

To Examine the Performance and Emission Studies of Neem Oil Bio-Diesel Blending with VCR Engine

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Abstract: Biodiesel is a good substitute for oil-based diesel today and is growing in popularity as an alternative fuel. In its most basic form, biodiesel is produced from fats and oils via a variety of procedures, including weakening, pyrolysis, small-scale emulsification, and transesterification, which is now the most economically viable technique. Neem oil biodiesel was created via the transesterification process by overcoming production barriers such as the alcohol-to-oil molar weight ratio, the focus on driving power, and others. The motor plan is also crucial since it affects both performance constraints and fuel consumption. This proposal has centred on the most efficient method of neem oil biodiesel production, then on the use of biodiesel mixes with diesel while taking into account the characteristics of nearby fume emanation and motor performance, as well as on improving the pressure ratio and the mixes made with biodiesel and diesel. The execution and emanation boundaries were measured using a single chamber, four-stroke variable pressure proportion motor. Four different volume percentages of biodiesel are used to compare the fire point and calorific value of the biofuel to those of the diesel fuel. After looking at the execution and outflow bounds, it was determined that the biodiesel mix B10 was the best for the motor's most productive activity. By contrasting the exhibition boundaries for all pressure proportions, including BTHEff, BSFC, EGT, etc., the CR 14 was found to be the best.

Keywords- *Neem Biodiesel, Transesterification, VCR Engine, Pyrolysis.*

1. Introduction

Several factors favour the use of biodiesel manufactured from vegetable oils as an alternative to petroleum-based diesel, including the limited availability and rapid depletion of petroleum fuel supplies, daily increases in the price of crude oil, and environmental concerns. In diesel engines, methyl/ethyl esters of vegetable oils are employed; they provide nearly the same power but have slightly lower thermal efficiency. Lower tailpipe emissions are necessary for both the use of biodiesel and the research stage of engine development. the requirements for using biodiesel in terms of preventing pollution and protecting the environment. A disadvantage of using plain vegetable oils in long-running engines is their high viscosity, moderate volatility, and polyunsaturated composition. The main problems include thickening and gelling of the lubricating oil as a result of contamination with vegetable oils, lubricating oil pollution, carbon buildup, oil rings that cling, trumpet formation on injectors, and sticking lubricating oil.

The current method for producing biodiesel (Methyl Ester) uses neem oil to determine whether the test biodiesel could replace diesel oil using the alkaline catalysed transesterification process, its fuel characteristics were identified, and its performance and emissions were assessed on a four-stroke, single-cylinder, variable compression ratio direct-injection diesel engine. Biodiesel contains around 7% fewer calories than pure diesel.

Neem methyl ester has a higher viscosity than regular diesel [1]. All countries' industrial economies depend on diesel and other fossil fuels. It serves as fuel for power generators, farm machinery, earthmoving equipment, delivery vehicles, railroads, heavy machinery, and underground mining machinery. According to research by B. R. Singh et al. [2], the motorization industries' rapid global expansion is pushing up the world's average fuel consumption by 1.1% annually. By 2040, it is anticipated that the transportation industry would use 60% of all liquid fuels consumed globally. Hazardous gases like CO₂, CO, NO_x, and other greenhouse gases are discharged into the environment by the automotive industry and other businesses, according to M. Davis et al. [3]. This adds to global warming, which changes the world's weather patterns. There will never be a decrease in the price of petrol. As a result, investigating unique energy sources is crucial.

Since previous studies indicate that the main difficulties are the rising price of vegetable oil and the scarcity of food crops, it is imperative to market gasoline made from vegetable oil. Vegetable oils' higher density, higher viscosity, and pitifully low volatility, according to M. Mofijur et al. [4], can cause some problems, including fuel filter clogging, decreased fuel atomization, and inappropriate burning. To overcome the limitations of using traditional vegetable oil, the following four techniques can be used: thermal pyrolysis, blending with low-viscosity fuel, producing micro-emulsions, and trans-esterification. Trans-esterification is the preferred and most dependable method for lowering the viscosity and density of ordinary vegetable oils to produce biodiesel, according to a thorough study by E. Alptekin et al. [5]. Biodiesel is a type of non-organic fuel that is made from either plant or animal matter, depending on the raw material's availability. As recovered fats or bio-oils are separated from the underlying hydrocarbons, their calorific value rises. The extracted hydrocarbon can be combined with ethanol, methanol, or any other alcohol group to create the end product, biodiesel. By combining this biodiesel with regular diesel or using it straight in the engine, the ideal fuel for automobiles can be created. Regardless of the planned blend, the quantity of CO, particulate matter, and hydrocarbons (HCs) emitted by an engine using biodiesel is equal to that of an engine using normal diesel fuel. The carbon footprint of sculpture-free biodiesel during combustion is significantly lower than that of ultra-low sculpture diesel, in addition to it burning cleaner and more efficiently. The use of Straight Vegetable Oils (SVOs) in engines to produce biodiesel has some negative effects on the environment and society.

Numerous environmental issues are mentioned by S. K. Hoekman et al. [6], including water source, terrain change, and food safety. These factors led to the conclusion that using pure vegetable edible oil was a poor substitute. Native to India and the nations bordering it, *Azadirachta Indica*, also known as neem, is a plant. Neem oil is mostly produced from the neem tree's fruits and seeds. Neem tree fruits and seeds are used to press neem oil, a type of vegetable oil. Neem plants can produce between 10 and 20 kilograms of neem oil in their first few years. In the tenth year, or when the plants reach maturity, the production will increase to 30–50kg per tree. Neem seeds will contain more oil in regions with higher rainfall. Neem oils, which are mostly made of triglycerides, include triterpenoid compounds that are in charge of the bitter taste. It smells strong, has a golden-yellow hue, and is naturally hydrophobic. Neem oil is produced from the fruits and seeds of the neem tree using one of the following procedures, such as cold pressing or expeller pressing. According to W. Islam et al. [7], neem cake is a beneficial by-product of the hot or cold pressing of neem oil. Neem oil biodiesel and biodiesel blends were made, and their densities and viscosities were evaluated by ASTM test requirements. The aforementioned study discovered that when the biodiesel concentration increased, the density and viscosity of the neem oil biodiesel blends increased as well.

Table 1. Physical and chemical properties of raw neem oil [7].

S No.	Property	Neem Oil	Diesel
1.	Fire Point	235° C	72° C
2.	Flash Point	225° C	62° C
3.	Density at 15° C	0.9260 gm/ml	0.832 gm/ml
4.	Viscosity at 40° C	44.0 cst	32.0 cst

5.	Calculated Cetane Index	38	48
6.	Gross Calorific Value	9051 Kcals/kg	9881 Kcals/kg

Numerous studies have been conducted in the past on the performance, combustion, and emission properties of various grades of biodiesel at various compression ratios. But there hasn't been much investigation on the effectiveness, combustion properties, and emission quality of neem oil bio-diesel for full and partial loads. There is a good chance that neem oil seed methyl ester biodiesel will replace conventional diesel fuel. Therefore, a detailed study of the methyl ester of neem oil's performance characteristics and emission quality when used with a compression ignition engine is required.

The current study focuses on the effects of combustion and how well neem oil methyl ester performs. The following engine experiment was carried out utilizing blends of traditional diesel fuel (D100) and biodiesel made from neem oil (B10, B20, B30, B40, B50, B60). Performance and combustion physiologies of compression ignition engines using B20 and B60 blends under various loading circumstances. Neem oil methyl ester exhaust physiologies from a VCR engine operating under different loads and using standard diesel fuel. According to the test results, compression ignition engines running on neem oil biodiesel display improved combustion characteristics, higher performance, and fewer emissions without any modifications.

It is critical to find alternative fuels due to the effects of increased environmental pollution, declining fossil fuel supply, and rising energy demand. Since diesel engines are widely employed in the transportation, industrial, and agricultural sectors, a diesel alternative must be created. Vegetable oil seems to be the most agreeable substitute because it shares many properties with diesel in terms of both chemistry and physical composition. Vegetable oils are easily accessible, renewable, secure, and clean [8, 9].

