of HC with Load for ZOME blends

4.3 Nitrous oxide (NO_X) emissions

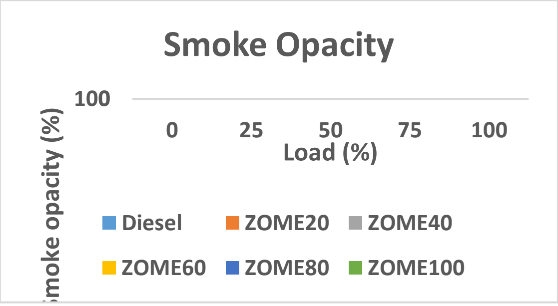
NOx generally increases with an increase in combustion duration, i.e., an increase in combustion temperature [36]. The emissions of NO_X with.load for ZOME20, baseline diesel, ZOME 40, ZOME60, ZOME 80, and ZOME100 are represented in supplementary figure 12. NO_X emissions of ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100 registered higher values with baseline diesel. Generally, the innate availability of Oxygen in ZOME can result in releasing more NO_X.Therefore, if fatty acids are combined, NOX releases operate at greater levels in comparison to standard diesel.Additionally, the chemical structure of ZOME/Diesel mixes has a greater amount of oxygen. A larger air of oxygen after burning might result in increased conditions that will in return promote the production of NOx particles [34]. Numerous investigations employing bio-diesel generated via various suppliers revealed comparable trends.The emissions of NO_X at the full load registered with 2144 ppm for baseline diesel, 2255 ppm for ZOME100, 2153 for ZOME20, 2153 for ZOME40, 2190 for ZOME60, 2212 for ZOME80, which were illustrated in Figure 9. The outcomes of NO_X for ZOME20 are around 0.4% above standard diesel.



Supplementary Figure 12. Variation of NO_X with Load for ZOME blends

4.4 Smoke Opacity Emissions

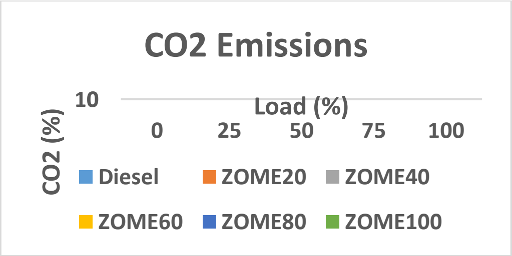
The phenomenon of smoke opacity in the engine exhaust line constitutes one of the primary environmental concerns, apropos conventional fuel-burning IC engines .Attributable to the formation of smoke is the partial oxidization of fuel due to insufficient oxygen levels in the combustion chamber. The emissions for Smoke Opacity with load for ZOME20, baseline diesel, ZOME40, ZOME60, ZOME80, and ZOME100 are represented in Figure 13. The emissions of Smoke Opacity for ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100, registered inferior values with baseline diesel.The emissions for Smoke Opacity at crest load were 64.4 % for baseline diesel, 45.6% for ZOME100, 61.5 % for ZOME20, 57.33 % for ZOME40, 48.6 % for ZOME60, and 66.9 % for ZOME80 at the crest load which was illustrated in supplementary figure 10. The smoke opacity of ZOME20 was recorded with a 5% lower value with baseline diesel.The amount of air inside the combustion chamber with the oxygen content contained in the fuel also has a major impact on smoky visibility. Combinations of ZOME and diesel, because of their higher intrinsic oxygen levels, burn more easily and produce fewer fumes. Many examinations employing bio-fuel produced from different suppliers revealed comparable trends.



Supplementary Figure 13.variation of smoke opacity with Load for ZOME blen**ds**

4.5 Carbon dioxide (CO_2) emission

The carbon in the ZOME diesel blends reacts with oxygen to form CO_2. The percentage of CO_2 with load for ZOME20, baseline diesel, ZOME40, ZOME60, ZOME80, and ZOME100 is represented in supplementary figure 14. CO_2 emissions of ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100 were noticed with higher values than baseline diesel. CO_2diesel vehicle exhaust suggests measuring of the effectualness of the combustion for the ZOME-diesel blends. Compared with standard diesel, ZOME-diesel mixtures had greater oxygen accessibility [29]. Consequently, total burning is accomplished.The emissions of CO2 registered as 9.19 % for baseline diesel, 9.73 % for ZOME100, 9.21 % for ZOME20, 9.34 % for ZOME40, 9.49 % for ZOME60, 9.57 % for ZOME80 at the crown load. CO2 emissions of ZOME20 are around 0.3% higher vis-a-vis baseline diesel.



Supplementary Figre 14.Variation of CO_2 with Load for ZOME blends

Conclusions

The analysis was carried out from the experimentation results and observations. The following conclusions can be drawn.

- CO for ZOME-diesel blends registered lower values with baseline diesel. The CO for ZOME 20 is 5.7 % lower vis-a-vis baseline diesel.
- HC for ZOME-diesel blends registered inferior values with baseline diesel. The HC for ZOME20 is 8.1 % lower vis-a-vis baseline diesel.
- NO$_X$ emission for(ZOME20, ZOME40, ZOME60, ZOME80, and ZOME100) registered higher values with baseline diesel. Howeverthe NO$_X$ emission of ZOME20 is only just 0.4% superior to diesel.
- CO_2 for ZOME20 is around 0.3 % superior to diesel.
- The smoky opacity of ZOME20 is 5 % below than diesel. The experimentation analysis concludes that ZOME20 could be a better substitute owing to its similar characteristic behavior to diesel.

Future Research Direction:

To improve the use of ZOME as a workable diesel engine oil replacement, subsequent studies will give priority to numerous important sectors. Enhancing both transesterification process could increase the amount produced and effectiveness of bio-fuel generated as ZOME.

Furthermore, investigating cylinder changes to improve compliance using ZOME mixes—such as modifying burning chamber layouts & implementing infusion injection systems—may facilitate faster vehicles and maximize efficiency. Analyzing combust variables under different vehicle weights and velocities could offer insightful information about nox effectiveness, ignite postponement, or burning economy under different running conditions. Continuous endurance testing and emission surveillance may be carried out over a longer amount of time to assess the ecological impact and reliability of vehicles running upon ZOME mixtures. Moreover, studying how ZOME combines affect particles is important as well as conducting financial and ecological studies will assist in measuring the possible benefits of widespread use of ZOME biodiesel in regards to lower greenhouse gases and improved sustainable development in real-world situations. The results of the study indicate that Wild Jujube fatty acids can function as an economically feasible and effective diesel-powered alternative fuel, thus achieving all of its promises.

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