2. Literature Review

S Pal et. al (2022) [10] examined that the Concerns about climate change, rising energy costs, and depleting oil stocks and supplies have necessitated a significant amount of interest in the search for alternative fuel sources. An alternative renewable fuel called biodiesel has attracted a lot of attention in recent years. According to studies on the physical properties of biodiesel, it is completely miscible with petroleum diesel. Because biodiesel blends release more locally concentrated emissions of particulate matter and greenhouse gases than petroleum-based diesel, they have shown a significant reduction in these emissions. In this review paper, the performance and exhaust emissions of using pure biodiesel or biodiesel blends have been compared to those of using petroleum diesel or mineral diesel.

J Hemanandha et. al (2022) [11] studied that the development of alternative fuel for engines has been made possible by the need for gasoline with lower carbon content and by a rise in energy consumption. An environmentally beneficial substitute for regular fuel is biodiesel. When the engine is not running, thermal barrier coating limits heat flow to the cooling system and shields engine parts from extreme thermal stresses. The mixing of used fish fry methyl esters in a single-cylinder, four-stroke, DI diesel engine with a stellite-6 coated engine head is examined in this work. Waste fish fry oil (WFFO) was trans esterified in this work using methanol and a catalyst made of NaOH. After obtaining the methyl esters, several test fuels (WFFO10, WFFO20, and WFFO30) were produced. Performance tests were carried out after starting the DI diesel engine with these blended samples.

GP Rao et. al (2022) [12] investigate the influence of compression ratio and EGR on the various characteristics of diesel engines operated with a 20% Palmyra oil methyl ester (POME 20) blend at different load conditions. The transesterification process is used to produce the palmyra oil methyl ester from the palmyra crude oil, which is extracted from the palmyra seeds by the application of mechanical pressing operation. ASTM standards have been used to determine the physico-chemical characteristics of palmyra oil methyl ester and these properties are close competing with the diesel fuel. Preliminary tests are conducted with blends of palmyra oil methyl ester (POME 10, POME 20 and POME 30) on diesel engines working at standard conditions and it is found improved engine performance and reduced emissions for POME20. One of the viable techniques to enhance the engine characteristics is to change the operating parameters. 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 POME 20 blend.

PSP Dharsini et. al (2022) [13] studied that various CZ nanocomposite blended fuels, including B20CZ25 (B20 + 25 ppm CZ), B20CZ50 (B20 + 50 ppm CZ), B20CZ75 (B20 + 75 ppm CZ), and B20CZ100 (B20 + 100 ppm CZ), were created and used for analysis. The blend B20 (10% PME +10% NME +80% diesel) was also used. Due to their high economic viability, neem and pumpkin seed oils were used in this investigation. To produce the appropriate methyl esters, the oils were trans-esterified with methanol and sodium hydroxide (NaOH). The results of the experiment show that the addition of CZ nanocomposite enhances brake thermal efficiency (BTE) and decreases brake specific fuel consumption (BSFC) at full load, as well as being advantageous in lowering harmful gases like carbon monoxide (CO), hydrocarbon (HC), and nitrogen oxides (NO_x). According to the study, using CZ nanocomposite with a ternary mix will be a practical new tactic for enhancing engine performance and reducing emission characteristics without changing the engine.

R Saha et. al (2022) [14] examined that to prevent a future in which diesel fuels are not available as energy resources, inventors are scrambling to find alternate sources of energy due to the continuous growth in energy demands brought on by the ever-increasing population, rapidly depleting fossil fuel reserves, and over-dependence on petroleum-based fuel. These factors are also reflected in the corresponding economic developments. Due to their affordability and low toxicity, waste cooking oil (WCO) biodiesel blends are employed as alternative fuels in diesel engines. In addition, compared to emissions of carbon dioxide (CO₂), smoke, and nitrogen oxides (NO_x), they are renewable and produce the least net greenhouse gas emissions. The impact of biodiesel blends on a single-cylinder diesel engine's performance and emission characteristics under various load circumstances.

GS Bist et. al (2021) [15] examined that Acid-base transesterification was used to turn neem seed, which has between 30 and 60 percent oil, into biodiesel. We employed 1.2% (v/v) sulfuric acid during pretreatment, a 1:6 methanol to oil ratio, and KOH as an alkali catalyst to achieve the highest output possible. It was done by ASTM standards to characterize the prepared biodiesel. Blends of 10% Neem biodiesel and 90% conventional diesel (NBD10), 15% Neem biodiesel and 85% conventional diesel (NBD15), and 20% Neem biodiesel and 80% conventional diesel (NBD20) were created, and their performance and emission characteristics were investigated. With changing loads of 1 kg, 3 kg, 6 kg, 9 kg, and 12 kg, the test was run at 230 bar injection pressure and a compression ratio of 17:1. On these various loads, the brake thermal efficiency (BTE), specific fuel consumption (SFC), torques, and exhaust gas temperature (EGT) were all examined.

S Sayyed et. al (2021) [16] studied Various blends of different biodiesels' effects on the parameters of the DIC engine in conjunction with the ANN modeling of NO_x. Using four distinct biodiesels, including Jatropa, Karanja, Mahua, and Neem, six sets of dual biodiesel/diesel mixes (10% and 90%) are created. The tests are run on a single-cylinder VCR engine with a constant compression ratio (CR) of 17.5:1 and full throttle. To determine whether biodiesel is a suitable alternative fuel, its physicochemical and thermal properties are examined. The physicochemical characteristics are found to be within the ASTM-permitted bounds. Maximum weight loss is seen in the pyrolytic zone (Zone-II), which is analyzed using TGA and FTIR analysis of the mass loss research and functional groups. Reduced BTE, AFR performance characteristics range from 0.77% to 5.60%. EGT (11.95%) and BSEC (8.91%) both show variations. The CP, MGT, MFB, NHR, and RPR combustion properties of biodiesel mixes are comparable to those of neat diesel.

KSRID Kumar et al (2020) [17] defined that as an alternative fuel that is a credible replacement for oil-based diesel, biodiesel is currently gaining popularity. In its most basic form, biodiesel is produced from fats and oils via a variety of procedures, including weakening, pyrolysis, small-scale emulsification, and transesterification, which is now the most economically viable technique. By improving the production constraints, such as the alcohol-to-oil molar weight ratio, the emphasis on the driving power, and so forth, neem oil biodiesel was produced using the transesterification process. And focused on the most efficient way to make biodiesel from neem oil, then recommends using biodiesel blends with diesel while taking into account the characteristics of nearby fume emanation and motor performance, as well as improving the pressure ratio and the blends made with biodiesel and diesel.

NS Rao et al. (2020) [18] examined the Pure diesel and pure neem oil biodiesel (NeME) were tested in a variable compression diesel engine at various compression ratios, starting at 15:1, 17:1, 19:1, and 21:1. The

statistics for each compression ratio using only pure diesel as a baseline. The goal of the experiment was to determine how pure NeME impacts compression ratio and its utilization at a constant engine speed of 1500 rpm. Specific fuel consumption (SFC), brake thermal efficiency (BTh), and CO, CO₂, HC, and NO emissions were all compared during engine tests. Significant improvements in NO and HC were seen while still maintaining a high level of thermal efficiency by using the right quantity of Neem biodiesel. Pure NeME operating at a compression ratio of 17:1 demonstrated good performance and enhanced emission characteristics.

M Arya et al (2020) [19] stated that Biodiesel is among the most well-liked and well-known alternative fuels. Future energy demands can be met with this source, which is also environmentally friendly and biodegradable. In compared to pure diesel, the effectiveness and emissions of CI engines employing Neem oil Methyl Ester with Dimethyl Carbonate (DMC) addition are evaluated. Transesterification is used to create the methyl ester of neem oil. The brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and exhaust gas temperature (EGT) of various mixes with additives are compared. The results show that BSFC increases with biodiesel concentration (the B20+1% addition), declines with load, and increases in both load and blend concentration cause an increase in EGT. At a given engine speed of 1500 rpm, the B20+1% blend offers a higher thermal efficiency for the brakes.

NK Konada et. al (2020) [20] defined that the development of alternative fuels for internal combustion engines is a result of rising energy demand, stricter emission regulations, and the depletion of oil reserves. In the transportation industry, some alternative fuels, including alcohol, petroleum gas, and compressed natural gas, have already achieved commercial viability. In the current study, diesel and pongomia and neem oils are combined and used as an alternative fuel for CI engines. With the aid of the chemical process of transesterification, pongia and neem oil can be transformed into bio diesel. The method of mixing bio diesel in amounts of 10%, 15%, 20%, 25%, and 30% (B10, B15, B20, B25, and B30) has resulted in a variety of fuel mixes. Each blend's fuel characteristics are identified. In this study, a 4-stroke diesel engine using mixes of Pongomia oil and Neem oil with diesel underwent a load test as well as smoke and exhaust gas analyses. An engine's performance metrics are calculated for various blends.

KSW Joseph et al. (2020) [21] studied that Rapid urbanization and population growth have drawn a lot of attention to the need for biofuel production to address socioeconomic problems, environmental difficulties, and fuel shortages. In recent years, biodiesel production from agro-industrial feedstocks including used cooking oil, animal fat, grease, non-edible fruit oils, etc., has taken center stage to close the supply-demand imbalance. To obtain high lipid yield, a necessary component for the production of biodiesel by transesterification, dried fruits of *Lagerstroemia speciosa* were subjected to mild ultrasonication at a frequency of 33 kHz for 20 minutes at a temperature of 35 °C in the current investigation. The biodiesel chemicals 2,4di-tert-butylphenol, hexadecanoic acid methyl ester, 9,12-octadecadienoic acid (Z, Z) methyl ester, 9-octadecenoic acid methyl ester, methyl stearate, cis-11,14-eicosadienoic acid methyl ester, 18-methylnonadecanoate were detected as the major compounds in GC-MS analysis.

JV Tirkey et. al (2020) [22] examined that through transesterification, castor, linseed, mahua, and neem biodiesels were created, and tests on their performance and emission characteristics were performed on a four-stroke, constant speed (1500 rpm), variable compression ratio compression ignition engine that was fully loaded with biodiesel blends (B10, B20, B30, and B50). According to experimental findings, boosting compression ratio boosted brake power while lowering brake-specific fuel consumption (BSFC). The brake power, on the other hand, fell as the percentage of biodiesel blends grew, while the BSFC climbed. Neem biodiesel performs similarly to diesel, producing higher brake power and BSFC that is lower than that of mahua, castor, and linseed. With increasing compression ratio from 15 to 18, it was discovered that carbon monoxide (CO) emission decreased by 25.37% for diesel and by 30.71, 31.85, 30.38, and 27.73% for castor, linseed, mahua, and neem biodiesel blends, respectively. It increased with an increasing proportion of biodiesel blends, however. Contrarily, the production of nitrogen oxides (NO_x) increased by 14.06% for diesel and by 27.39, 23.15, 23.23, and 21.11% for blends of castor, linseed, mahua, and neem.

P. Shivkumar et. al (2019) [23] determined that as a result of their massive increase in consumption in recent years worldwide, fossil fuels are quickly running short. Numerous studies are being carried out to find alternate energy sources to resolve this conundrum. One of the most significant subfields in the realm of alternative fuels is biodiesel. Without sacrificing the Bharat and European emission standards, biodiesel may replace fossil fuels.

In this study, base-catalyzed transesterification will be used to turn neem seed oil into biodiesel. Biodiesel was created when the neem seed oil was removed. Neem seed oil methyl ester was subjected to tests to determine its qualities, and it was discovered that the measured values fell within the standard tolerances of ASTM D 6751-03. B20 and B60, two different neem seed oil to regular diesel ratios, were employed. In a four-stroke, single-cylinder compression ignition engine, the two-neem seed oil and diesel combinations underwent performance and emissions testing. Performance-wise, the outcomes were comparable to those of regular diesel fuel.

M. Rambabu et al. (2018) [24] explained that animal or vegetable fat, whether edible or not, is used to create biodiesel, a fuel substitute. This is the finest renewable substitute for regular petrol. When used as a substitute for petroleum fuel, it is cleaner. Its physical makeup is comparable to that of standard diesel fuel. In an experimental assessment of variable compression diesel engine performance and emission under varied load conditions. We utilised Pure Diesel and Neem Methyl Ester Bio Diesel (NeME). The outcomes were contrasted using Pure Diesel as the standard for each compression ratio. The objective of the engine testing was to improve the emission characteristics while comparing the specific fuel consumption (SFC), brake thermal efficiency (BTh), CO, CO₂, and HC emissions. The engine speed for the experiment was set to 1500 rpm.

D Gopinath et al. (2016) [25] studied that 90% of these fuels are used to produce and transport energy, which accounts for the lion's share of the energy used for transportation globally. Consuming fossil fuels adds to environmental pollution because they are in short supply. Finding a fuel alternative that is environmentally friendly and sustainable is therefore essential. This article presents the findings of an experimental examination of the performance, emissions, and combustion of NOME-diesel mixes in a stationary single-cylinder diesel engine. The study indicated that 20% mixes perform more efficiently than 20% and 30% blends, whereas diesel and B30 blends produce more pollutants than 20% and 30% blends.

S Arunprasad et. al (2014) [26] defined improving engine settings by fuelling them with biodiesel. Neem oil, a biodiesel used in CI engines, is produced by the transesterification method. The brake thermal efficiency (BTHE), indicated thermal efficiency (ITHE), and specific fuel consumption (SFC) were all optimized using the Taguchi method. Additionally, they contrasted the diesel value with the findings of their investigation into neem oil biodiesel blends.

AV Kulkarni et. al (2014) [27] defined the world's declining petroleum reserves and growing environmental concerns have inspired a search for environmentally friendly alternative fuel. In the future, biofuels might take the place of fossil fuels as the main fuel source. The "biodiesel" fuel is produced using long-chain fatty acid monoalkyl esters derived from vegetable or animal oils. The fact that biodiesel lowers exhaust emissions while being dependable, strong, and biodegradable is well known. One sort of vegetable oil that can take the place of diesel is neem oil. The objective of this experiment is to assess the effectiveness and emission properties of CI engines that utilize Neem biodiesel.

K Murlidharan et. al (2011) [28] studied that how well a single-cylinder, four-stroke, variable compression multifuel engine will operate, emit, and burn used cooking oil methyl ester and its blends with traditional diesel. The engine was tested using fuel combinations of 20%, 40%, 60%, and 80% biodiesel with regular diesel at 1500 rpm and a needed compression ratio of 21. Among the performance metrics provided are brake thermal efficiency, specific fuel consumption, brake power, indicated mean effective pressure, mechanical efficiency, and exhaust gas temperature. Among the exhaust gas emissions are nitrogen oxides, hydrocarbons, carbon monoxide, and carbon dioxide. These contrasts show that experimental performance measures and exhaust emissions outperform those of conventional diesels. Nitrogen oxide emissions rise when the blends are used as fuel, but carbon monoxide, hydrocarbon, and carbon dioxide emissions fall. It was found that the combustion characteristics of used cooking oil methyl ester and its diesel mixes were extremely similar to those of regular diesel.

Table 2: Comparison of Reviews

Author & Year	Motive	Key Findings	Results
S Pal et al. (2022)	Investigate the performance and exhaust emissions of using pure biodiesel or biodiesel blends compared to petroleum diesel.	Biodiesel blends release more localized emissions of particulate matter and greenhouse gases compared to petroleum diesel. A significant reduction in these emissions is observed.	Examined performance and exhaust emissions of pure biodiesel/biodiesel blends vs. petroleum diesel.
J Hemanandha et al. (2022)	Examine the impact of using used fish fry methyl esters blended with DI diesel engine.	Used fish fry methyl esters blended with DI diesel engine. Waste fish fry oil (WFFO) trans esterified to produce methyl esters (WFFO10, WFFO20, WFFO30). Performance tests were conducted on blended samples.	Tested used fish fry methyl esters blended with DI diesel engine.
GP Rao et al. (2022)	Investigate the effects of compression ratio and EGR on a diesel engine using Palmyra oil methyl ester (POME) blend.	Palmyra oil methyl ester (POME) is produced from the transesterification of palmyra crude oil. Preliminary tests with POME blends (POME10, POME20, POME30) on diesel engines at various conditions. Improved engine performance and reduced emissions with POME20 blend. Compression ratios (16:1, 18:1, 20:1) effects studied.	Explored compression ratio and EGR impact on diesel engines using POME blend.
PSP Dharsini et al. (2022)	Investigate CZ nanocomposite blended fuels' effects on engine performance and emissions.	CZ nanocomposite enhanced brake thermal efficiency (BTE), decreased brake specific fuel consumption (BSFC), and lowered harmful gases (CO, HC, NO _x). Ternary mix with CZ nanocomposite was found practical for enhancing engine performance and reducing emissions.	Evaluated CZ nanocomposite blended fuels' impact on engine performance and emissions.
R Saha et al. (2022)	Examine the impact of biodiesel blends from waste cooking oil (WCO) on diesel engines' performance and emissions.	WCO biodiesel blends are used as alternative fuels in diesel engines. Renewable, low toxicity, and reduced greenhouse gas emissions. Evaluated the impact of biodiesel blends on engine performance and emission characteristics under various load conditions.	Investigated the effect of WCO biodiesel blends on diesel engine performance and emissions.
GS Bist et al. (2021)	Investigate neem seed biodiesel production and its blends' effects on engine performance and	Neem seed biodiesel is produced via acid-base transesterification. Blends (NBD10, NBD15, NBD20) examined. Performance	Explored neem seed biodiesel production and its blends' impact on engine performance and

	emissions.	and emission characteristics evaluated at varying loads.	emissions.
S Sayyed et al. (2021)	Investigate the effects of various biodiesel blends (Jatropha, Karanja, Mahua, Neem) on DICI engine parameters and NO _x using ANN modeling.	Physicochemical and thermal properties of biodiesels examined. The maximum weight loss was observed in the pyrolytic zone (Zone-II) through TGA and FTIR analysis. Reduced BTE, AFR performance (0.77% to 5.60%). Variations in EGT (11.95%) and BSEC (8.91%). Combustion properties were comparable to diesel.	Explored effects of biodiesel blend on DICI engine parameters and NO _x through ANN modeling.
KSRID Kumar et al. (2020)	Investigate neem oil biodiesel production, characteristics, and blends' effects on engine performance and emissions.	Neem oil biodiesel is produced via transesterification. Emphasis on efficient neem oil biodiesel production. Suggested using biodiesel blends considering emission characteristics, pressure ratio, and engine performance.	Explored neem oil biodiesel production, characteristics, and blends' impact on engine performance and emissions.
NS Rao et al. (2020)	Examine the effects of pure neem oil biodiesel (NeME) on compression ratio and engine performance in diesel engines.	Pure NeME tested in variable compression diesel engine. Specific fuel consumption (SFC), brake thermal efficiency (BTh), CO, CO ₂ , HC, and NO emissions were compared. Improved NO and HC emissions while maintaining high thermal efficiency with NeME.	Investigated effects of pure neem oil biodiesel (NeME) on compression ratio and engine performance.
M Arya et al. (2020)	Evaluate effectiveness and emissions of Neem oil Methyl Ester with Dimethyl Carbonate (DMC) addition in CI engines.	Evaluated Neem oil Methyl Ester with DMC addition compared to pure diesel. Brake thermal efficiency (BTE), brake-specific fuel consumption (BSFC), and exhaust gas temperature EGT) were compared (for different blends with additives).	Assessed the use of Neem oil Methyl Ester with Dimethyl Carbonate (DMC) addition in CI engines in terms of effectiveness and emissions.
NK Konada et al. (2020)	Examine the performance and emissions of diesel and pongomia/neem oil blends as alternative fuels for CI engines.	Blends of diesel and pongomia/neem oils (B10-B30) tested in a 4-stroke diesel engine. Fuel characteristics identified. Performance and emission characteristics evaluated.	Investigated performance and emissions of diesel and pongomia/neem oil blends as an alternative fuel for CI engines.
KSW Joseph et al. (2020)	Investigate biodiesel production from Lagerstroemia speciosa dried fruits and identify major compounds in GC-MS analysis.	Biodiesel production from Lagerstroemia speciosa dried fruits via ultrasonication. Major compounds were identified through GC-MS analysis.	Explored biodiesel production from Lagerstroemia speciosa dried fruits and identified major compounds using GC-MS analysis.
JV Tirkey et al.	Explore the performance	Biodiesels created via	Examined performance

(2020)	and emissions of castor, linseed, mahua, and neem biodiesels in diesel engines.	transesterification (B10, B20, B30, B50) tested in diesel engines. Effects of compression ratio and biodiesel blends on performance and emissions evaluated.	and emissions of castor, linseed, mahua, and neem biodiesels in diesel engines.
P. Shivkumar et al. (2019)	Investigate neem seed oil biodiesel production, characteristics, and blends' effects on engine performance and emissions.	Base-catalyzed transesterification is used to convert neem seed oil to biodiesel. Neem seed oil methyl ester qualities tested (within ASTM standards). B20 and B60 neem seed oil/diesel blends tested. Comparable performance to regular diesel in single-cylinder compression ignition engine.	Explored neem seed oil biodiesel production, characteristics, and blends' impact on engine performance and emissions.
M. Rambabu et al. (2018)	Examine the performance and emissions of variable compression diesel engines using Pure Diesel and Neem Methyl Ester Bio Diesel (NeME).	Utilized Pure Diesel and Neem Methyl Ester Bio Diesel (NeME) in variable compression diesel engines. Tested performance and emissions under varying load conditions. Objective to improve emission characteristics, and compare SFC, BTh, CO, CO ₂ , and HC emissions.	Investigated engine performance and emissions using Neem Methyl Ester Bio Diesel (NeME) in variable compression diesel engines.
D Gopinath et al. (2016)	Study performance, emissions, and combustion of NOME-diesel blend in a stationary single-cylinder diesel engine.	Experimental examination of NOME-diesel blends (20%, 30%, B30) in single-cylinder diesel engine. 20% blends perform more efficiently than 30% and B30 blends. Diesel and B30 blends produce more pollutants than 20% blends.	Explored performance, emissions, and combustion of NOME-diesel blends in stationary single-cylinder diesel engines.
S Arunprasad et al. (2014)	Optimize engine settings using the Taguchi method with neem oil biodiesel blends.	Neem oil biodiesel is produced through transesterification and used in CI engines. Taguchi method was used to optimize BTHE, ITHE, and SFC. Diesel values contrasted with neem oil biodiesel blends.	Examined engine optimization using neem oil biodiesel blends through the Taguchi method.
AV Kulkarni et al. (2014)	Assess the effectiveness and emission properties of CI engines using Neem biodiesel.	Neem biodiesel is considered an environmentally friendly alternative fuel due to declining petroleum reserves and environmental concerns. Aim to evaluate the effectiveness and emission properties of CI engines using Neem biodiesel.	Evaluated effectiveness and emission properties of CI engines using Neem biodiesel.
K Murlidharan	Evaluate engine performance and	Studied engine operation, emissions, and combustion using	Investigated engine performance and

et al. (2011)	emissions using used cooking oil methyl ester blends.	blends of used cooking oil methyl ester and diesel (20%, 40%, 60%, 80%). Compared to regular diesel, better performance and exhaust emissions for biodiesel blends.	emissions using blends of used cooking oil methyl ester and diesel.
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3. Materials And Method

3.1 Preparation of Bio-Diesel

Neem oil is produced in a laboratory setting by cold pressing the neem seed. After that, the base-catalyzed transesterification procedure uses the extracted oil as a catalyst. After transesterification, glycerin in the oil settles to the bottom. After around 24 hours of inactivity, the glycerin will condense into sediment that might be drained out. The remainder will be biodiesel that has not been processed. Raw biodiesel can be successfully run in compression ignition engines once the contaminants have been removed using water. Figure 1 depicts a flowchart of the trans-esterification procedure.

3.2 Blending of Bio-Diesel

Biodiesel can be incorporated into engines in a range of ratios, much like normal diesel. According to the ASTM D975 standard, the three most common blends are B2, B5, and B20, which combine 2%, 5%, and 20% of biodiesel with 98%, 95%, and 80% of conventional diesel, respectively. Two different blends of conventional diesel and biodiesel—B20 (80% conventional diesel, 20% biodiesel) and B60 (60% biodiesel, 40% conventional fuel)—were employed in this investigation.

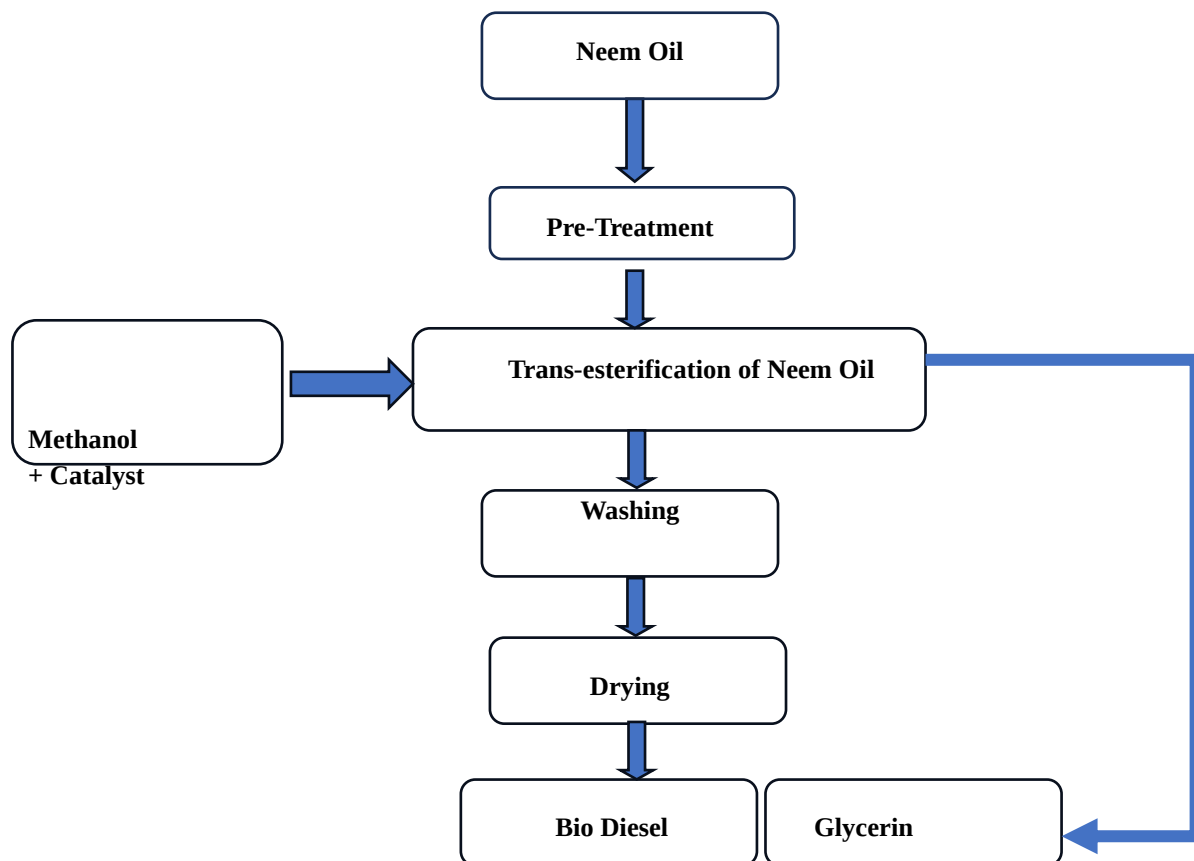


Figure 1: Trans-esterification Process

3.3 Tested Engine specifications

A data collection tool was used to capture data from a compression ignition, single-cylinder, four-stroke engine. The engine is linked to an eddy current dynamometer for electrical loading. Everything required to assess the fuel's performance, combustion, and emission characteristics is included in the engine test equipment. When operating under a variety of loads and operational situations, the gas analyser and data gathering system are interfaced to measure exhaust emissions. In Figure 2, the gas analyser is displayed. The following testing criteria were used for the engine.



FIGURE 2: VCR Engine Used for Testing

- ❖ Power: 3.50 kW @ 1490 rpm
- ❖ Cylinder: one
- ❖ Stroke: 4 strokes
- ❖ Speed: Constant Speed
- ❖ Coolant: Water
- ❖ Engine: CI
- ❖ Bore: 88 mm
- ❖ Stroke: 112 mm
- ❖ C.R length: 235.00 mm
- ❖ Compression Ratio: 18.00
- ❖ Swept volume: 661.45 cc

3.4 Emission Testing

The emissions from an engine running on B20, B60, or pure diesel can be continuously measured with a smoke meter under any load conditions.



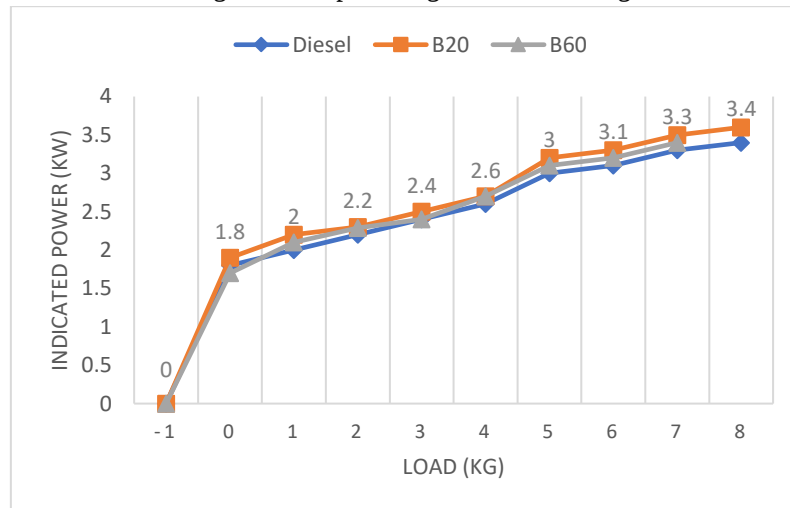
Figure 3: Smoke Meter

4. Results And Discussion

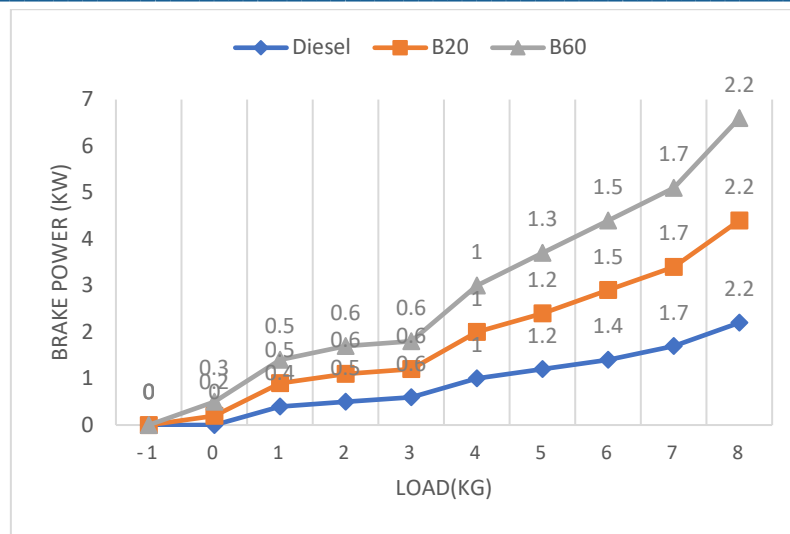
Convenience Efficiency Compression ignition engines and B20, B60, and 100% diesel biodiesel blend performance data were discussed under various loading situations. This investigation's primary objective is an analysis of engine performance and emission characteristics for typical engine specifications.

4.1 IP and BP for Various Loads

Under various loading situations, Figure 4 depicts the projected performance and stopping power of a compression ignition engine utilizing the tested fuels. Engine pressure (BP) increased for B20 and then decreased for B60 due to the increasing biodiesel percentage of the blended gasoline.



(a)



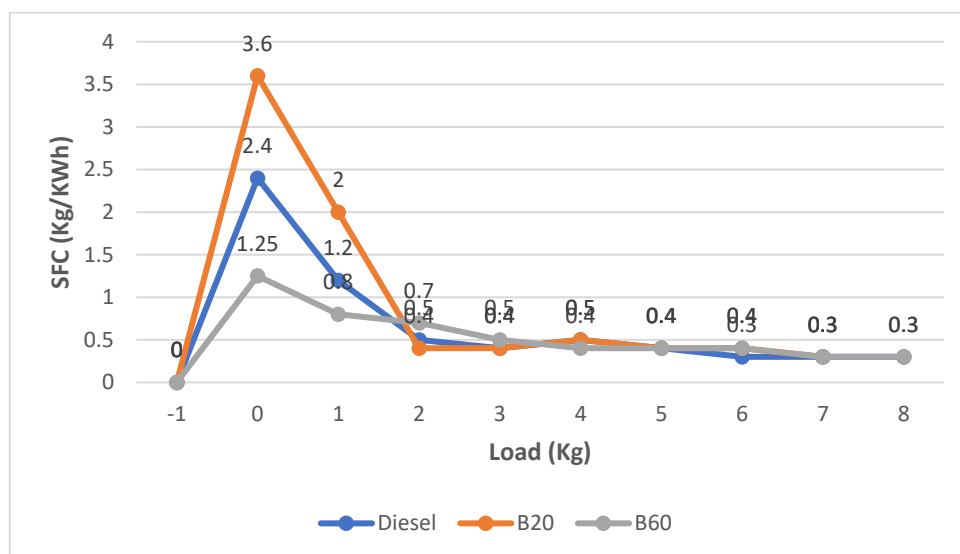
(b)

Figure 4: Indicated Power and Brake Power

However, at the same engine settings, the BP for B20 and B60 biodiesel blends was 0.5% and 0.7% greater than that for regular diesel fuel, respectively. Because biodiesel blends have a higher viscosity and less friction power than regular diesel fuel, they perform differently from the latter.

4.2 Specific Fuel Consumption

According to the loading conditions, Specific Fuel Consumption fluctuates, as shown in Figure 5. While the consumption of regular diesel fuel decreases with load, it increases for B20 and B60 blends. Low loading conditions cause the compression ignition engine's operating temperature to drop, which has a detrimental effect on spray characteristics since biodiesel and its blends have a higher viscosity. SFC values for B20 and B60 are 7-8% lower than those for conventional diesel when loaded to the same levels. The SFC has a volume that is roughly 2-2.5% lower than diesel when it is fully loaded. This is due to the biodiesel's greater oxygen content, which causes complete combustion. Similar results were observed, however, SFC decreases as engine load rises. When there are heavier loads present, biodiesel has a lower SFC than regular fuel. Due to their higher specific gravity and lower heating value, biodiesel and its mixes have a lower SFC than normal diesel.

**Figure 5: Specific Fuel Consumption**

4.3 Brake Thermal Efficiency

In Figure 6, the brake thermal efficiency (BTE) of the B20 and B60 blends is compared to that of standard diesel. As can be seen from the graph, BTEs for B20 and B60 are significantly lower than those for regular diesel fuel. Contrary to blends, where the claimed BTE for conventional diesel was 30% but the actual BTE was closer to 26%. Therefore, the biodiesel's low heating value, increased density, and increased viscosity result in poorer combustion efficiency. This is consistent with what was found.

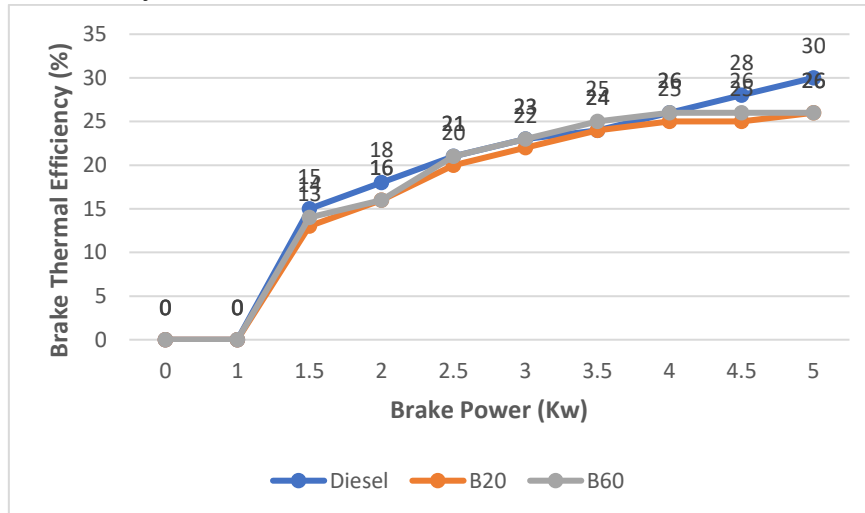


Figure 6: Brake Thermal Efficiency vs. Brake Power

4.3.1. Brake thermal efficiency at different Blend ratio

Because of the oxygen contained in blends, which may have also contributed to the complete burning of the fuel, there has been a rise in brake thermal efficiency. It was shown that the braking thermal efficiency of B10 is fairly similar to that of diesel. Brake Due to the higher oxygen concentration, B20 has a higher thermal efficiency than B10. It has been discovered that B30's efficiency has somewhat decreased as a result of inefficient combustion, which may be related to its higher viscosity than B10 and B20. due to increased viscosity, which could cause a poor combination to form.

Increases in the engine's brake thermal efficiency, along with an increase in the brake power of the engine. In other words, it may be assumed that the relationship between braking power and brake thermal efficiency is straightforward. The chart makes it clear that blend B50 of neem and coconut oil has a higher brake thermal efficiency. The quick burning of the fuel is what causes the increase in brake thermal efficiency.

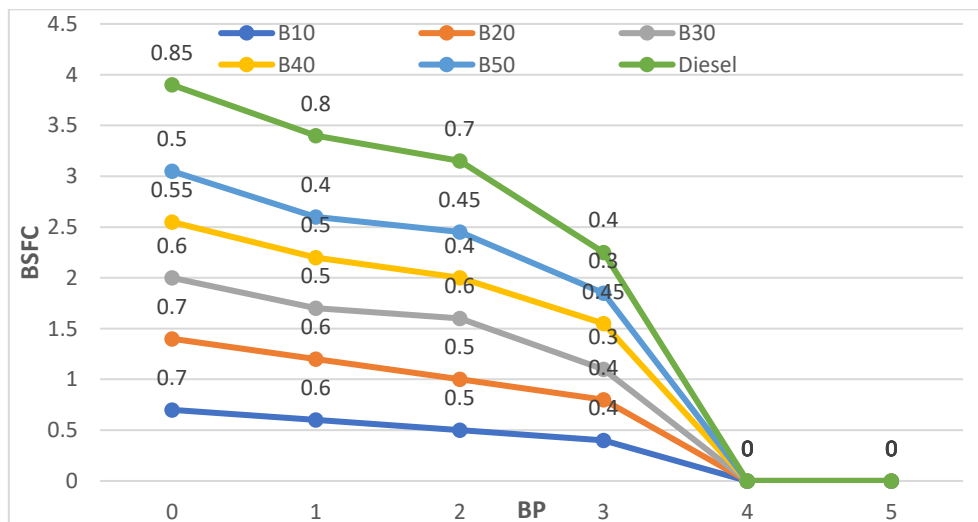


Figure 7: Variation of Brake Power with Brake Specific Fuel Consumption.

4.4. Comparison of Brake thermal efficiency with Load and Compression ratio

The fluctuation of BTE with the input parameters is shown in Figure 8. BTE is found to be highly reliant on load. As the load grows, BTE rises. It is evident from the literature that the engine should constantly be run at higher loads. BTE rises as the blend percentage rises until it reaches a maximum value, at which point it starts to fall as the blend percentage rises further. Thus, there exists a blend percentage optimal value for which the related BTE is greatest. Diverse researchers have also looked at these employing mixtures of various vegetable oil origins. Compared to plain diesel, vegetable oils have a lower calorific value. This contributes to the engine's decreased thermal efficiency at higher mix % numbers. Therefore, the mix % needs to be tuned to maximize BTE. Similar to this, when the compression ratio is changed from 16 to 18, BTE initially rises, peaks, and then falls. However, as shown in Figure 8, the change of BTE with CR and blend percentage is determined to be the least.

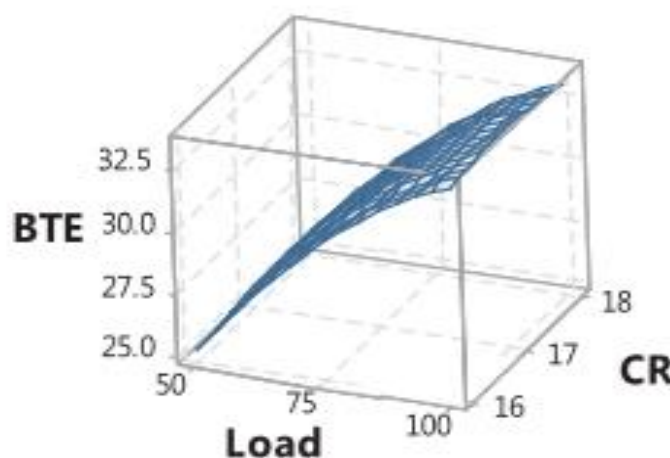


Figure 8: Brake thermal efficiency vs Load vs Compression ratio

4.5 Emission Characteristics

The emissions emanating from the tailpipe were calculated using a 5-gas analyzer. Readings are taken with the probe of the 5-gas analyser that has been placed into the exhaust pipe once the engine has stabilized. The CO, HC, CO, NO_x, and O₂ concentrations in the exhaust have been measured with this analyser. According to research by E. Khalife et al., the engine's pollution levels are within acceptable bounds.

4.5.1 Unburnt hydrocarbon emission

Figure 9(a) displays the unburnt hydrocarbon emission for both regular fuel and biodiesel. Unburned hydrocarbon emissions have been seen to decrease as engine load increases. Complete combustion is achieved thanks to the high oxygen content of biodiesel blend B60, as evidenced by a 17% decrease in unburned hydrocarbon emissions as compared to conventional diesel.

4.5.2 Oxides of Nitrogen Emission

When employing blends of conventional diesel and biodiesel, Figure 9(b) shows the relationship between the concentration of nitrous oxides (NO_x) and the load placed on the engine. It has been found that utilizing biodiesel causes slightly more NO_x to be produced than using standard diesel fuel. The B60 biodiesel mix emits 10.42% higher NO_x than regular diesel fuel when running at full load. As the load climbs to a high number, the NO_x emission increases under full load conditions. This is due to greater NO_x emissions caused by biodiesel's higher oxygen content and higher combustion temperatures.

4.5.3 Carbon Monoxide Emission

Figure 9(c) can be used to extrapolate the CO emissions for regular diesel, biodiesel, and its blends under varied loads. Experimental data demonstrates that, in comparison to conventional diesel, CO emissions from B20 and B60 are 25% and 50% lower, respectively. More carbon molecules in the fuel oxidise and release carbon dioxide

as a result of biodiesel's higher oxygen content. CO emissions findings and S. Lahane et al. discoveries both have an impact.

4.5.4 Carbon dioxide Emission

Figure 9(d) shows that when engine load increases, CO₂ emissions from both conventional fuel-burning engines and biodiesel blends increase. In comparison to B60 and regular diesel, B20 releases fewer emissions at all load levels. In comparison to diesel, biodiesel emits less pollutants because of its lower carbon content and lower elemental carbon to hydrogen ratio. E. Alptekin's experiments demonstrate that biodiesel burns completely because it contains less carbon than normal diesel.

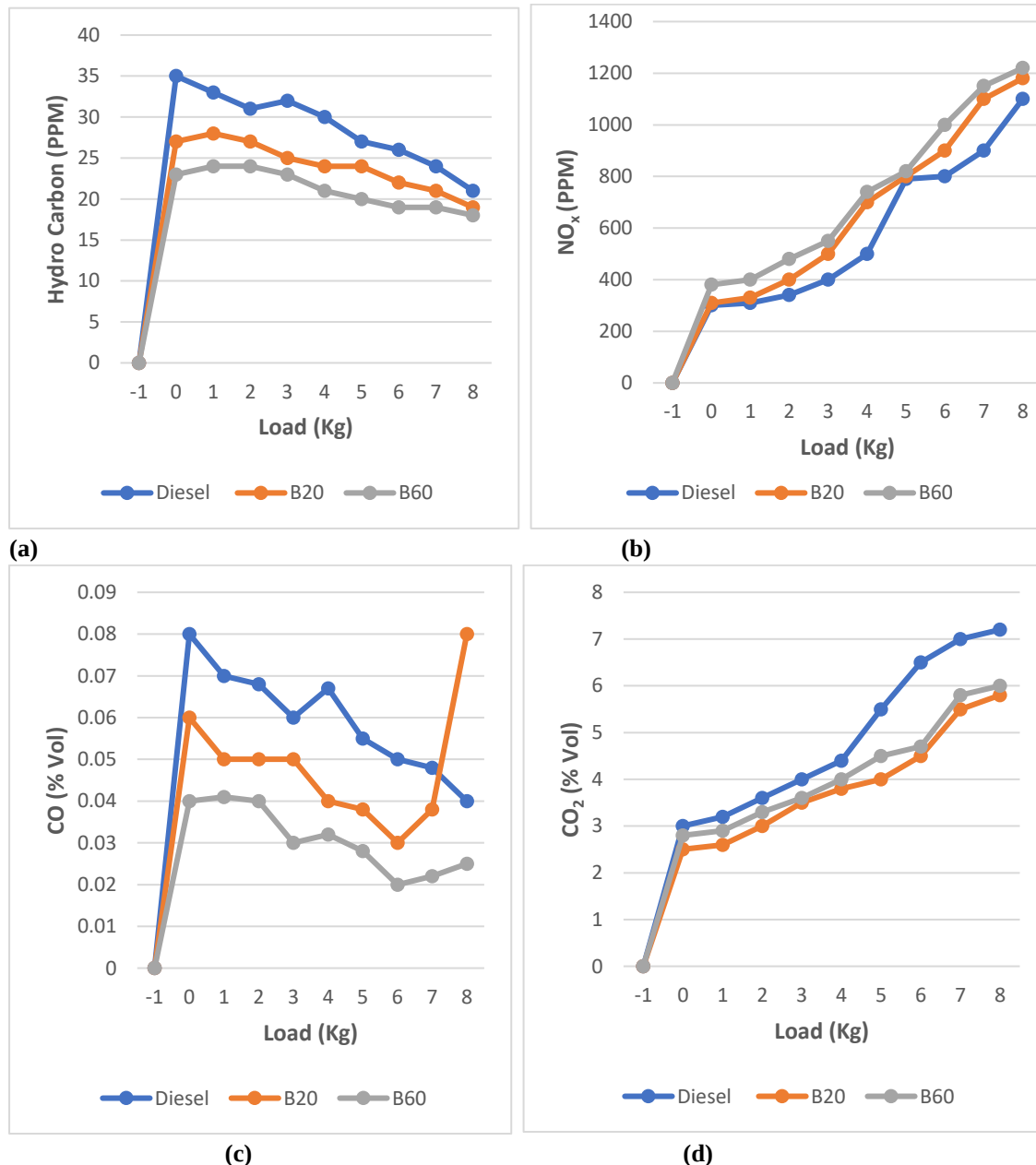


Figure 9. Emission Characteristics

5. Conclusion

In a compression ignition engine with conventional diesel serving as the reference fuel, neem oil bio-diesel B20 and B20 blends were investigated. Following is a summary of the investigation's findings:

- ✓ When trans-esterified, neem oil has shown to be a useful, eco-friendly source of biodiesel. Trans-esterification greatly decreases the viscosity of neem oil.
- ✓ Compression ignition engines can be engineered to function effectively in biodiesel blends without the need for modification since transesterified neem oil bio-diesel has physical and chemical properties that are almost equal to those of regular diesel fuel.
- ✓ Compared to regular diesel, the measured thermal efficiency of the brakes for the biodiesel blends was 4-5% lower. Biodiesel burns inefficiently because of its lower heating value, higher viscosity, and higher density. 050006-9.
- ✓ Additionally, biodiesel blends significantly lower CO, CO₂ and unburned HC emissions when compared to regular diesel fuel. However, utilizing biodiesel blends causes slightly higher nitrogen oxide engine emissions when compared to using conventional gasoline.

B60 beats other fuels in terms of performance and emission characteristics. B60 may thereby eliminate the requirement for drug-containing diesel fuel. This bio-diesel may be used in engine applications in place of conventional diesel, particularly if it helps to reduce air pollution from stationary engines.

References

- [1] Rambabu, M., and K. Eswararao. "Experimental Analysis of a VCR Engine Performance Using Neem Methyl Ester and its Diesel Blends."
- [2] B. R. Singh and O. Singh, "Global Trends of Fossil Fuel Reserves and Climate Change in the 21st Century", Fossil Fuel and the Environment, Dr. Shahriar Khan (Ed.), ISBN: 978-953-51-0277-9, pp. 167-192, 2012.
- [3] M. Davis and A. Kumar, "How will Canada's greenhouse gas emissions change by 2050? A disaggregated analysis of past and future greenhouse gas emissions using bottom-up energy modelling and Sankey diagrams", Applied Energy, vol. 220, pp. 754–786, 2018.
- [4] M. Mofijur, M. G. Rasul, J. Hyde, and M. M. K. Bhuyia, "Role of Biofuels on IC Engines Emission Reduction," Energy Procedia, vol. 75, pp. 886–892, 2015.
- [5] E. Alptekin and M. Canakci, "Determination of the density and the viscosities of biodiesel-diesel fuel blends", Renewable Energy, vol. 33(12), pp. 2623–2630, 2008.
- [6] S. K. Hoekman and A. Broch, "Environmental implications of higher ethanol production and use in the U.S.: A literature review. Part II – Biodiversity, land use change, GHG emissions, and sustainability", Renewable and Sustainable Energy Reviews, Vol. 81, pp. 3159–3177, 2018.
- [7] W. Islam, M. Mourshed, M. H. Masud, S. I. Sozal, and S. Bin Sabur, "Prospects of non-edible neem (Azadirachta indica) oil in Bangladesh: performance and emission evaluation in a direct injection diesel engine", International Journal of Ambient Energy, pp. 1–12, 2018, doi: 10.1080/01430750.2017.1421578.
- [8] Ramadhas, A.S., Jayaraj, S. and Muraleedharan, C. Use of vegetable oils as I.C. engine fuels- A review. Renewable Energy, 2004, 29 (5), 727-742.
- [9] Agarwal, D. and Agarwal, A.K. Performance and emissions characteristics of jatropha oil (preheated and blends) in a direct injection compression ignition engine. Applied Thermal Engineering, 2007, 27, 2314-2323.
- [10] Pal, Shivam, et al. "Comparative Analysis of Performance and Emission Characteristics of Diesel and Bio-Diesel as A Fuel in VCR Engine."
- [11] Hemanandh, J., et al. "Investigation of Bio-Diesel in Uncoated Piston Head Vs Bio-Diesel in Coated Head." IOP Conference Series: Earth and Environmental Science. Vol. 1100. No. 1. IOP Publishing, 2022.
- [12] Rao, Geddam Prasada, and Lankapalli Sathya Vara Prasad. "Combined influence of compression ratio and exhaust gas recirculation on the diverse characteristics of the diesel engine fueled with novel palmyra biodiesel blend." Energy Conversion and Management: X 14 (2022): 100185.
- [13] Dharsini, P. Shalini Priya, et al. "Performance and environmental effects of CeO₂/ZrO₂ nanocomposite in triple blend methyl ester of pumpkin and neem seed oil dosed with diesel on IC engine." Journal of Nanomaterials 2022 (2022): 1-9.
- [14] Saha, Roshan, et al. "Performance and emission characteristics of a diesel engine using waste cooking biodiesel blends." International Journal of Energy for a Clean Environment 23.8 (2022).

-
- [15] Bist, Gagan Singh, and Surya Prasad Adhikari. "Performance and emission characteristics of diesel engine fueled with blends of Neem biodiesel." *Kathmandu University Journal of Science Engineering and Technology* 15.3 (2021).
- [16] Sayyed, Siraj, Randip Kumar Das, and Kishor Kulkarni. "Performance assessment of multiple biodiesel blended diesel engine and NOx modeling using ANN." *Case Studies in Thermal Engineering* 28 (2021): 101509.
- [17] Kumar, Kanakala Sri Durga, And Ms Mvdm Bharathi. "Performance And Comparison Of Ci Engine Using Neem Bio Diesel And Diesel As Fuel With Different Blends." (2020).
- [18] Raol, N. S., N. Hari Babu, and B. V. Rao. "Experimental investigations of a variable compression ratio diesel engine fueled with neem methyl ester (NeME)." *Int J Eng Res Technol* 4.4 (2015): 141-145.
- [19] Arya, M., et al. "Effect of Additive on Performance and Emission of CI Engine using Neem Bio-Diesel." *Advances in Thermodynamics and Heat Transfer* (2020): 44.
- [20] Konada, Naresh Kumar, K. N. S. Suma, and BB Ashok Kumar. "Experimental investigation on performance, smoke and exhaust gas analysis of four stroke diesel engine using pongomia/neem oil biodiesel." *International Journal of Engineering, Science and Technology* 12.4 (2020): 23-40.
- [21] Joseph, Kamal S. William, et al. "Production of bio-diesel from non-edible dried fruits of *Lagerstroemia speciosa*." *Current Trends in Biotechnology and Pharmacy* 14.2 (2020): 141-146.
- [22] Tirkey, J. V., Ajeet Kumar, and S. K. Shukla. "Comparative analysis of engine performance and emission characteristics of different biodiesels." *Biofuels* 11.8 (2020): 893-901.
- [23] Sivakumar, P., M. Sathish Kumar, and B. Susila. "Investigations on performance and emission characteristics of single cylinder four stroke CI engine fueled with diesel-Azadirachta indica oil blends." *AIP Conference Proceedings*. Vol. 2128. No. 1. AIP Publishing, 2019.
- [24] Rambabu, M., and K. Eswararao. "Experimental Analysis of a VCR Engine Performance Using Neem Methyl Ester and its Diesel Blends."
- [25] Gopinath, D., and E. Ganapathy Sundaram. "Experimental studies on performance and emission characteristics of diesel engine fuelled with neem oil methyl ester blends." *International Energy Journal* 15.1 (2016).
- [26] Arunprasad, S., and T. Balusamy. "Optimization of Performance Parameters of a CI engine Fueled with Neem Biodiesel using Taguchi Technique." *Advanced Materials Research* 984 (2014): 867-872.
- [27] Kulkarni, A. V., and S. D. Bhopale. "Performance Analysis and Investigation of Emissions of CI Diesel Engine Using Neem Oil as Blending Agent."
- [28] Muralidharan, K., D. Vasudevan, and K. N. Sheeba. "Performance, emission and combustion characteristics of biodiesel fuelled variable compression ratio engine." *Energy* 36.8 (2011): 5385-5393.